

**STANDARD TESTING PROCEDURES (STP)  
FOR  
EVALUATION OF REMOVAL EFFICIENCY OF  
COOKING FUME CONTROL EQUIPMENT**

**Environmental Protection Department**

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**(For Trial Use)**

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## **1. BACKGROUND**

Similar to other developed cities, Hong Kong is a small, densely populated city with large number of restaurants located in urban area. The exhaust emissions from restaurants have been an environmental issue in Hong Kong as oil mist of cooking fume cause nuisance to the general public and deteriorate the nearby environment. In recent years, complaints about restaurant emissions have been quite substantial. The HKSAR Government intends to control cooking fume emissions from restaurants and commercial kitchens and encourage them to install appropriate types of control equipment.

There is a variety of cooking fume control equipment available in Hong Kong to reduce cooking fume emissions, such as hydrovents, water scrubbers, air washers, grease filters, electrostatic precipitators, etc. However, the cooking fume removal efficiency is variable among these types of equipment. It is difficult for the users or the authority to assess whether the control equipment is effective in removing cooking fume. Moreover, it will be even more difficult to compare the efficiency of two pieces of control equipment on equal footing since there is no standard test for cooking fume.

Hong Kong Productivity Council was commissioned by the Environmental Protection Department in 2001 to develop standard testing procedures (STP) to determine the cooking fume removal efficiency of typical control equipment. After that, a couple of studies were undertaken with particular reference to the real-life cooking process in a bid to refine the STP. The purpose of this revised STP is to lay down the details of the equipment and testing procedures for determining the cooking fume removal efficiency of control equipment.

## **2. PURPOSE OF THE STP**

The purpose of this STP is to provide standard testing procedures for suppliers and manufacturers of cooking fume control equipment, testing laboratories and other concerned organizations to assess the performance of cooking fume control equipment. This STP provides specific details on the sampling and analysis procedures so that the removal efficiency of different cooking fume control equipment can be evaluated on equal footing.

Testing laboratories or other testing organizations should follow this STP for certification with awareness of quality assurance while carrying out the performance test for cooking fume control equipment.

### **3. STRUCTURE OF THE DOCUMENT**

This STP provides information and testing procedures to evaluate the operational performance of cooking fume control equipment. The structure of this document is summarized as follows:

Section 1 discusses the background and the objective of the document.

Section 2 states the purpose of the document

Section 3 illustrates the structure of the document

Section 4 of this document is to introduce the scope, application, principles and the referenced standard testing methods for the performance evaluation

Section 5 details the apparatus and chemicals required for the performance test.

Section 6 details the standard testing procedures to determine the cooking fume removal efficiency of typical cooking fume control equipment with a laboratory scale setup.

Section 7 discusses the quality assurance and quality control (QA/QC) for the evaluation of cooking fume removal efficiency. The QA/QC is essential to ensure the quality and reliability of test results.

Section 8 illustrates the safety precautions when carrying out performance test. The performance test involves generation of cooking fume using cooking woks over LPG / Town Gas fired stoves which may cause burns and fire hazards.

Section 9 contains a list of relevant reference documents.

## 4 PRINCIPLE OF THE EVALUATION TEST

### 4.1 Scope and Application

This STP intends to provide the techniques for determination of overall removal performance of control equipment using a continuous stream of oily fumes generated under specified conditions. The testing procedures should be followed to measure the collection efficiency of equipment by comparing the concentration of oil particles in the upstream to that in the downstream.

The test equipment may include electrostatic precipitators (EP) – duct-type EP and hood-type EP, hydrovent, grease filter, water scrubber, air washer, etc. The testing procedures can also be applied to assessing overall removal efficiency of control equipment which are aligned in series along the exhaust duct.

This method is applicable to cooking fumes flowing in exhaust ducts or stacks. The setup outlined in this STP is intended for a typical system with flow rate of 4000 m<sup>3</sup>/hr which is normally used in a small scale commercial kitchen with 2 stoves. For control equipment exceeding this handling capacity, scaling up the appropriate design features such as ducting, exhaust blower and fume generating unit would be needed but the inlet fume concentration at control equipment must be made to 100 ± 20 mg/m<sup>3</sup> (expressed at 0°C and 101.325 kPa) and the flow rate of exhaust stream must tally with the rated flow rate of the control equipment for optimal collection of oil particles.

### 4.2 Determination of Cooking Fume Removal Efficiency

The primary function of cooking fume control equipment is to eliminate or reduce the level of cooking fume in restaurant exhausts which cause nuisance to the nearby environment. Cooking fume control equipment, such as electrostatic precipitators, water scrubbers, air washers, hydrovents or grease filters should have certain cooking fume removal efficiency. The aim of the standard testing procedures is to determine the efficiency of a cooking fume control equipment to remove total cooking fume from the kitchen exhaust. The principle of the evaluation of the cooking fume removal efficiency as detailed in the Section 6 is summarized as follows:

- a. Setting up of a standard testing system including a cooking fume generation system, an inlet and outlet exhaust ductings which comply with the standard isokinetic stack sampling requirements, a variable exhaust gas flow rate controlling device and the cooking fume control equipment under test;
- b. Generation of a constant and persistent level of cooking fume which is similar to the cooking fume emission from local restaurants <sup>iii</sup>;

- c. Measurement of the levels of total cooking fume at both the inlet and outlet ductings at the same time in accordance with USEPA Method 5 “Determination of Particulate Matters Emissions from Stationary Sources”<sup>i</sup>;
- d. Conducting the efficiency test at the 100% of the design flow rate of the cooking fume control equipment under test;
- e. Analysis of the level of cooking fume in the samples by infra-red spectroscopy in accordance with the PRC National Emission Standard GB-18483-2001<sup>ii</sup>;

The standard test methods referenced for the evaluation of cooking fume control equipment in the STP is based on the *Report on Literature Survey of Legislative Control and Testing Method of Cooking Fume Control Equipment for Cooking Fume Control*.<sup>iv</sup> issued on 11 February 2002 and, *Report on Evaluation of Cooking Fume Emission Characteristics*<sup>viii</sup> (27 February 2004).

It was known that rapeseed oil is usually used in restaurants and food stores for cooking; therefore rapeseed oil shall be used as the sources of cooking fume for the performance test. Rapeseed oil with characteristics similar to those described in para. 5.5 should be used.

## **5 APPARATUS AND CHEMICALS**

The section details the list of equipment, apparatus, chemicals and other accessories which is required to carry out the tasks of determination of total cooking fume removal efficiency of a wide range of cooking fume control equipment.

### **5.1 The Setup of Testing Equipment**

A laboratory scale testing setup shall be prepared to carry out the evaluation. The setup shall consist of a cooking fume generation system to simulate cooking process and generate sufficient cooking fume for the evaluation, an inlet and outlet ductings connected to the equipment under test without air leakage.

In addition, the setup shall also include a flow rate control damper and an exhaust fan (or the built-in fan of the testing equipment) to facilitate the measurements of the desired flow rate. The drawings of the testing system are shown as Figure 5.1.

#### Design Specifications of the testing setup

The design specifications of the experimental setup are summarized in Table 5.1

Table 5.1 Design Specifications of the Testing Setup for Determination of Total Particulate Removal Efficiency

Item	Symbol In Drawing	Specifications
Cooking fume generating chamber	A	The cooking fume generation chamber shall be in the form of a range of two cooking stoves under an overhead exhaust hood as shown in Figure 5.1. <u>Apparatus</u> i. Two LPG/Town Gas fired stoves; ii. Two cooking woks of size 42 cm diameter each providing oil bath capacity of 3 litres; iii. Rapeseed cooking oil; iv. Stirring rods (or ladle) or any mechanical stirrer ; v. J-type thermocouple ((0-500°C) fixed at stand; vi. Protective shields; vii. Fire extinguishers (CO2/dry powder type).
Inlet ducting	B	The dimensions of the inlet ducting shall follow the requirements of USEPA Method 1 <sup>viii</sup> . The length of the inlet ducting shall be more than 10 times of effective diameter of the ducting. If the ducting is rectangular shape, the effective (hydraulic) diameter is calculated as $2LxW/(L+W)$ where L is length and W is width. (See Figure 5.1)
Outlet ducting	C	The dimensions of the outlet ducting shall follow the requirements of USEPA Method 1. The length of the outlet ducting shall be more than 10 effective diameters of the ducting. The ducting shall be made of galvanized iron sheet.
Flow control damper	D	The flow control damper shall be able to control the flow rate of the test system (Flow control damper is not necessary if the flow rate of the exhaust air fan is adjustable).
Exhaust fan	E	The exhaust fan shall be capable of maintaining the flow rate at 125% of the design flow rate of the test control equipment.
Inlet sampling holes	F	The inlet sampling holes shall be located at least 8 effective diameters of the ducting from the inlet of the ducting and 2 effective diameters away from the outlet. Three 100 mm sampling holes should be prepared corresponding to the level of the three rows in fig. 6.2
Outlet sampling holes	G	The outlet sampling holes shall be assigned at least 8 effective diameters of the ducting from the inlet of the ducting and 2 effective diameters away from the flow control damper. Three 100 mm sampling holes should be prepared corresponding to the level of the three rows in fig. 6.2.



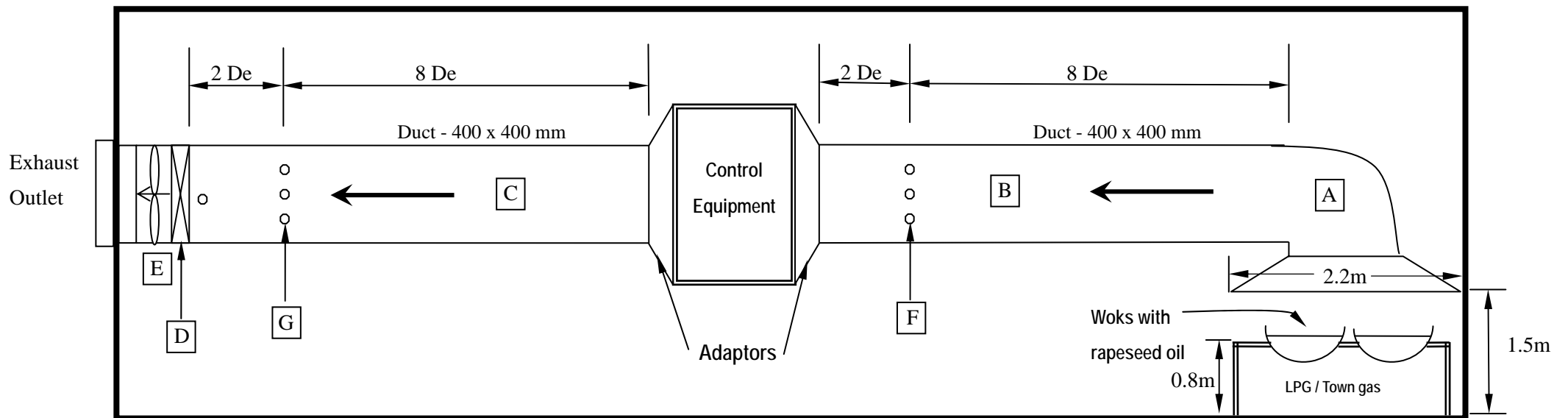


Figure 5.1 Schematic View of the Testing System

$De = \text{Effective / Hydraulic diameter} = 4A/P = 2(L*W)/(L+W)$

where A refers to area; P to perimeter; L to length; W to width.

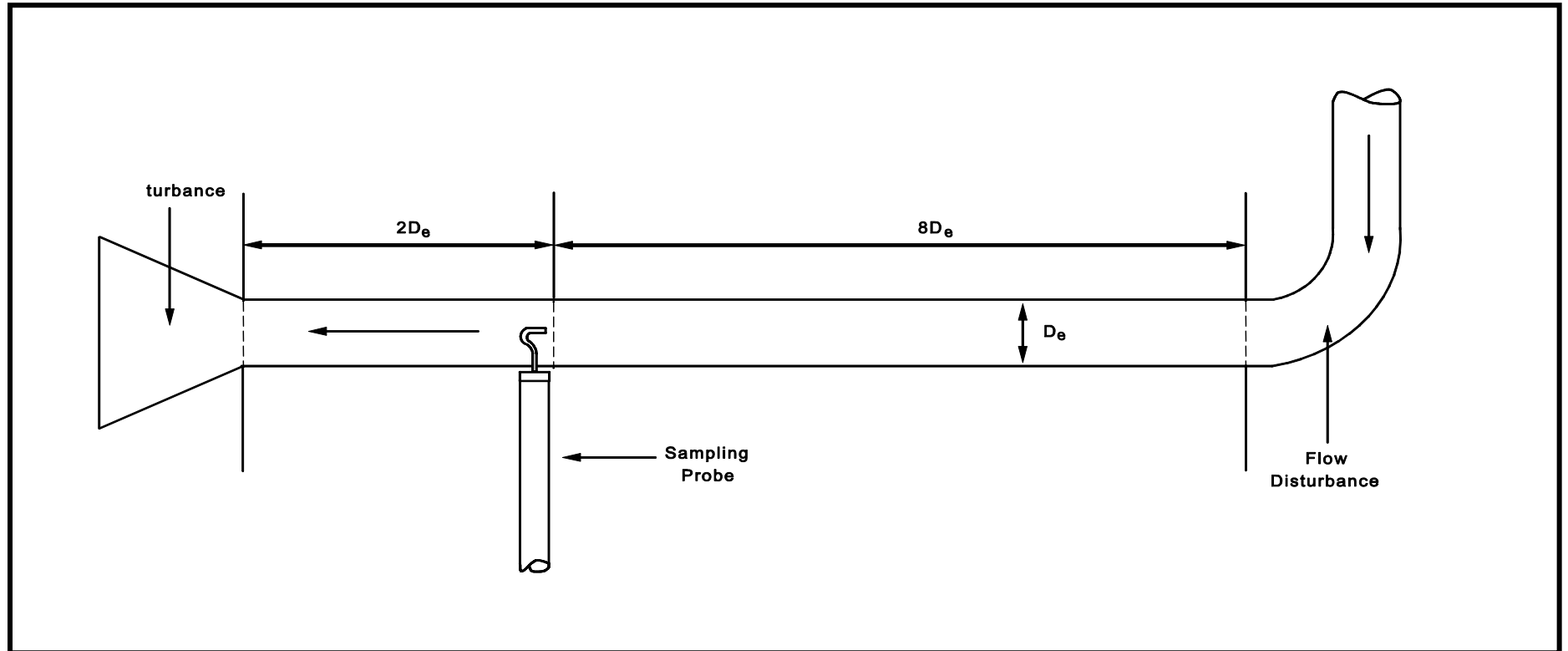


Fig 5.2 Arrangement of Sampling probe into the duct

## 5.2 Sampling of Total Cooking Fume Particulates

The sampling of total cooking fume particulates at inlet and outlet streams of the test equipment shall be carried out simultaneously and in accordance with USEPA method 5. The setup of the sampling system is shown in Figures 5.1 and 5.2. The sample collection system shall include the following items:

5.2.1 Standard isokinetic Total particulate sampling system is equipped with

- Total Particulate sampling nozzle
- S-type pitot tube
- Heated glass sampling probe, filter holder and impingers;
- Universal stack sampling system with stack sampling panel, equipped with control console, water manometer, dry gas meter, etc.

5.2.2 0 - 360°C thermometer;

5.2.3 Barometer;

5.2.4 Quartz filter

5.2.5 Distilled water and ice;

5.2.6 Anhydrous silica gel;

5.2.7 Perchloroethylene, Analytical Reagent grade or above;

5.2.8 Wash bottle;

5.2.9 Petri dish and clean glass sampling bottles

5.2.10 Forceps and clean gloves

5.2.11 Stopcork grease (if ball-joint type sampling glassware is used, stopcork silicon grease shall be applied to ball joints to avoid air leak)

## 5.3 Preparation of Calibration Standard for Infra-red Analysis

5.3.1 High quality rapeseed cooking oil;

5.3.2 Perchloroethylene, (Analytical Reagent grade)

5.3.3 Round bottom flask and water condenser for reflux of cooking oil

5.3.4 Heater or heating mantle

5.3.5 Mercury in glass thermometer of range 0 - 360°C

5.3.6 Boiling stone

5.3.7 Clean glass sampling bottle

5.3.8 0 – 5 ml glass syringe

5.3.9 Electronic balance

5.3.10 50 ml volumetric flask

5.3.11 15 ml glass vials with teflon lined cap

#### 5.4 Sample Preparation and Analysis of Cooking Fume Samples

5.4.1 Perchloroethylene, (Analytical Reagent grade)

5.4.2 Conical flask

5.4.3 Separating funnel

5.4.4 25 ml and 50 ml Volumetric flasks

5.4.5 0 – 10 ml measuring cylinder

5.4.6 15 ml glass vials with teflon lined cap

5.4.7 Wash bottle and dropper

5.4.8 Ultrasonic bath for laboratory use

5.4.9 FT-IR or IR spectrometer

5.4.10 Liquid cell for IR spectrometer

5.4.11 Tissue paper

5.4.12 Waste solvent container

5.4.13 Laboratory gloves

#### 5.5 Specifications of Cooking Oil

**The cooking oil used for testing should be the kind of rapeseed oil with the following general specifications:**

- Acid value  $\leq 0.2$ ;
- Peroxide value  $\leq 5$ ;
- Colour Y  $\leq 20$ , R  $\leq 2.0$ ;
- Refractive Index 1.465-1.467;
- Smoke point  $\geq 230^{\circ}\text{C}$ ;
- Fatty acid composition C<sub>16:0</sub> 2.5-7.0%, C<sub>18:0</sub> 0.8-3.0%, C<sub>18:1</sub> 51-70%, C<sub>18:2</sub> 15-30%, C<sub>18:3</sub> 5-15%, C<sub>20:0</sub> 0.2-1.2%, C<sub>20:1</sub> 0.1-4.3%, C<sub>22:0</sub> < 0.6% C<sub>22:1</sub> < 2%, C<sub>24:0</sub> < 3% C<sub>24:1</sub> < 0.4%

## 6 STANDARD TESTING PROCEDURES TO EVALUATE THE COOKING FUME REMOVAL EFFICIENCY OF COOKING FUME CONTROL EQUIPMENT

### 6.1 Setting up of the Testing System

- 6.1.1 Setup the testing system as per schematic diagrams Figures 5.1 & 5.2. Ensure all the connections and interfaces with the control equipment under test are air-leak free.
- 6.1.2 Connect electric supply to the testing system. Verify all the components are working properly. Check whether the flow rate of the testing system is adjustable.
- 6.1.3 Check the operation of the cooking fume control equipment under test. Connect water supply whenever necessary.
- 6.1.4 Setup the Total Particulate sampling system<sup>1</sup>. Connect the sampling probe with the sampling panel. Check all the components of the sampling system are in proper operation.
- 6.1.5 Check the flow rate of testing system with the sampling system whether it can attain 100% design flow rate of the testing equipment.
- 6.1.6 Check whether all the safety measures are in order. (Refer to Section 8 for details of safety measures of the test).

### 6.2 Generation of Cooking Fume

- 6.2.1 Setup the cooking fume generation chamber with fabrication of the LPG / Town Gas fired stoves, cooking woks, rapeseed cooking oil and stirring mechanism.
- 6.2.2 Each cooking wok should be of size 42 cm (approx. 17 inches) diameter to accommodate an oil bath quantity of 3 litres.
- 6.2.3 Use commercially available rapeseed oil (see Para. 5.5 for specifications) for generation of fumes for the test. Maintain oil bath temperature at  $300 \pm 10^{\circ}\text{C}$  (can be continuously monitored by thermocouples). Replenish oil regularly to make up for the loss.
- 6.2.4 The acceptable range of the concentration of total cooking fume in the inlet stream shall be maintained at  $100 \pm 20 \text{ mg/m}^3$  (expressed at  $0^{\circ}\text{C}$  and 101.325 kPa). The oily fumes should be generated by constant stirring of oil in woks over stoves (at frequency 20-30 strokes per minute).
- 6.2.5 To achieve such a high fume concentration, two identical woks must be used at the same time.
- 6.2.6 The volume flowrate will be similar to the real life situation, i.e.  $4000 \text{ m}^3/\text{hr}$  for 2 woks and the cross-sectional area of the exhaust duct where the control equipment to be tested must be around 400 mm x 400 mm as the flow velocity has to be set for 7 m/s in line with the real-life situation.

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<sup>1</sup> The sampling procedure for total cooking fume efficiency test shall follow the relevant requirements as set out in US EPA Method 5 on Determination of Particulate Matter Emissions from Stationary Sources.

- 6.2.7 The above setup is designed for a typical system with flow rate of 4000 m<sup>3</sup>/hr which is being used in a small scale restaurant with 2 stoves. If the control equipment to be tested exceeds this capacity requirement, scaling up the appropriate design features such as ducting and fume generating unit will be needed in order to ensure the inlet fume concentration at control equipment be maintained at 100 ± 20 mg/m<sup>3</sup>.
- 6.2.8 Should any set of test data after IR analysis reveal the inlet fume concentration falling beyond 100 ± 20 mg/m<sup>3</sup>, the results for the removal efficiency should be made void and it is required to redo the sampling for an acceptable set of test data.

### **6.3 Pre-sampling Preparation Work**

- 6.3.1 Switch on the cooking fume generation system and the cooking fume control equipment and warm up the systems for at least 15 minutes;
- 6.3.2 Adopt USEPA Method 5 “Determination of Particulate Matter Emissions from Stationary Sources” for isokinetic sampling and PRC National Standard “Emission Standards of Cooking Fume, GB 18483-2001” for determining the mass concentrations of the collected samples before and after the control equipment under testing;
- 6.3.3 Check the flow rate of the testing system whether the flow rate is 100% of the design flow rate of the equipment under test;
- 6.3.4 Clean the sampling components with perchloroethylene thoroughly to remove any contaminant, air dry the clean sampling inlets;
- 6.3.5 Setup the two total particulate sampling systems in accordance with the USEPA Method 5 for the inlet and outlet streams respectively. Figure 6.1 shows the sampling setup;
- 6.3.6 Check the integrity of the particulate filter, there shall be no other contaminant and pin hole on the filter. Place the particulate filter at the filter house with gloved hands and a pair of forceps;
- 6.3.7 Conduct a leak check on each sampling train. Seal the sampling inlet with a teflon tape and pressed with the thumb. Switch on the sampling pump to create a vacuum environment to about -20 psi. Switch off the sampling pump and note the pressure change. If the pressure increases steadily, that is a sign of air leak. Check all the fittings to rectify the problem. Otherwise if the vacuum pressure is maintained, the sampling system is considered as leak free and can be used for sampling.
- 6.3.8 Two units of isokinetic sampling system as stated in Para. 6.3.5 above are set one at the inlet and another one at the outlet ducting to collect cooking fume simultaneously.

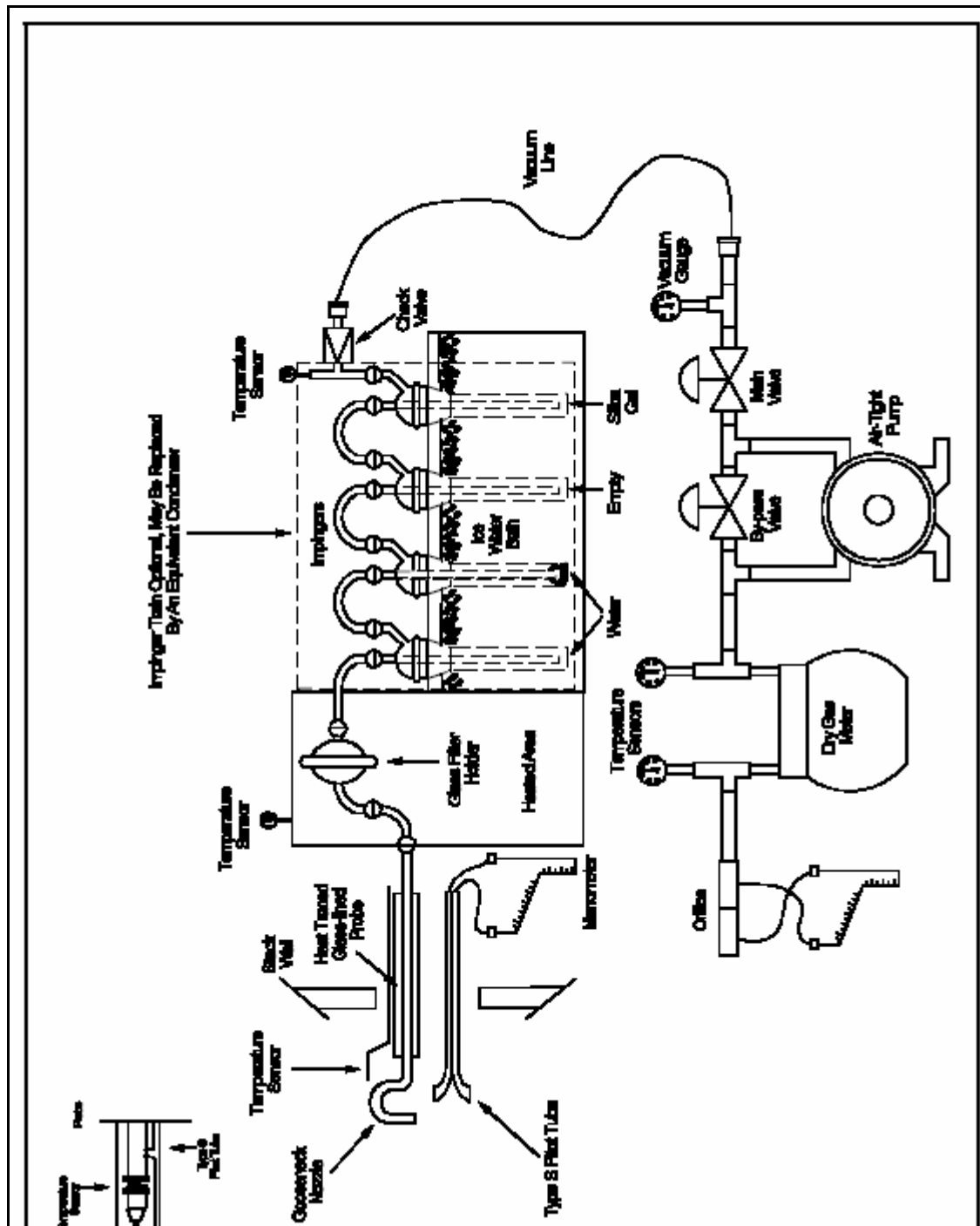


Figure 6.1 Drawing of the Stack Sampling System adopted from USEPA method 5 (Figure adopted from USEPA Method 5, 40 CFR 60 Appendix A)



## 6.4 Collection of Cooking Fume Samples

- 6.4.1 Start the sampling at inlet and outlet at the same time. During the sampling run, maintain an isokinetic sampling rate (within 10 percent of true isokineticity);
- 6.4.2 When inserting the sampling inlet, make sure the sampling inlet is parallel to the air ducting and pointing upstream;
- 6.4.3 Collect cooking fume sample according to the sampling traverse plan shown in Fig 6.2 (USEPA Method 1)<sup>vii</sup>. The total sampling time for each sample is around 30 minutes, so the sampling time at each of the “X” locations shown below is around 3 minutes.

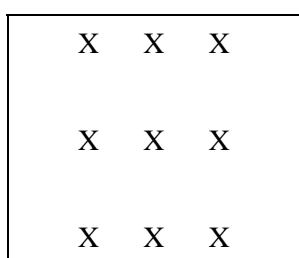


Figure 6.2 Transverse plan of the ducting showing the sampling locations

- 6.4.4 For each test, record the data required on a data sheet.
- 6.4.5 Record the actual sampling time for each sample. It should be around 30 minutes. During sampling, monitor the flow rate of the system in order to adjust the sampling flow rate to maintain the isokineticity.
- 6.4.6 Determine the overall isokineticity. If the isokineticity is beyond the range of 90% to 110%, void the sample. If the isokineticity pass the criterion, calculate the total sample volume corrected to 0°C and 101.325 kPa using the temperature measured by thermocouples secured to the sampling probe inlet.
- 6.4.7 After sampling, conduct a post leak check similar to step 6.3.7. If the post leak check fails, void the sample.
- 6.4.8 Collect the particulate filter with gloved hand and a pair of forceps. Put the filter on a petri dish which shall then be properly labelled.
- 6.4.9 Rinse the internal surface of the sampling probe up to the filter holder with perchloroethylene to remove any oil particulates deposited on such surface.
- 6.4.10 Record the sample identity of the “Filter” and “Rinsing” respectively.
- 6.4.11 Repeat the procedures of 6.4.1 to 6.4.10 for 4 more times to get a total of 5 sets of sample.

## 6.5 Preparation of Calibration Standard

- 6.5.1 Use commercially available rapeseed oil as the calibration standard;
- 6.5.2 Reflux rapeseed oil at 220°C for 2 hours using a 25 ml round bottom flask and a water condenser;
- 6.5.3 Cool down the 25 ml round bottom flask to room temperature;
- 6.5.4 Put a dried 50 ml volumetric flask, prewashed with perchloroethylene,<sup>1</sup> onto an electronic balance, and tare the balance to zero;
- 6.5.5 Transfer about 170 mg of the refluxed rapeseed oil to the volumetric flask and record the actual weigh of rapeseed oil to 0.1 mg;
- 6.5.6 Dilute the 50 ml volumetric flask to the mark with perchloroethylene; cap the flasks and shake vigorously;
- 6.5.7 Pipette 0.2, 0.3, 0.5, 1.0, 3.0 and 5.0 ml of the solution, prepared in Para. 6.5.6 above, into six separate dried and cleaned 50 ml volumetric flasks;
- 6.5.8 Top up the volumetric flasks to the marks with perchloroethylene, cap the flasks and shake vigorously;
- 6.5.9 The calibration standards represent 0.014, 0.020, 0.034, 0.068, 0.205 and 0.341 mg/ml cooking fume in solvent. (May be different for different batches of cooking oil used, but must use the same one for IR analysis)

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<sup>1</sup> Analytical Reagent grade

## 6.6 Preparation of Cooking Fume Quartz Filter Sample

- 6.6.1 Place a filter sample into a clean conical flask, fill in 5 ml perchloroethylene with a measuring cylinder;
- 6.6.2 Sonicate the samples for 16 minutes;
- 6.6.3 Transfer the extract to a dried 50-ml volumetric flask, rinse the conical flask and filter with perchloroethylene for 3 times, transfer all the rinsing to the volumetric flask;
- 6.6.4 Top up to the mark (50-ml) with the solvent, cap the flask and shake vigorously.

## 6.7 Preparation of Probe Rinsing Sample

- 6.7.1 Transfer the probe rinsing sample, volume about 150 ml, into a prewashed 250 ml round bottom flask;
- 6.7.2 Concentrate the sample solution to a volume of 5-10 ml with a rotavapor;
- 6.7.3 Transfer the concentrated solution to a dried 25-ml volumetric flask. Rinse the round bottom flask with perchloroethylene for 3 times and transfer all the rinsing to the volumetric flask;
- 6.7.4 Top up to the mark (25-ml) with the solvent. Cap the flask and shake vigorously.

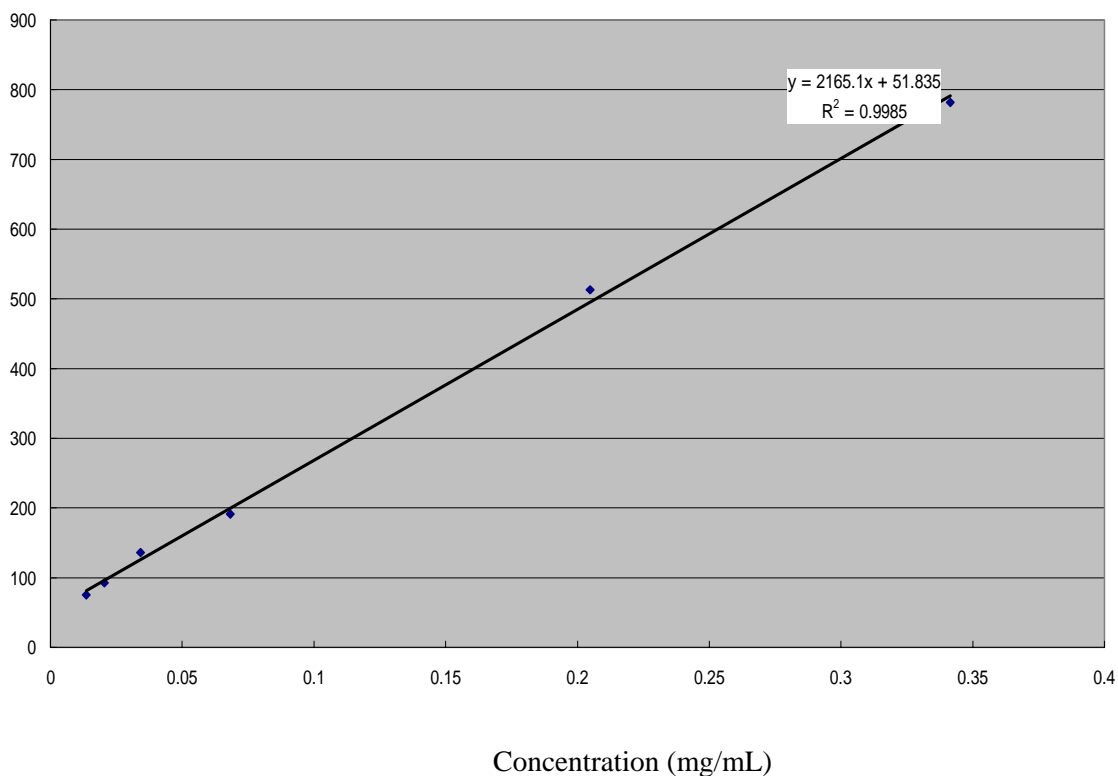
## 6.8 Preparation of IR Calibration Curve

- 6.8.1 Warm up the IR spectrometer for 1 hour before sample analysis;
- 6.8.2 Rinse the IR liquid cell with perchloroethylene;
- 6.8.3 Prepare IR spectra of the perchloroethylene and 6 calibration standards prepared at Para. 6.6 to determine the absorbance of the absorption peaks nearest to the wavenumbers of 2,930, 2,960 and 3,030  $\text{cm}^{-1}$  of each solution (sample interference may cause slight off-set of absorption peaks). Rinse the liquid cell with solvent after analyzing each solution;
- 6.8.4 The most possible sample interference is moisture. Sodium sulfate can be added to dry the sample solution before measuring in the FT-IR machine;
- 6.8.5 Sum up the 3 absorbance values of each solution. Determine the net absorbance of the 6 standard by subtracting the sum absorbance from corresponding sum absorbance of the solvent;
- 6.8.6 Record the test results in a data sheet;
- 6.8.7 Establish a calibration curve by plotting the net absorbance against the cooking fume concentration.
- 6.8.8 Establish the linear regression relation of  $[Y (\text{net absorbance}) = m (\text{slope}) X (\text{cooking fume conc.}) + b (\text{intercept})]$  (EQ 6.1), determine the regression coefficient of cooking fume concentration on Y. Draw a straight line of best fit for all the available points.

Figure 6.3 IR Calibration Curve for Analysis of Cooking Fume

(For illustration ONLY)

Area of Peak



## 6.9 Chemical Analysis of Sample

- 6.9.1 Rinse the liquid cell with perchloroethylene before analyzing each sample;
- 6.9.2 Rinse the liquid cell with small amount of sample extract;
- 6.9.3 Transfer the sample extract from the vial to the liquid cell Clean the surface of the cell with tissue paper;
- 6.9.4 Prepare an IR spectrum of the sample as the step 6.8.3. Determine the net absorbance of the sample by subtracting the sum of absorbance of 2930, 2960 and 3030  $\text{cm}^{-1}$  of the sample from the absorbance value of the solvent;
- 6.9.5 Record the test results in a data sheet;
- 6.9.6 Repeat the steps 6.9.1 through 6.9.5 to analyze other samples;
- 6.9.7 Determine the concentration of cooking fume by comparing with the calibration curve.

## 6.10 Data Treatment and Reporting

- 6.10.1 Determine the concentration of cooking fume in air sample at 0°C and 101.325 kPa in mg/m<sup>3</sup> by the equation EQ 6.2

$$\text{Conc. of cooking fume in air sample} = \frac{(\text{Conc. of cooking fume in extract, mg/ml}) \times \text{marked volume of flask used}}{(\text{total air sample volume at } 0^\circ\text{C and } 101.325 \text{ kPa, m}^3)} \quad \dots \text{EQ 6.2}$$

- 6.10.2 Compare the pair of cooking fume concentrations in both inlet stream and outlet stream air, calculate the removal efficiency by the equation EQ 6.3

$$\text{Cooking fume removal efficiency} = \left(1 - \frac{(\text{Conc of cooking fume in outlet stream})}{(\text{Conc of cooking fume in inlet stream})}\right) \times 100\% \quad \dots \text{EQ 6.3}$$

- 6.10.3 Calculate the cooking fume removal efficiencies of the 5 sets of valid samples obtained in Section 6.4 under the same system flow rate. (check also the criteria in para. 7.6.4 are met)
- 6.10.4 Calculate the average removal efficiency with the valid samples;

## **7 QUALITY ASSURANCE/QUALITY CONTROL**

Following are major considerations that can be taken to help ensure reliable and quality test runs:

### **7.1 Qualification And Training Of Technical Staff**

- 7.1.1 Technical staff to operate the cooking fume removal efficiency test system and collection of cooking fume samples shall possess a diploma or above in science or engineering discipline;
- 7.1.2 Laboratory staff to prepare and analyze cooking fume samples shall possess a diploma or above in chemistry;
- 7.1.3 Technical staff to operate the testing system and collect cooking fume samples shall receive training in the requirement of the STP, operation of the testing system, isokinetic stack sampling, operation of stack sampling system and QA/QC. Training may be conducted in classroom lectures with illustration and/or on-site demonstration. Appropriate assessment shall be conducted to assess the capability of the trainees. Only competent persons who pass the respective assessment are allowed to conduct the cooking fume sampling work.
- 7.1.4 Laboratory staff to prepare and analyze cooking fume samples shall receive training in the preparation of sample, operation of the respective IR spectrometer, data interpretation and QA/QC. Training may be conducted in classroom lecture and/or on-site demonstration. Appropriate assessment shall be conducted to assess the capability of the trainees. Only competent persons who pass the respective assessment are allowed to conduct the cooking fume analytical work.
- 7.1.5 Training and assessment record for each staff shall be maintained and filed.

### **7.2 Flow Rate Determination of the Testing System**

- 7.2.1 A standard pitot tube shall be used to measure the flow rate of the testing system. The flow measuring equipment shall be calibrated by the manufacturer or other qualified agents. A valid calibration certificate shall be obtained after calibration.
- 7.2.2 The condition and performance of the flow measuring equipment shall be checked prior to each measurement to ensure proper operation.

### **7.3 Thermocouple**

- 7.3.1 The thermocouple used for temperature measurement shall possess a valid calibration certificate, otherwise calibration against a certified mercury-in-glass thermometer shall be conducted. The linear regression relation of the actual temperature against measured temperature between the temperature range 0 - 500°C shall be established with at least 5 calibration points.

## 7.4 Isokinetic Sampling System

- 7.4.1 Isokinetic sampling system shall be calibrated according to the requirements of “Quality Assurance Handbook for Air Pollution Measurement System, Vol. III, Stationary Sources Specific Methods”, USEPA<sup>vi</sup>.
- 7.4.2 To collect a representative sample of cooking fumes from an exhaust duct, insert a probe coupled to a filter holder. Achievement of accurate isokinetic sampling demands that the gas linear velocity at the probe opening match that in the duct. Failure to match the probe and duct velocities will cause a distortion of testing data resulted from drawing in either larger particles (probe velocity lower than duct velocity) or smaller particles (probe velocity higher than duct).

## 7.5 Analysis of Cooking Fume Sample

- 7.5.1 All volumetric glassware shall be calibrated by gravimetric method;
- 7.5.2 Electronic balance shall be calibrated against standard weights;
- 7.5.3 IR spectrometer shall be maintained properly in accordance with the requirements of the service manual.

## 7.6 Quality Assurance and Quality Control of Measurement Results

### 7.6.1 Determination of Method Detection Limit

- 7.6.1.1 Calibrate the IR spectrometer according to the steps 6.8;
- 7.6.1.2 Prepare a standard rapeseed oil mixture in perchloroethylene with concentration of about 10% of the calibration range;
- 7.6.1.3 Analyze the concentration of the rapeseed oil standard according to the steps 6.9 for 7 times, calculate the average and the standard deviation of the concentration;
- 7.6.1.4 Determine the detection limit of the IR-spectrometer according to the equation EQ-8.1

$$\text{Detection limit (DL)} = 3.14 \times \text{standard deviation} \quad \dots \quad \text{EQ-8.1}$$

- 7.6.1.5 Determine the average total sample volume of 80% design flow rate (0°C and 101.325 kPa). Determine the method detection limit (MDL) according to the detection limit of the IR-spectrometer according to the equation EQ-8.2

$$\text{MDL} = \frac{(\text{DL of the IR spectrometer, mg/ml}) \times 25 \text{ ml}}{(\text{average air sample volume of 80\% flow rate, m}^3)} \quad \dots \quad \text{EQ -8.2}$$



### 7.6.2 Recovery of Standard Rapeseed Oil Samples

The test of rapeseed oil recovery is to evaluate whether the IR-spectrometer reports accurate cooking fume concentration in perchloroethylene extract.

7.6.2.1 Calibrate the IR spectrometer according to the steps 6.8;

7.6.2.2 Prepare 3 standard rapeseed oil mixtures in perchloroethylene with concentrations of about 30%, 50% and 80% of the calibration range;

7.6.2.3 Analyze the concentration of the rapeseed oil mixtures according to the steps 6.9, compare the measured concentration and the standard concentration and calculate the percentage recover according to the equation EQ-8.3

$$\% \text{ recovery} = \frac{(\text{measured concentration}) \times 100\%}{(\text{standard concentration of rapeseed mixture})} \quad \dots \text{EQ -8.3}$$

### 7.6.3 Recovery of Spiked Filter

The test of recovery of spiked filter is to evaluate the recovery of cooking fume from sampled particulate filters through the ultrasonic extraction process.

7.6.3.1 Weigh about 2 mg of rapeseed oil with a glass syringe and electronic balance, record the actual weight of rapeseed oil;

7.6.3.2 Spike the weighed oil to a clean particulate filter, then air dry the filter;

7.6.3.3 The range of relative humidity for preparing the clean filter paper and for air drying the filter should be within 30 – 45%. The time taken to air dry each filter is 15 minutes;

7.6.3.4 Prepare and analyze the filter according to the steps 6.7 to 6.9. Record the measured total rapeseed oil in the filter;

7.6.3.5 Compare the actual and measured weights of the samples and calculate the percentage recovery similar to the equation EQ-8.3. The average percentage spike recovery shall be greater than 70%.

### 7.6.4 Rejection of test data

The test data should be rejected if the following criteria are not met:

- Leak found – Leaks in the system can be serious since they will impair the accuracy of flow rate readings and thus concentration of oil fumes measured. Every precaution must be

taken to ensure tightness in joints, instrument filters and fittings. Leak proof of the ducting system and connecting joints should be assured by undergoing measurements along the ducting with velocity meter. Leak found on sampling train is also not acceptable. Refer to para. 6.3.7 for leak check.;

- Isokineticity - maintaining an isokinetic sampling rate (within 10 percent of true isokineticity);
- Inlet fume concentration - the required concentration of total cooking fume in the inlet stream shall be maintained at  $100 \pm 20 \text{ mg/m}^3$ .

## 8 SAFETY PRECAUTIONS

- 8.1 Maintain adequate ventilation and supply of fresh air. Since the test system extracts large volume of air inside the laboratory, sufficient ventilation and supply of fresh air should be adequately maintained. Open the doors and use of mechanical fan whenever necessary.
- 8.2 It is important to make sure that the edge of the stove is so designed that there will be no naked flame coming out from the gap between the wok and the gas-fired stove to avoid fire hazard. The internal rim of the stove should be constructed in such a way that the wok sits squarely on it without any gap so that there will be no naked flame coming out from below the wok.
- 8.3 LPG / Town Gas fired stove shall be handled with extreme care. When the stove is being operated, the oil in woks can be heated up to a very high temperature. The cooking stove may cause fire especially the scene is fraught with flammable cooking oil and LPG / Town Gas containers. Wear heat proof gloves when handling the gas stoves.
- 8.4 When the oil generation system is being operated, dense cooking fume and high temperature oil droplets are generated continuously. Such cooking fume and oil droplets may cause severe burns. Do not put the hands inside the cooking fume generation chamber when it is in operation unless sufficient protective clothing and gloves are worn.
- 8.5 Heat resisting thermometer must be inserted into the oil bath throughout the test. During the generation of oily fume, the burners must be manually controlled and adjusted to maintain the bulk oil temperature in woks STRICTLY below 310°C.
- 8.6 Cooking oil may burn when the bulk oil temperature is higher than the fire point. Must handle oil bath with care to avoid fire hazards.
- 8.7 Sufficient safety equipment shall be available in the testing laboratory. Safety equipment shall include but not limited to the following (fire extinguisher, first aid box, etc) :
- Fire blanket
  - Fire extinguishers (carbon dioxide type and/or dry powder type)
  - Fire alarm
  - Cotton gloves and heat proof gloves
  - Protective clothing and lab gown
  - Eye goggles
  - Waste oil container
  - First aid box

8.8 Some cooking fume control equipment may require water supply, properly manage the wastewater discharge, and avoid wetting the floor which may be slippery. Wastewater may contain residue cooking oil, such residual oil and other waste oil should be treated as chemical waste and handled properly. Do not discharge waste oil to toilet or other improper drainage.

8.9 Maintain good housekeeping of the laboratory to avoid potential accidents.

8.10 Perchloroethylene is a suspected carcinogen. Handling of the solvent shall be inside a fume cupboard or at a well ventilated area to avoid accumulation of high concentration of perchloroethylene vapour.

8.11 Analyzed sample extracts and waste perchloroethylene shall be handled properly and treated as chemical waste.

8.12 Safety Training shall be provided to technical staff and laboratory staff to raise the awareness of safety. The safety training shall include but not limited to the following :

- instruction on using safety equipment
- procedures in case of accident and fire
- potential hazards of the testing system and the testing procedures
- proper handling of waste oil, wastewater and chemical waste
- use of protective facilities

## **9 REFERENCES**

- i. USEPA Method 5 “Determination of Particulate Matters Emissions from Stationary Sources”, USEPA
- ii. PRC National Standard “Emission Standard of Cooking Fume” (中國國家標準 GB 18483-2001 – 飲食業油煙排放標準)
- iii. Report on Survey of Restaurant Emission of Cooking Fume Emissions from Local Restaurants, EPD .
- iv. Report on Literature Survey of Legislative Control and Testing Method of Cooking Fume Control Equipment for Cooking Fume Emission Control, EPD
- v. USEPA Method 2 “Determination of Stack Gas Velocity and Volumetric Flow Rate”, USEPA
- vi. Quality Assurance Handbook of Air Pollution Measurement System, Volume III, Stationary Sources Specific Methods, USEPA
- vii. USEPA Method 1 “Sample and Velocity Transverses for Stationary Sources”, USEPA
- viii. Report of Study on Evaluation of Cooking Fume Emission Characteristics, EPD

