STUDY OF KITCHEN HOOD WATER MIST SYSTEM FOR COOKING EMISSION (UL1046) FILTRATION WITH LOW PRESSURE DEFLECTED NOZZLE

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SPECIAL GRATITUDE TO;

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For their support in whole of my life

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ABSTRACT

Most kitchen hoods in restaurants and hotels used standard water mist filtration. There are two types of filtration used in the kitchen hood, namely the washing water and water mist. Water mist spray works continuously to filter the system and facilitate cleaning purposes by collecting oil and disposing it. In a study undertaken previously, for heavy work activity on kitchen hood water mist system, water only is not effective in dissolving oil to clean the filter in kitchen hood system. In fact, water generates a high level of reading on the emission of the kitchen hood plenum system. Flat fan spray nozzle is used only for liquid spray to produce to spray water mist on kitchen hood filtration and require a low pressure water spray. In this study, mixtures of organic citric acid (lemon water) with ratio (1:10) and (3:10) were used. Citric acid was selected because it has the same characteristics as detergent for cleaning processes. The AL 75 nozzle was used on kitchen hood system to replace the flat fan spray nozzles for determining the water and air reduction. Kitchen hood system was built to carry out research and Grease Machine (UL1046) was used to produce a vapor as heavy work cooking activities. Results of the study showed that flat fan spray nozzle with a mixture of citric acid on Lemon 30 % and Water 70% (L30W70) is more effective as it is able to decrease 26.4 % of CO_2 emission in comparison to no water mist test. Results of studies using AL 75 (1:1) with L30W70 condition is effective in reducing the amount of CO_2 on average, from 5678 ppm to 4187 ppm. Mixtures of organic with experiment instruments showed that the vapor released can be controlled and nozzle AL 75 (1:1) is effective as a filtration system. The mixed water with citric acid can reduce the emission for heavy work cooking activity on kitchen hood water mist.

ABSTRAK

Jenis hud dapur yang lebih efektif dalam penapisan adalah jenis basuhan air atau pun semburan kabus air. Jenis hud dapur ini menggunakan semburan kabus air secara berterusan kepada sistem penapis dan sistem saluran untuk membersih dan memudahkan minyak untuk dilupuskan. Namun seperti yang diketahui, air tidak boleh melarutkan minyak secara berkesan terutama semasa proses pembersihan alat penapis. Air akan menghasilkan tahap bacaan pelepasan wap yang tinggi pada sistem hud dapur dan bahagian dapur. Nozel kipas rata yang digunakan hanya menggunakan cecair untuk menghasilkan semburan dan memerlukan tekanan air yang tertentu bagi menghasilkan semburan yang lebih baik. Dalam kajian ini, campuran organic citric acid (Air Lemon) dan air dengan nisbah (1:10) dan (3:10) digunakan sebagai memenuhi syarat yang ditetapkan. Citric Acid dipilih kerana mempunyai ciri-ciri yang sama seperti bahan pencuci untuk proses pembersihan. Nozel AL 75 telah digunakan untuk menggantikan nozel kipas rata bagi melihat kecekapan campuran air dan udara dengan tekanan nisbah (1:1) dan (1:2). Hud dapur telah dibina untuk menjalankan kajian dan *Grease Machine* (UL1046) yang digunakan untuk menghasilkan pelepasan wap pembakaran sebagai aktiviti masakan berat. Keputusan kajian menunjukan, nozel kipas rata adalah lebih efektif dengan campuran acid citric Lemon 30 % Air 70% (L30W70) dapat mengurangkan 26.4 % bacaan pelepasan karbon dioksida antara ujian yang tidak menggunakan nozel. Keputusan kajian menggunakan AL 75 (1:1) dengan proses L30W70 adalah sangat berkesan dengan menurunkan jumlah CO_2 pada 5678 ppm hingga 4187 ppm dalam lingkungan purata. Campuran air dan lemon yang telah ditetapkan menunjukkan bahawa pelepasan wap pembakaran boleh dikawal dan nozzle AL 75 adalah lebih berkesan sebagai sistem penapisan. Campuran acid citric dengan air mentah akan memberikan kadar penurunan bacaan wap pembakaran pada hud dapur jenis semburan kabus.

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Kitchen hood ventilation functions as a system to reduce heat, moisture, smoke and vaporized grease from the kitchen area to the outdoor. Commercial Kitchen Ventilation (CKV) systems have a major impact on the energy consumption of food service facilities. CKV has a high fire risk because the grease discharged will accumulate in kitchen hood surface and can easily burn even with a small fire. Therefore, kitchen hoods must be clean from contaminant that sticks at the filter and a large amount of water is needed in the cleaning process. The main task for this project is to remove grease from the filter and reduce the amount of water used for cleaning.

In a kitchen hood ventilation system (KHV), the type of nozzle used for water mist system is the flat fan nozzle. These nozzles produce tapered edge, flat-fan spray patterns. The standard flat-fan nozzle normally operates between 30 and 60 pounds per square inch (psi), with an ideal range between 30 and 40 psi (Kabir, 2011). These nozzles are used to clean up the filter by using water. However, the filtration capacity is not satisfactory because water cannot dissolve oil and grease on the filter. Therefore, a new nozzle of mist spray using organic citric acid and water mixture for the kitchen hood ventilation system will be tested in order to analyses the characteristic of the mist spray. The apparatus of the flow control system will be used to test the nozzle. Direct imaging analysis, can examine the formation of spray pattern, spray angle, and spray penetration (Bachus, 2008).

1.2 Significance of Study

In kitchen hood ventilation water mist system filters systems available is the baffle. This study is expected to provide further information on the new design of the deflected flat spray internal mix nozzle using chemical and air mixture for the kitchen hood ventilation system. Additionally, this study will expose the emission characteristic of the grease loading machine after passing through water mist spray. The results obtained through the experiments will be a reference in order to improve the efficiency of the filtration system of the kitchen hood.

The result may be helpful to others to gain insights on the filtration system using a nozzle. A good nozzle design will provide the perfect effect of a spray formation and high efficiency in reducing emission. In addition, this study also provide new information on the benefit of organic citric acid and water mixture for filtration system as well the cleaning process. Therefore, this study will be crucial in finding good filtration for grease emission and cleaning processes.

1.3 Problem Statement

Currently water mist is used for kitchen hood ventilation system, efforts are being made to effectively reduce the emission. In the kitchen hood ventilation system cleaning process the use of nozzles can reduce the grease emission and reduce the temperature on the wall surface kitchen plenum. Water alone cannot dissolve oil and grease effectively to clean up the filter unit and decrease the amount of emission (heavy work cooking activity). For study concentrations on the ventilation requirement for heavy work is through grease machine process. The filtration of nozzle AL 75 and flat fan spray nozzle is done to maintain an effective kitchen ventilation capacity level. The heavy work cooking activity on kitchen hood can create a non-healthy environment for workers. In this study, the kitchen hood ventilation water mists system uses the AL 75 nozzle. The kitchen hood ventilation system is low level cleanliness of standard filter (Baffle filter).

1.3 Objective

The purpose of this research is to study the effect of cooking using low-pressure spray mist atomizer deflector on the hood ventilation system used for cleaning the kitchen. In particular, this study aims to:

i. Study the emission characteristic through grease loading test (UL1046) with the filtration system using AL 75 nozzle and flat fan spray nozzle.
ii. Determine the optimum mixture ratio between organic citric acid and water.

1.4 Scope of study

To achieve the objectives above, the following scopes were outlined:

i. Type of kitchen hood is commercial kitchen hood ventilation water mist island canopy.
ii. 2 types of low pressure deflected nozzle, flat fan spray and AL 75 with 3 different conditions water 100 %, lemon 10% water 90% and lemon 30% water 70%.
iii. Cooking activity through grease machine (UL1046) with water and vegetable oil at 385°C ± 14°C in vapor box. Flow rate standard UL1046 in the ducting of kitchen hood provides air delivery of 65 m^3/min.
iv. Measurement of temperature, CO, CO_2, SO_2, and TVOC.
v. Experiment parameters carry out 47 minutes testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In kitchen room area can be found moisture, grease, odors, and heat from the stove-top food preparation. Commercial kitchen hood ventilation from a range hood or vent was invented to remove stale, odorous steamy air through ducts which in turn will eliminate or lessen these problems. Steam from cooking condenses on windows and walls, and carbon monoxide from gas-range combustion can build up.

Type of hood offers a continuous water mist that is sprayed into the filters and ducts area, which will emulsify or harden the grease. One of the more effective types of commercial kitchen hoods, in terms of grease collection and removal, is the water wash or water mist type of exhaust hood.

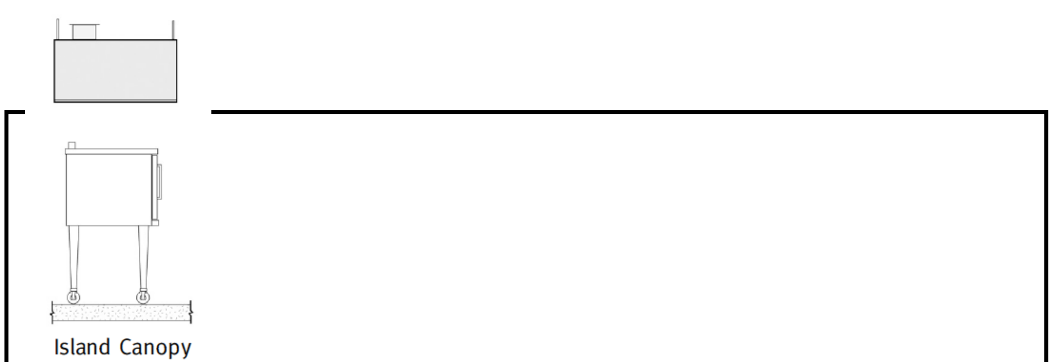
Instead of the grease vapors floating around until they settle, it will immediately cool and can be collected in a trough area which is far easier to clean. In kitchen ventilation exhaust with water wash or water mist, the type of nozzle that is being used is the flat fan spray nozzle (Accurex, 2009).

2.2 Types of Kitchen Hood Ventilation System

Every commercial kitchen requires ventilation, and in the past, the importance of a proper ventilating system has been overlooked. At present, commercial kitchen hood ventilation is a significant component of energy consumption in restaurants and fast-food kitchens. Kitchen ventilation function is to reduce fire hazards and exhaust cooking effluent to comply with air quality standards within a commercial kitchen. Thus, an adequate ventilation system is required to efficiently remove smoke, volatile organic compounds, grease particles and vapor from a kitchen space (Abanto, 2006).

Table 2.1 : Hood compilation table - Specification (Rivera, 2009)

Type of kitchen hood	Kitchen Ventilation	Kitchen Double	Kitchen indoor	Kitchen Back shelf
Baffle Filtration	/	/		
Lighting IP 6S			/	/
Grease Filter	/		/	/
Capture Jet system			/	/
Make-up air supply		/		/
Capture Ray UV system				
Water Wash system	/			
Low Proximity	/			
ANSUL fire suppression		/		
LED lighting			/	
Halogen Spot light			/	
MARVEL DCV system			/	



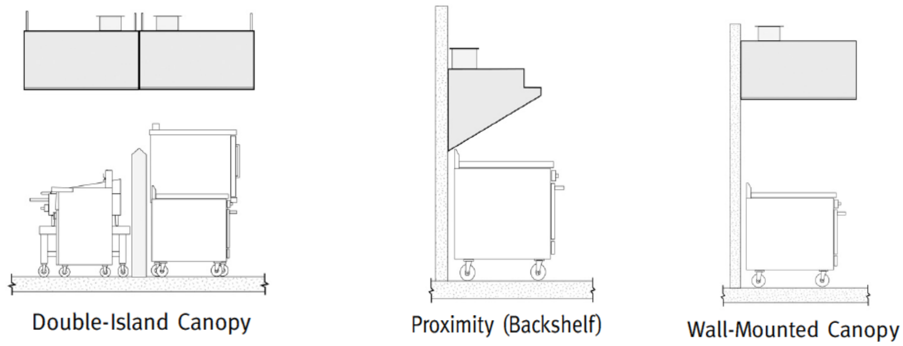


Figure 2.1: Common exhaust hood styles (Rivera, 2009)

Commercial kitchen exhaust hoods are available in many different configurations and specifications as shown in Table 2.1. These varying configurations can impact the hoods ability to capture and contain effluent, including odors, gases, heat, and oil. The commercial kitchen hood style as shown in Figure 2.1, construction features, and proximity of hood installation, give different capture area of hood (Rivera, 2009).
The hood styles, in order from the highest exhaust requirement to least, generally include:

i. Single-island canopy hood.
ii. Double-island canopy hood.
iii. Wall mounted canopy hood.
iv. Back-shelf hood.

2.3 Design of Kitchen Hood

The purpose of kitchen hood system is to remove the heat, smoke, effluent, and other contaminants. The thermal plume from appliances absorbs the contaminants that are released during the cooking process. Room air replaces the void created by the plume. If convective heat is not removed directly above the cooking equipment, impurities will spread throughout the kitchen, leaving discolored ceiling tiles and greasy countertops and floors. Therefore, contaminants from stationary local sources within the space should be controlled by collection and removal as close to the source as it is practical (Z, (Accurex, 2009).

Table 2.2: Process for development of industrial Kitchen (Accurex, 2009)

1. Kitchen Layout Design	2. Kitchen equipment definition	3. Kitchen Hood Design
a) Kitchen type b) Kitchen menu c) Cooking process Cooking equipment d) Setting the Indoor Air Quality criteria e) Loads f) Room properties g) Preliminary room system selection	a) Cooking equipment b) External Loads c) Equipment Loads d) Light e) Workers	a) Hood type b) Air flow rate c) Capture efficiency

2.3.1 Type of Kitchen Hood

Cooking appliances are categorized as light, medium, heavy, and extra heavy duty, depending on the strength of the thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By nature, these thermal plumes rise by natural convection. However, they are turbulent and different cooking processes have different “surge” characteristics. For example, the plume from hamburger cooking is strongest when flipping the burgers. Ovens and pressure fryers may have very little plume until they are opened to remove food products. Open flame, non-thermostatically controlled appliances, such as under fire broilers and open top ranges, exhibit strong, steady plumes. Thermostatically controlled appliances, such as griddles and fryers have weaker plumes that fluctuate in sequence with thermostat cycling (particularly gas-fired equipment). As the plume rises, it should be captured by the hood and removed by the suction of the exhaust fan. Air in the proximity of the appliances and hood moves in to replace it. This replacement air, which must ultimately originate as outside air, is referred to as makeup air (Nickel, 2004).

The design exhaust rate also depends on the hood style and construction features. Wall-mounted canopy hoods, island (single or double) canopy hoods, and proximity (back shelf, pass over, or eyebrow) hoods all have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (see Figure 2.2). Generally, for the identical (thermal plume) challenge, a single-island canopy hood requires more exhaust than a wall-mounted canopy hood, and a wall-mounted canopy hood requires more exhaust than a proximity (back shelf) hood. The performance of a double- island canopy tends to emulate the performance of two back-to-back wall- canopy hoods, although the lack of a physical barrier between the two hood sections makes the configuration more susceptible to cross drafts (Nickel, 2004)

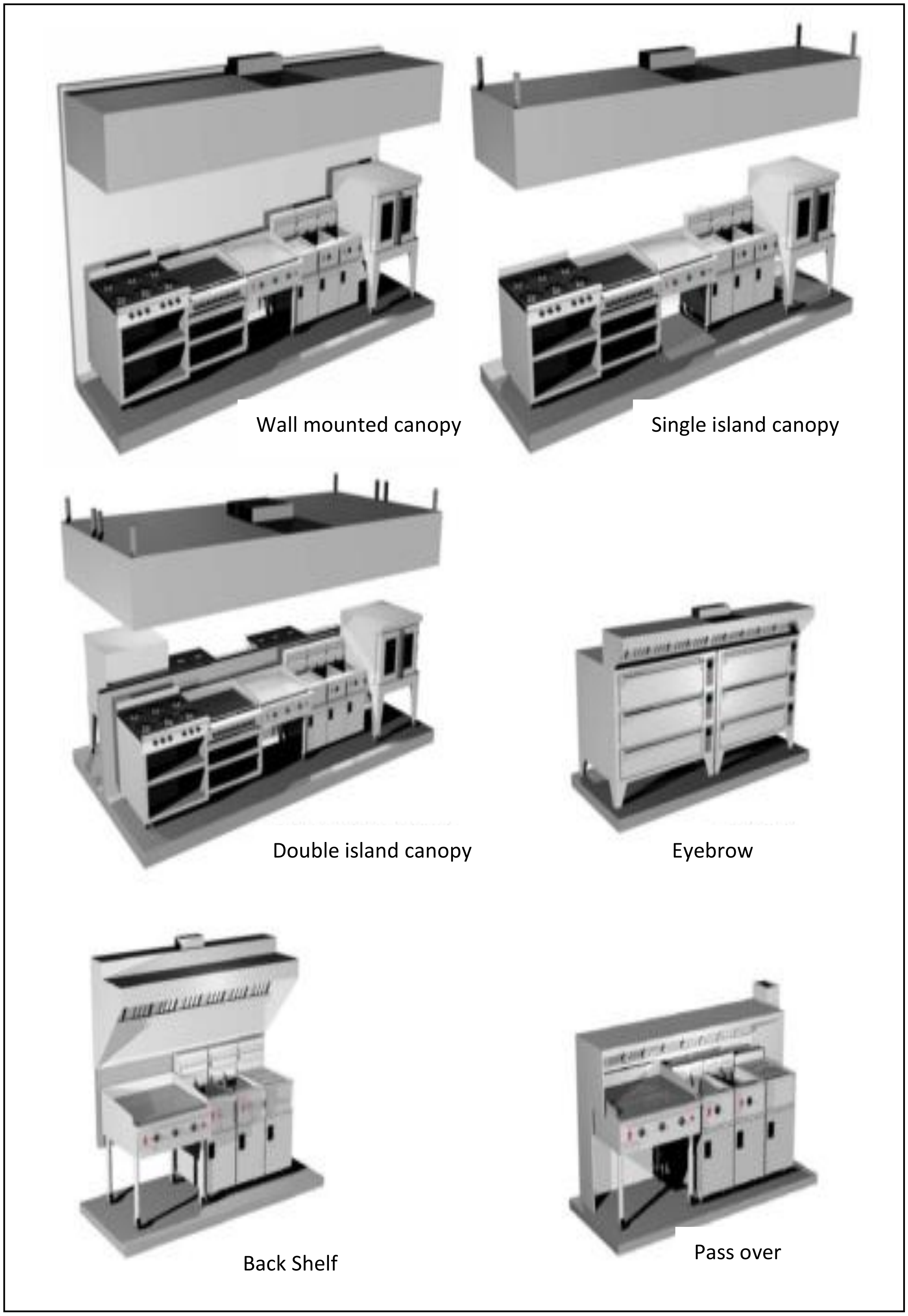


Figure 2.2: Style of kitchen hood system exhaust hood (Nickel, 2004)

2.4 Types of Filtration

Most commercial cooking equipment such as ranges, griddles, and fryers requires the use of an exhaust hood. These hoods are designed to remove smoke, heat, steam, and fumes, as well as dirty kitchen air. However, the air in commercial kitchens is filled with bits of grease and food residues that can quickly clog up the ductwork in a hood system if not properly filtered out. By selecting the appropriate hood filter for your establishment, you can keep your exhaust hood working at peak performance and ensure clean kitchen air (Greenheck's, 2011).

Table 2.3 : Filtration options (Greenheck's, 2011)

Filter	Application	Appliances	Static Pressure	Grease removal (9x4 foot hood)	Grease removal (at 8 microns)
Grease Grabber Multistage Filtration System	Heavy to extra heavy duty grease	Solid fuel cooking appliances upright broiler gas, electric and lava.	1.1 to 1.3 in.wg	100 %	99%
Grease x factor Centrifugal Filtration	Medium to heavy duty grease	Combination ovens gas and electric fryers griddles grill up-right broiler Electric char-broiler	0.7 to 0.8 in. wg	69%	51%
High-Velocity Cartridge	Light Duty Grease	Gas and electric ovens / Steamers / Rangers food warmers and Pizza ovens	0.7 to 0.8 in.wg	42%	21%
Baffle	Light duty grease	Gas and electric Ovens / Steamers / Rangers / Food warmers and Pizza ovens	0.5 to 0.6 in.wg	28%	16%

Table 2.3 shown different types of filtration options. Baffle filters are durable and easily washable, making them great for high volume establishments where saving time is important. Baffle filters are used in this case study.

2.4.1 Standard Baffle

These standard baffles are designed to remove smoke, heat, steam, and fumes, as well as dirty kitchen air. Stainless steel hood filters are durable and easily washable, making them great for high volume establishments where saving time is important. For maximum convenience, baffle filters can be placed in the dishwasher or soaked in water, unlike filters made of aluminum. This baffle can also be cleaned by hand or with a pressure washer and are available in an array of styles and sizes to fit common kitchen exhaust hoods (Kosonen, 2006).

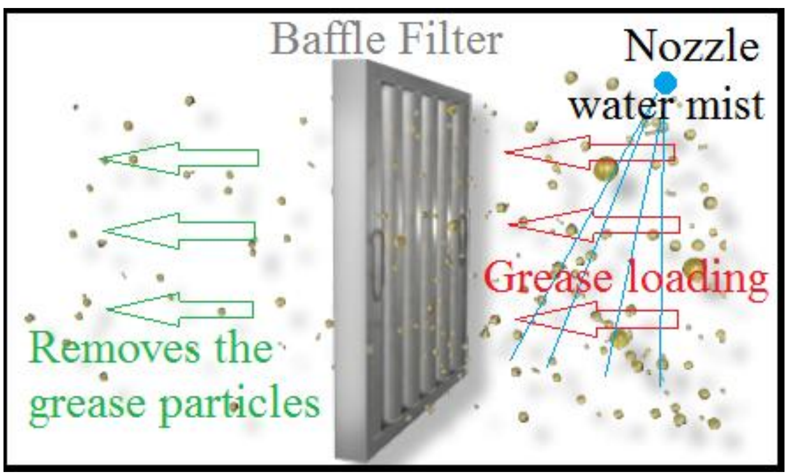


Figure 2.3: The baffle filter removes 28% of the grease particles at 8 microns

As shown in figure 2.3, the particles momentum throws the grease out of the air stream into the baffles. The grease then runs down the baffle into the grease trough which drains into a removable grease container. The baffle filter removes 28% of the grease particles at 8 microns (Kosonen, 2006).

2.5 Grease Emissions and Ambient Room Temperature

The removal process of grease from the exhaust airflow is a very important part of commercial kitchen operation because grease can create fire hazard, odors at cooking areas etc. These problems can be greatly reduced through the use of proper nozzle devices for cleaning. The grease particulate is in liquid form or solid particles of grease that have become suspended in the air. The particulate can range in sizes from 0.01 to 100 µm. Grease vapor refers to grease in the gaseous state that is much smaller than grease particulate. Vapor is condensable and may turn into grease particulate or remain in a vapor state while being exhausted into the atmosphere (Livchak et al., 2003).

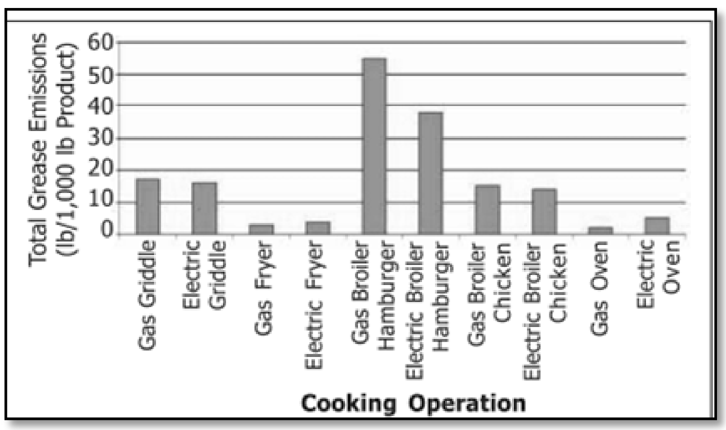


Figure 2.4: Cooking emission as a function of cooking process.

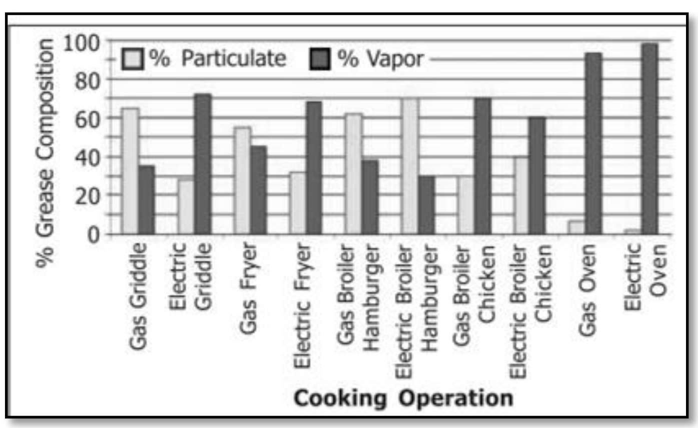


Figure 2.5: Vapor and particulate ratio in cooking emissions.

The study by Livchak (2003) revealed that kitchen hood manufacturers claim the efficiency of their grease filters is 90% or higher and referred several standards to support the performance measurements. Unfortunately, none of these standards represent filter performance under cooking conditions. Grease emissions from cooking processes consist of particulate and vapor. Mechanical grease extractors are effective only at capturing particulate and are not able to extract vapor (Livchak et al, 2003).An ASHRAE research project, RP-745, documented emissions from different cooking processes. The results are presented in Figures 2.4 and 2.5. Figure 2.3 showed total emissions as a function of the cooking process and Figure 2.4 gave the breakdown between vapor and particulate in cooking emissions. The percentage of particulate in this figure corresponds to the theoretical maximum efficiency of a mechanical grease extractor (Livchak et al., 2003).

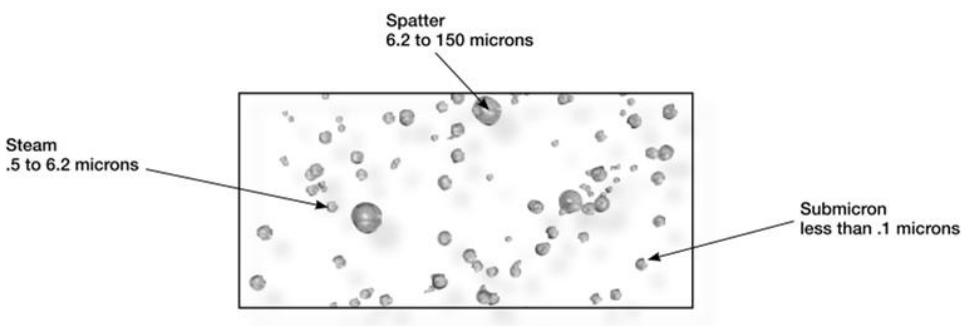


Figure 2.6 : Grease particles (Accurex, 2009).

According to a study carried out by Accurex, grease could be removed and broken down into three different categories (Accurex, 2009). First is the submicron particle. It is produced when a drop of grease or water comes in contact with a hot surface and immediately burns off. Figure 2.6 has shown that particle size range from 0.03 μm to 0.55 μm (smoke). The second is steam condition. Grease covered moisture and air mixture are produced by the long burning of cold or frozen food on a hot cooking surface. Particle sizes range from 0.55 μm to 6.2 μm. Third is Spatter, which is the larger more visible effluent that is produced during the cooking process. Particle sizes range from 6.2 μm to 150 μm.

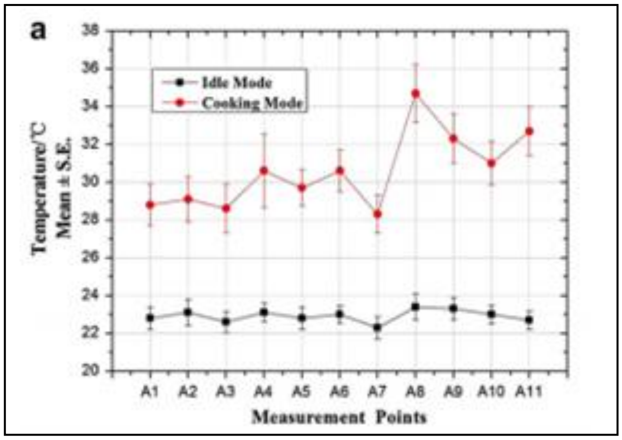


Figure 2.7: The variation of temperature across different measurement points of section 8 in kitchen

Temperature concentration of the non cooking area exceeded the value of the measurement points besides the cooking range. In Figure 2.7 is shown a ambient temperature with cooking activity in kitchen room. The higher temperature in kitchen is 34°C for ambient temperature (Bramfit, 2006).

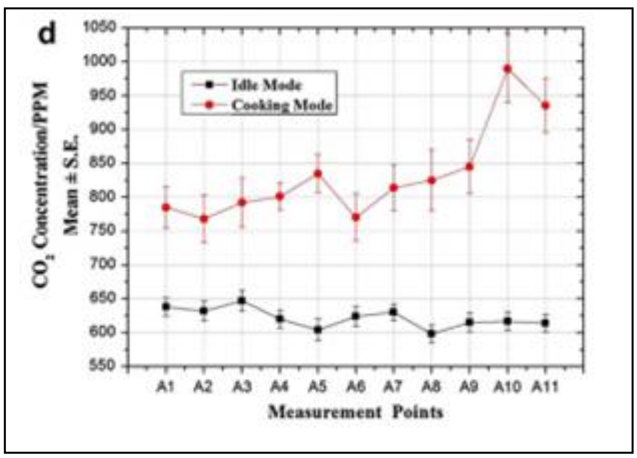


Figure 2.8: The variation of CO_2 concentration across different measurement points of section 10 in kitchen

To understand the effect of the ventilation system, the study focused on temperature field, relative humidity field, and concentration distribution varying with following whether cooking or none cooking. In Figure 2.8 is shown a higher CO_2 is 980 ppm on point 10. For the middle and small commercial kitchens that used the natural air supply system, the temperature and CO_2 concentration were far more than the acceptable level (Bramfit, 2006).

Location 1 is 0.5 meters in front of the kitchen ventilation system. The higher outdoor temperature is 49°C. Figure 2.9 shows a higher point temperature because of active cooking, and after cooking, the temperature returns to normal condition.

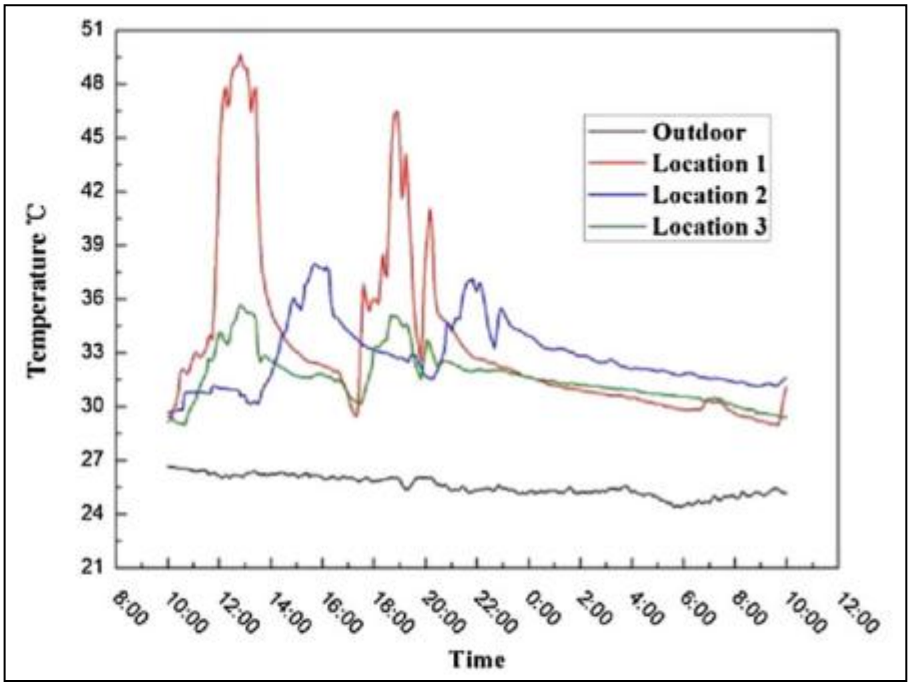


Figure 2.9: The outdoor temperature and the 3 measurement locations in kitchen

2.6 Basic Parameters

The measured parameters were TVOC, CO_2, CO, SO_2, temperature, and relative humidity. The parameters were measured on the kitchen hood ventilation, ducting and in kitchen room.

2.6.1 Relative Air Temperature

This temperature will show if the space is hot or cold and comfortable or otherwise. Air temperature influences the heat rejection from body through three processes which are convection, radiation and evaporation. So, in an attempt to produce a comfortable space, a proper ventilation system should be ensuring that it could control air temperature in tandem with the ventilation rate.

2.6.2 Relative Humidity

Relative humidity is an amount of water vapor in the air at any given time, which is normally less than that required to saturate the air. The relative humidity is the percent of saturation humidity, generally calculated in relation to saturate vapor density. Relative humidity can be changed as follows:

i) To increase relative humidity, either the air temperature is decreased or the actual moisture of the air is increased.

ii) To decrease relative humidity, either the air temperature is increased or the actual moisture of the air is decreased.

An acceptable comfort range for the human body is 22.22°C to 26.67°C at 45% to 50% relative humidity (Burroughs, 2004).

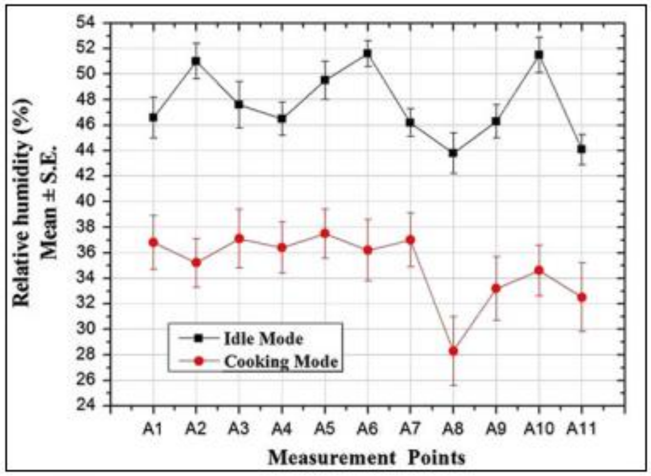


Figure 2.10: The relative humidity data on cooking test (Yujiao , 2012).

In addition, the variation of relative humidity was contrary to the ambient temperature. The minimum relative humidity during cooking of point 8 was 34.0%. The relative humidity, the decrease in minimum value when moving from point 2, was 5.6%. For the middle and small commercial kitchens in China, the indoor temperature during cooking activity was too high and the relative humidity was too low, which made the chef feel very uncomfortable (Ishige, 1992).

2.6.3 Carbon Dioxide (CO_2)

CO_2 gas is colorless and odorless or extremely cold liquid under pressure or refrigeration. The CO_2 gas can displace O_2 gas in air. Headache, nausea, sweating, restlessness, disorientation and dizziness are caused by very high concentrations of CO_2 gas. CO_2 which is produced by human respiration gaseous.

Table 2.4: Ventilation rates required to limit CO_2 gas concentrations (Awbi, 2000).

Minimum ventilation required (liters/s per person)			
Activity	0.1% CO_2	0.25% CO_2	0.5% CO_2
At rest	5.7	1.8	0.85
Light work	8.6 – 18.5	2.7 – 5.9	1.3 – 2.8
Moderate work	-	5.9 – 9.1	2.8 – 4.2
Heavy work	-	9.1 – 11.8	4.2 – 5.5
Very heavy work	-	11.8 – 14.5	5.5 – 6.8

Table 2.4 shows that the level of CO_2 gas depends on the quantity of occupants in a space. The Environmental Protection Agency (EPA) recommends a maximum level 1000 ppm (1.8 g/m^3) for continuous CO_2 gas exposure specifically for school and residential occupancy as a guideline for other building types.

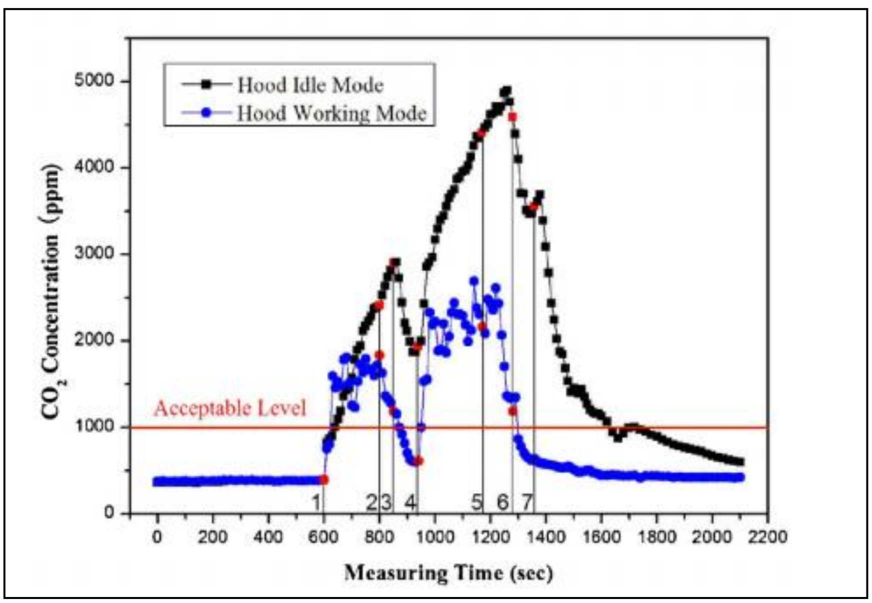


Figure 2.11: CO_2 concentration (Yujiao, 2012)

Figure 2.11 shows that an accepted level for a maximum concentration of CO_2 gas within an occupied space is 5000 ppm or 0.5% by volume for an exposure of 1200 seconds. It is recommended by ventilation standard that the lower concentrations are required to avoid discomfort and headache. The ventilation rates required to limit CO_2 gas concentration are given in Table 2.5. This table gives 0.1%, 0.25% and 0.5% of CO_2 gas in different cooking activity (Awbi, 2000).

2.6.4 Carbon Monoxide (CO)

CO is produced as a product of combustion process, fuel burning appliance, vehicle or other device and has the potential. CO is an odorless, colorless gas often formed in the process of incomplete combustion of organic substances, including fuels CO gas. It is the most common type of fatal poisonous gas in many countries and is dangerous because it interferes with normal O_2 necessary to live. Exposure to CO can lead to significant toxicity of the central nervous system and heart.

In general, CO is produced when any material burns. More is produced when there isn’t enough O_2 for efficient burning. Common sources of CO in homes include fuel-burning devices such as: furnaces, gas or kerosene space heaters, boilers, gas cooking stoves, water heaters, clothes dryers, fireplaces, charcoal grills, wood stoves, lawn mowers, power generators, camp stoves, motor vehicles and some power tools with internal combustion engine. Smoking is another common source of CO that can negatively impact IAQ.

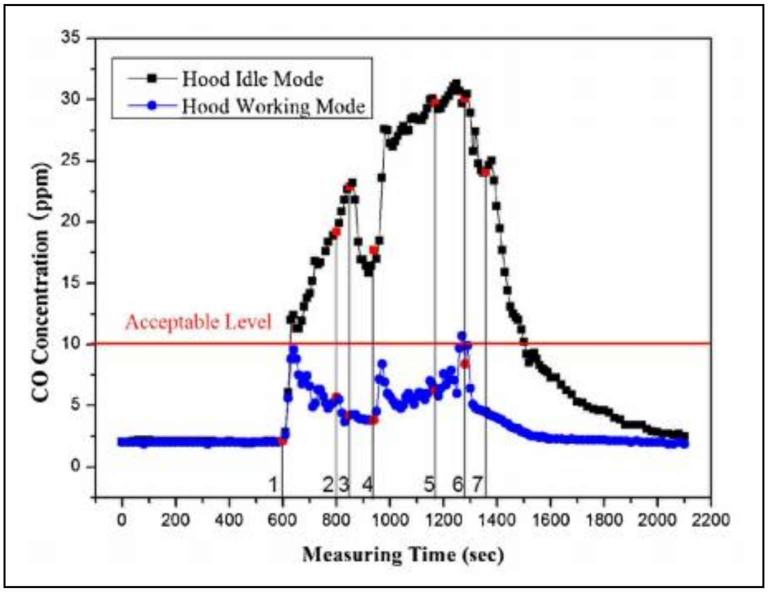


Figure 2.12: CO concentration (Yujiao, 2012).

Ideally, CO concentrations indoors are expected to be the same as CO concentrations outdoors. CO concentration in the outdoor air ranges from 0.03 – 2.5 parts per million parts (ppm). Figure 2.12 has shown a concentration over an 8-hour period. These averages are below the IAQ standard acceptable level of 9 ppm for CO in outdoor air quality. In general, higher CO concentrations indoor will affect the health of worker. The health effects of CO concentration on healthy and toxic symptoms are shown in Table 2.6 (Awbi, 2000).

Table 2.6: Health effects of various concentration of carbon monoxide (Awbi, 2000)

Exposure (hours)	CO Concentration (ppm)		
	Perceptible	Sickness	Deadly
0.5	600	1000	2000
1	200	600	1600
2	100	300	1000
4	50	150	400
6	25	120	200
8	25	100	150

1. ppm – parts per million – is defined as the mass of the component in solution divided by the total mass of the solution multiplied by 10^6 (one million)

2. The maximum exposure allowed by OSHA in the workplace over an eight hour period is 35 ppm.

3. Typical sickness symptoms are mild headaches, fatigue, nausea and dizziness.
4. A CO concentration of 12000 to 13000 ppm is deadly after 1 -3 minutes. A CO concentration of 1600 ppm is deadly after one hour.

Table 2.5: Concentration of CO in the air (ppm) (Awbi, 2000)

Concentration of CO in the air (ppm)	Inhalation Time	Toxic Symptoms
9	Short term exposure	ASHRAE recommended maximum allowable concentration in living area
35	8 hours	The maximum exposure allowed by OSHA in the workplace over an eight hour period
200	2-3 hours	Slight headache, tiredness, fatigue, nausea and dizziness.
400	1-2 hours	Serious headache-other symptoms intensify. Life threatening after 3 hours.
800	45 minutes	Dizziness, nausea and convulsions. Unconscious within 2 hours. Death after 2-3 hours.
1,600	20 minutes	Headache, dizziness and nausea. Death within 1 hour.
3,200	5-10 minutes	Headache, Dizziness and nausea. Death within 1 hour.
6,400	1-2 minutes	Headache, dizziness, nausea. Death within 25-30 minutes.
12,800	1-3 minutes	Death within 1-3 minutes.

Table 2.5 has shown CO concentration that produce toxic symptoms. For this study, concentration of CO is 400 ppm to 800 ppm in the kitchen hood ducting area.

2.6.5 Oxygen (O_2)

O_2 is a colorless and odorless gas. It is the second most abundant gas in the atmosphere after nitrogen (N_2) gas. O_2 gas exists in the gas state above - 183°C. O_2 gas is found on earth as a gas and constitutes about 21% of the air we breathe. Based on OSHA Standard, the maximum safe level is 23.5% volume and minimum safe level is 19.5% volume. The atmospheric concentration of O_2 gas is about 20.95% volume (Awbi, 2000).

2.6.6 Air Temperature

The air temperature must be maintained to make people comfortable. Most people work comfortably at a temperature between 20°C to 26°C. The device that controls the air temperature is air conditioner. The goal of controlling air temperature is to provide an environment that is not too cold and not too warm. The suitable and comfortable air temperature should comply with ASHRAE Standard 55-2004. In order to determine appropriate corrective actions following the use of this standard to analyze the environment, the following operations of the mechanical system shall be measured concurrently with the environmental data (Awbi, 2000) :

i) Air supply rate into the space being measured
ii) Room or supply air temperature differential
iii) Type and location of room diffuser or air outlet
iv) Discharge air speed
v) Perimeter heat type, location, and status
vi) Return grille location and status

vii) Type of air supply system

viii) Surface temperatures of heated or cooled surfaces

ix) Water supply and return temperatures of hydro systems

2.6.7 Total Volatile Organic Compounds (TVOC)

For this study, individuals exposed to moderate and high levels of CO over long period of time are subject to, increased risk of heart disease. However, the formation of TVOC were opposite from CO and CO_2. The formation of TVOC is attributed in large part to the use of seasoning, ingredients and the behavior of marinating. At the low level exposure of TVOC, little is known about the effects. Several studies indicated that exposure to TVOC may make symptoms worse in people who have asthma or are particularly sensitive to chemicals. To further understand, Table 2.6 showed the maximum increases of CO, CO_2 and TVOC for 3 types of dishes.

Table 2.6: The maximum increased of CO, CO_2 and TVOC during cooking (Zhao, 2014).

Type Gas		Kung Pao Chicken	Fried Sweet and Sour Chicken	Spring Rolls
Carbon Monoxide	Idle mode Working mode	143 % 64%	99% 1%	58% 79%
Carbon Dioxide	Idle mode Working mode	244.5% 37.2%	295.6% 59.7%	74.6% 68%
Total Volatile Organic Compound	**Idle Mode** **Working mode**	**1715%** **108.3%**	**1188.3%** **-**	**632%** **95%**

2.7 Nozzle

Theoretically, producing a nozzle with a good design makes the kitchen hood ventilation system more manageable and provides comfort to consumers' pollution free. The selection of proper nozzle is important for cleaning process which can affect efficiency of spray pressure. The nozzle selection was determined based on certain criteria such as the nozzle size, orifice, inlet, outlet, flow, liquid mixing, etc.

In atomizing nozzles, pressurized air is used to impact the fluid being sprayed. The impact would cause the fluid to break apart into a fine spray. This means that the energy required for atomization is no longer dependent on fluid pressure because these very fine sprays could be produced at low fluid pressures.

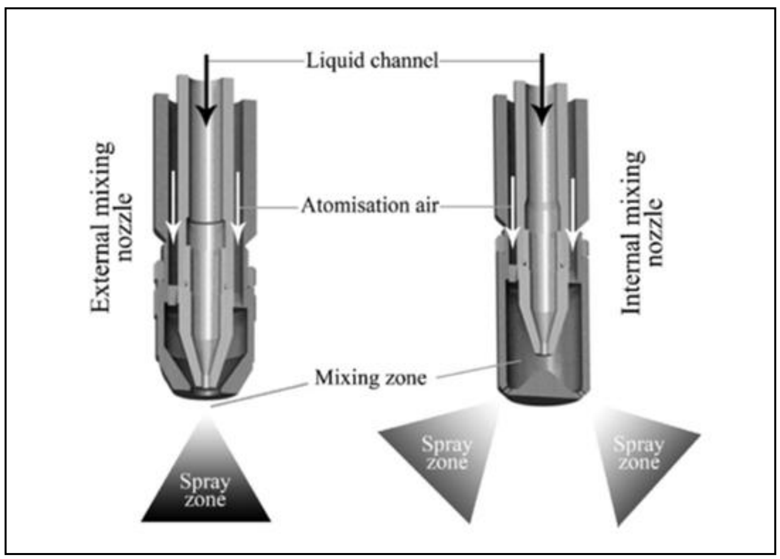


Figure 2.13: Examples of two fluid nozzle designs (Hede et al., 2008)

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