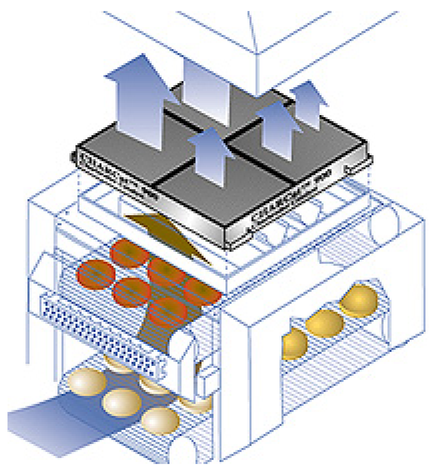
Bay Area Air Quality Management District

939 Ellis Street
San Francisco, CA 94109

Draft Staff Report

Regulation 6, Rule 2:
Commercial Cooking Equipment



April 2007

Prepared by:

Virginia Lau
Senior Air Quality Specialist
Planning and Research Division

Table of Contents

I. EXECUTIVE SUMMARY

Every day in the Bay Area, commercial and non-commercial cooking operations collectively emit an estimated 3.35 tons of particulate matter (PM) and 1.32 tons of volatile organic compounds (VOC). The Bay Area and neighboring regions are not yet in attainment with the State one-hour and eight-hour ozone standards and particulate matter standards and so further reductions of VOC and PM are needed.

Currently, no Bay Area Air Quality Management District (District) rule directly regulates emissions from restaurants. The District proposes adoption of Regulation 6, Rule 2 in accordance with its Senate Bill (SB) 656 Particulate Matter Implementation Schedule, and in connection with Further Study Measure (FS) 3 in the District's 2005 Ozone Strategy, which proposes evaluation of a rule to control emissions from commercial charbroilers.

The District focused its efforts on reducing emissions from two types of charbroilers: chain-driven charbroilers and under-fired charbroilers. Charbroilers are a central appliance for most restaurant kitchens and produce over 80% of commercial cooking emissions. Besides generating VOC and PM, charbroilers also produce carbon dioxide (CO_2), a gas contributing to climate change. The District estimates that the average CO_2 emissions for cooking activities per restaurant are approximately 25,000 pounds annually based on operation of the cooking appliances and associated ventilation equipment.

The District investigated a variety of control options for addressing emissions from charbroilers. To determine a list of available control technologies, the District reviewed reports and studies conducted either by universities, other air districts, or city-based health departments. Regulation 6, Rule 2 will require restaurants with chain-driven charbroilers to install a catalytic oxidizer or equivalent certified control to limit emissions of both PM and VOC. Owners of restaurants with one or more under-fired charbroilers with a total grill surface area of at least 10 square feet will be required to install a control certified to reduce PM emissions, by an effective date that depends on when the charbroilers were installed. The District anticipates these proposed standards will result in at least an 85% reduction in PM emitted by commercial charbroilers and a 60% reduction in VOC emitted by chain-driven charbroilers.

A socioeconomic analysis of the proposed regulation concludes that the new regulation would not have significant economic effects. An initial study of the proposed regulation concludes that the rule would not cause significant adverse environmental impacts, and a CEQA negative declaration is proposed for adoption.

Because this regulation addresses a new source category, the District undertook a comprehensive public outreach program to involve in the development of the proposed rule all stakeholders, including individual restaurant owners, hood manufacturers, restaurant trade organizations and industry representatives, county health departments, and vendors and installers of commercial kitchen appliances. The District held four public workshops on November 14 and 15, 2006, and based on public input, revised the draft proposal for presentation at a fifth workshop held on March 6, 2007.

II. BACKGROUND

A. Introduction

Restaurants vent substantial amounts of particulate matter (PM) and volatile organic compounds (VOC) into the atmosphere. Every day in the Bay Area, cooking operations collectively (commercial and non-commercial) emit an estimated 3.35 tons of PM and 1.32 tons of VOC.

Several California air districts have adopted rules limiting emissions from commercial cooking operations. The South Coast Air Quality Management District (SCAQMD) funded a detailed study that determined chain-driven charbroilers, under-fired charbroilers, and griddles generate most of the VOC and PM emissions from commercial cooking operations. At present, SCAQMD, the San Joaquin Valley Unified Air Pollution Control District, and the Ventura County Air Pollution Control District have each adopted a rule that limits emissions from restaurant charbroilers. Each of these rules requires chain-driven charbroilers to operate with a control device to limit the emissions of VOC and PM.

Currently, no District rule directly regulates emissions from restaurants. The District proposes adoption of Regulation 6, Rule 2 to fulfill a commitment in its Senate Bill (SB) 656 Particulate Matter Implementation Schedule, and in connection with Further Study Measure (FS) 3 in the District's 2005 Ozone Strategy, which proposes evaluation of a rule to control emissions from commercial charbroilers.

B. Source Description

Broilers are the central appliance for most restaurant kitchens and are used to cook steak, hamburgers, fish, chicken, and seafood, as well as to brown food and reheat plated food. All broilers are comprised of a grated grill and a heat source, where food resting on the grated grill cooks as the food receives heat either directly from the heat source, or indirectly by way of a radiant surface.

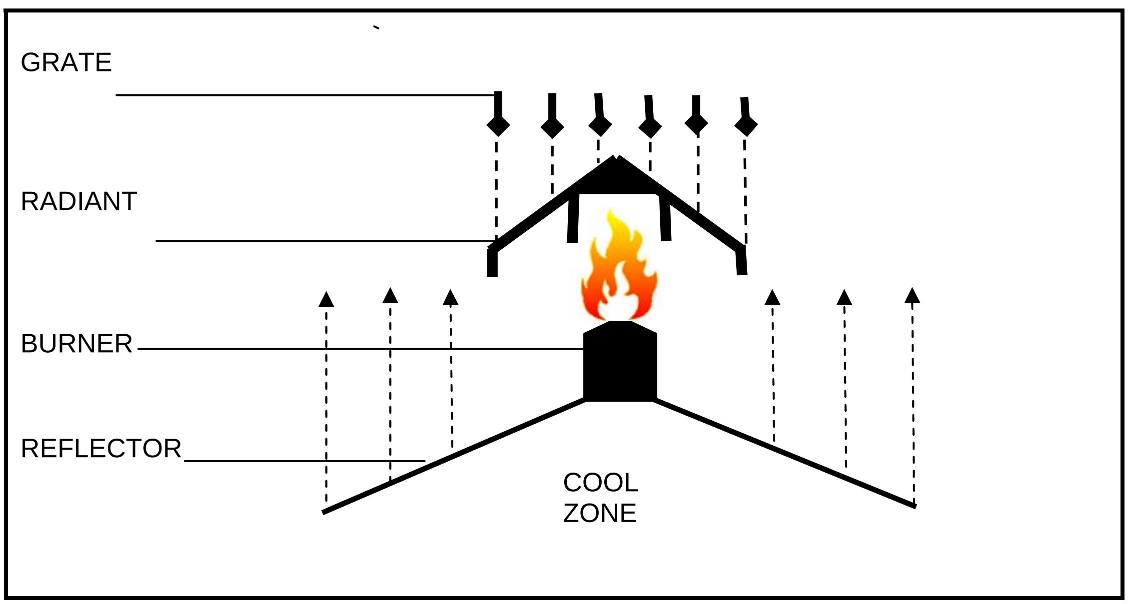
Proposed Regulation 6, Rule 2 would regulate two types of charbroilers: chain-driven and under-fired. Figure 1 presents examples of a chain-driven charbroiler and an under-fired charbroiler. A chain-driven (conveyorized) charbroiler is a semi-enclosed broiler designed to move food mechanically on a grated grill through the device as the food cooks. Food cooks quickly, because chain-driven charbroilers have burners located both above and below the grill. Chain-driven charbroilers are most common in fast food restaurants.

Figure 1. Examples of Chain-Driven Broiler (left) and Under-Fired Broiler (right)

Sources: Nieco and Magikitch'n

In an under-fired charbroiler, the heat source is positioned at or below the level of the grated grill. Designs of under-fired charbroilers vary widely. Some under-fired broilers use charcoal or wood for fuel, but usually, the broilers are fueled by gas or electricity. In gas under-fired charbroilers, a radiant surface, such as a bed of ceramic briquettes or a metal shield, placed above the burners diffuses heat from the burners. (See Figure 2.) The heating elements of electric charbroilers are often interwoven with, or sheathed inside, the grill. Under-fired charbroilers are common in fine dining and casual restaurants.

Figure 2. Diagram of Under-Fired Charbroiler



Source: Vulcan-Hart Company

C. Emissions Inventory

Charbroilers produce air pollutants through combustion. The air pollutants are primarily generated from incomplete combustion of grease and meat additives, such as tenderizers and marinade. The air contaminants are released when grease and meat additives fall onto the heat source, radiant surface, or hot plate, or when grease flares in the drip tray or bubbles at the surface.

The smoke and vapors generated from the process contain VOC and PM that consist of aldehydes, organic acids, alcohol, nitrogen and sulfur compounds, and polycyclic aromatic hydrocarbons (PAHs). VOC reacts with other compounds in the atmosphere to form ground-level ozone, commonly called smog. PM consists of airborne particles. PM can be emitted directly and also can be formed in the atmosphere through chemical reactions between other pollutants, including VOC. Cooking emissions include fine particles that are equal to or less than 10 microns in diameter, commonly referred to as PM_{10}. PM_{10} generated by cooking appliances passes through the ventilation system and is exhausted into the atmosphere.

Both VOC and PM_{10} present public health risks. Ozone produced from chemical reactions involving VOC may damage lung tissues and the respiratory tract. Once inhaled, PM_{10} may become lodged in the respiratory tract and lead to wheezing, nose and throat irritation, bronchitis, and lung damage.

The SCAQMD and the California Air Resources Board (CARB) sponsored several studies in order to determine the percentage of restaurants that use charbroilers, the amount and type of meat cooked on charbroilers, and the amount of PM_{10} and VOC produced from meat cooked on charbroilers. The District relied on these research studies, and on information provided by the health department of each of the nine Bay Area counties, to estimate the amount of PM_{10} and VOC emitted from restaurant charbroilers in the Bay Area. A more detailed description of the methodology is presented in Appendix A.

District staff estimated the number of restaurants in operation in the Bay Area with assistance from the health department of each county in the District. Each county health department provided the District with the number of restaurants permitted within the county. District staff refined the number of restaurants by eliminating the establishments that are not open to the public (e.g., private clubs, dormitories, and company cafeterias) because charbroiler usage would likely be much less in than a commercial restaurant. Restaurants that have gone out of business, as well as those that are less likely to cook, such as, ice cream parlors and delicatessens were also eliminated. The District estimates that there are approximately 14,838 restaurants in the Bay Area.

To estimate the number of charbroilers used in Bay Area restaurants, the District consulted the 1997 SCAQMD report, “Staff Recommendations Regarding Controlling Emissions from Restaurant Operations.” The SCAQMD report surveyed the type of equipment that was used in restaurant cooking operations in Southern California. The report found that approximately 33% of restaurants operate under-fired charbroilers and 4% operate chain-driven broilers. Based on these percentages, the District estimates that approximately 4,897 Bay Area restaurants operate under-fired charbroilers and 554 operate chain-driven charbroilers.

The District used several studies to estimate the amount of meat cooked on restaurant charbroilers and the associated emissions. The District relied on data developed for CARB by the Public Research Institute pertaining to the average amount of meat cooked on each type of appliance. Table 1 presents the estimated average pounds of meat cooked per year on an individual charbroiler in the Bay Area.

Table 1. Estimated Average Yearly Pounds of Meat Cooked in the Bay Area

Type of Food	Conveyorized Broiler (lbs/year)	Under-Fired Broiler (lbs/year)
Hamburger	41,486	14,049
Steaks	12,281	9,363
Poultry with Skin	7,651	7,485
Poultry without Skin	13,842	9,311
Pork	2,997	7,699
Seafood	6,179	7,416
TOTAL	**84,436**	**55,323**

Source: PRI

Emission factors developed by the University of California Riverside (UCR) and the University of Minnesota were used to quantify average emissions from each type of meat cooked on under-fired charbroilers including hamburger, steaks, chicken with or without skin, pork, and seafood. For the chain-driven charbroiler, emissions factors for hamburgers were applied to all meats because only hamburger was tested on this cooking appliance. The estimated emissions of PM_{10} and VOC by chain-driven and under-fired broilers are presented in Table 2 based on data regarding the number of charbroilers in the Bay Area, the average yearly amount of meat cooked, and the meat-specific emission factors, when available.

Table 2. Emissions from Charbroilers in the Bay Area

Type of Food	Chain-driven Broiler		Under-Fired Broiler	
	PM10 (tons/day)	VOC (tons/day)	PM10 (tons/day)	VOC (tons/day)
Hamburger	0.23	0.072	0.90	0.37
Steaks	0.069	0.021	0.78	0.32
Poultry with Skin	0.043	0.013	0.10	0.093
Poultry without Skin	0.078	0.024	0.19	0.17
Pork	0.017	0.0052	0.040	0.036
Seafood	0.035	0.011	0.14	0.016
Total Emissions (tons/day)	0.48	0.15	2.1	1.0
Total Emissions (tons/year)	174	53	782	369

In addition to VOC and PM emissions, cooking operations also produce carbon dioxide (CO_2), a gas contributing to climate change. In 2005, the District adopted a Climate Protection Program aimed at reducing greenhouse gas emissions. A University of Minnesota study found that gas charbroilers generated most of the CO_2 emitted by cooking operations. Charbroilers generate CO_2 through the combustion of natural gas and when grease drippings combust on hot radiant surfaces. The District estimates that the average CO_2 emissions for cooking activities per restaurant are approximately 25,000 pounds of CO_2 annually based on operation of the cooking appliances and energy usage for the associated ventilation system[1].

D. Regulatory Framework

The District is proposing Regulation 6, Rule 2, in accordance with the District's SB 656 Particulate Matter Implementation Schedule and in connection with FS 3 in the District's 2005 Ozone Strategy, as a means to reduce restaurant emissions of PM and VOC in the Bay Area. VOC are ozone precursors, and also contribute to indirect or secondary PM. The Bay Area is not yet in attainment of the State ozone and particulate matter standards, and so, further reductions of VOC and PM are needed.

SB 656 requires that all air districts in California adopt an implementation schedule that prioritizes appropriate measures for reducing PM emissions. The District's Particulate Matter Implementation Schedule, adopted in November

[1] Energy usage only accounts for the energy required to operate the cooking appliances and associated ventilation system. It does not include the energy required to power the air conditioning and heating systems, refrigeration units, make-up air, lights, and other types of equipment.

2005 proposes to adopt Regulation 6, Rule 2 as a measure to reduce direct and indirect PM emissions in the Bay Area.

Under FS 3, the District proposes to examine the feasibility of reducing ozone precursor emissions from restaurants. FS 3 is part of the District's 2005 Ozone Strategy, directed towards attainment of the State one-hour ozone standard.

Currently, no District rule directly regulates the emissions of air pollutants from restaurants. Restaurants, cafeterias, and other food establishments are exempt from obtaining a permit to operate under the District's Regulation 2, Rule 1. Nevertheless, restaurants must comply with the District's regulations of general applicability, such as Regulation 6: *Particular Matter and Visible Emissions*, and Regulation 7: *Odorous Substances*[2]. Regulation 6 sets limitations on the emission of visible particulate matter. Regulation 7 restricts the discharge of odorous substances.

Bay Area restaurants are issued permits to operate by county health departments and in some cases, city health departments. The health departments require restaurants to adhere to California building codes, fire protection codes, and retail food laws. These codes require restaurants to install an exhaust ventilation hood with a fire suppression system above commercial cooking equipment that generates grease, smoke, steam, and vapor. The health departments also monitor the handling of food and ensure that all of the grease traps and hood filters are routinely cleaned.

At present, the SCAQMD, San Joaquin Valley Unified Air Pollution Control District, and Ventura County Air Pollution Control District have each adopted a rule that limits emissions from restaurant charbroilers. These rules each require that chain-driven charbroilers be operated with a control device to limit emissions of VOC and PM.

In addition, the City of Aspen Environmental Health Department has an ordinance regulating restaurant charbroiler emissions under Municipal Code Section 13.08.100: Restaurant Grills. The ordinance requires all restaurants that operate any charbroiler to install a control device that is certified by the manufacturer to reduce PM_{10} emissions by 90%.

III. AVAILABLE CONTROL TECHNOLOGY

The District considered a variety of technologies to control emissions from charbroilers. District staff reviewed reports and studies conducted by the UCR, College of Engineering, Center for Environmental Research and Technology (CE-CERT), on available control technologies in support of the SCAQMD Regulation 1138 to control emissions from chain-driven charbroilers. In addition,

[2] On adoption of proposed Regulation 6, Rule 2, current Regulation 6 will be re-numbered as Regulation 6, Rule 1.

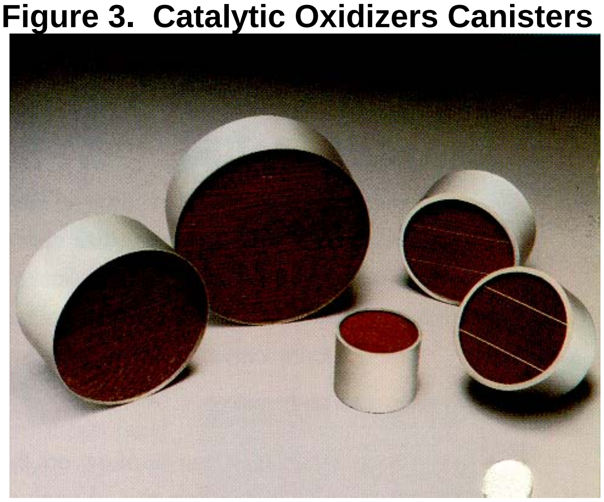
District staff contacted the City of Aspen Environmental Health Department regarding their ordinance regulating restaurant charbroiler emissions under Municipal Code Section 13.08.100: Restaurant Grills. District staff also consulted hood manufacturers and industry representatives.

Available control technologies that are effective at removing either or both PM and VOC from charbroilers include catalytic oxidizers and thermal incinerators. Each of these is a reliable, proven, and commonly-used control technology. The District also considered wet scrubbers, electrostatic precipitators (ESPs), fiber-bed filters, and high-efficiency particulate arresting (HEPA) filters as effective control devices for removing PM only. Other control technologies such as ultraviolet (UV) lamps and high-efficiency filters are available. The effectiveness of UV lamps at removing PM and VOC has not been investigated in an independent research study. High-efficiency filters have a significantly lower PM removal efficiency in comparison to the proven control technologies discussed below.

Catalytic Oxidizers (flameless)

A catalytic oxidizer is a flameless incineration device that is fitted to the top of a chain-driven charbroiler. Cooking exhaust is initially processed in the catalytic oxidizer through the heat exchanger where air is introduced. The air mixture then enters a flameless combustion chamber where it is evenly distributed onto the catalyst bed to ensure complete mixing of PM and VOC with oxygen. The PM and VOC oxidize into carbon dioxide and water vapor once the mixture reaches the combustion temperature. The released combustion energy is absorbed by the catalyst bed and is transferred to the heat recovery system. The control device is activated by the heat of the charbroiler and does not require any additional fuel to operate. The catalyst, which is a metal alloy, covers a substrate, typically either a honeycombed ceramic or a bed of ceramic beads housed in a canister. (See Figure 3.)

Figure 3. Catalytic Oxidizers Canisters



Source: W.R. Grace and Company

The catalyst is cleaned by immersion in water for one hour per month. Testing has shown catalytic oxidizers are capable of an overall PM and VOC removal efficiency of approximately 85% (83% for PM and 86% for VOC). Catalytic oxidizers are highly effective and virtually maintenance-free control devices for chain-driven charbroilers. However, this technology is not used to control emissions from under-fired charbroilers because of the high energy usage required to raise the exhaust temperature to activate the catalyst in such broilers.

Thermal Incineration

Thermal incineration oxidizes PM and VOC from an air stream at high temperatures, converting them into carbon dioxide and water. Thermal incinerators are not commonly used in commercial cooking applications. There are two types of thermal incinerators, recuperative and regenerative. Thermal recuperative incinerators consist of a gas preheating section (heat exchanger), a combustion chamber typically equipped with gas burner(s), and a heat recovery section. The heat exchanger is used to preheat the exhaust stream prior to combustion and may be used to recover heat to generate steam.

Regenerative incinerators use direct contact with a high-density medium such as a ceramic-packed bed or catalyst bed for heat recovery and to preheat the exhaust stream. Preheated PM and VOC enters the combustion chamber where they are converted to carbon dioxide and water. Cleaned gases are then diverted to reheat the packed beds. PM and VOC removal efficiency is dependent upon temperature, residence time, and mixing inside the incinerator.

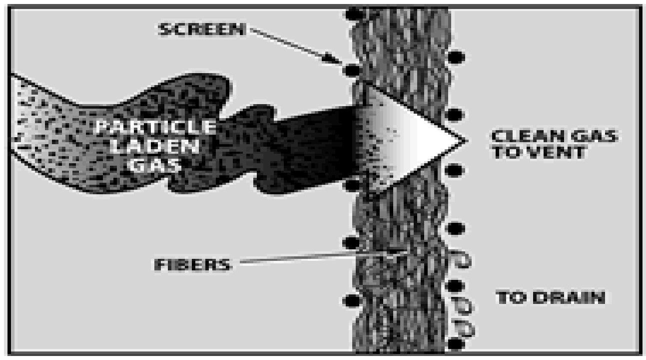
PM and VOC conversion efficiencies typically range from 97% to 99.9% for recuperative incineration and 95% to 99% for regenerative incinerators. Thermal incinerators may be used as a control device for both chain-driven and under-fired charbroilers.

Fiber-Bed Filters

Fiber-bed filters may be used as stand-alone control devices or in conjunction with another control device such as a wet scrubber. Fiber-bed filters use a combination of impaction, interception and Brownian diffusion to remove particulate matter from an air stream. Particulates become trapped in the fibers of the filter and eventually drain into a capture area below the filter as illustrated in Figure 4. The filter bed may be made of fiberglass, polyester, polypropylene, or ceramic, depending on the PM concentration, exhaust flow, and temperature of the air stream.

Periodically the filters must be replaced or washed to remove grease and other materials before returning to service. Fiber-bed filters have an overall PM removal efficiency of 90%. Filter-bed technology has been successfully used on chain-driven charbroilers in Southern California; however, they are not used in restaurants that operate under-fired charbroilers and thus, the costs for installing and maintaining the control device are not included for under-fired charbroilers.

Figure 4. Operation of Typical Fiber-Bed Filters



Source: Kimre, Inc.

Electrostatic Precipitators

Electrostatic precipitators (ESPs) have a proven track record of removing PM from the gas streams of many industries. An ESP functions by screening out large PM with a pre-filter, and then imparting an electrostatic charge in the remaining exhaust particles with a high voltage direct current. The charged particles then attach to an oppositely charged plate, from which they are later removed. An after filter is occasionally used after the plates to restore a positive back-pressure and ensure good gas distribution.

The PM removal efficiencies of ESPs range from 90% to 99%. The removal efficiencies depend largely on whether the ESPs are frequently and properly cleaned. ESPs are effective control devices for either chain-driven charbroilers or under-fired charbroilers.

Wet Scrubbers

Wet scrubbers use a finely atomized stream of water to capture PM from an air stream. An exhaust stream flows upward through a series of grated impingement plates. Water is introduced from the top of the wet scrubber and flows down to each successive plate, counter to the exhaust flow. The cooking exhaust rises through the grated grills and cools once it contacts the water. The particles adhere to the water droplets which are then collected as liquid waste. The liquid waste collected at the bottom of the scrubbers requires either treatment for reuse or disposal. Liquid particles entrained in the exhaust gas leaving the scrubber are removed using an after filter. PM removal efficiencies of 90% to 99% have been achieved depending on particle size, load, flows, and pressure drop. Wet scrubbers may be used as a control device for either the chain-driven or under-fired charbroiler.

HEPA Filters

HEPA filters are comprised of a series of three (3) filters designed to capture successively finer particles sizes. The first filter is called a pre-filter, which is a fully disposable pleated filter that must be replaced every four (4) weeks. The second filter is a medium filter that is a fully disposable bag filter that is replaced every eight (8) weeks. The final filter is a fully disposable 12 inch HEPA filter that is replaced every six (6) months. The PM removal efficiencies of HEPA filters varies from 95% to 99%. HEPA filters have been exclusively used at restaurants that operate under-fired charbroilers. Because there are more inexpensive control options available, restaurants with chain-driven charbroilers have not installed this control device.

IV. REGULATORY PROPOSAL

Under proposed Regulation 6, Rule 2: Commercial Cooking Equipment, the District is seeking to achieve further reductions of VOC and PM by requiring controls for under-fired and chain-driven charbroiler emissions. This chapter describes the proposed standards in Regulation 6, Rule 2.

A. Proposed Standard for Chain-Driven Charbroilers

Based on studies conducted by the UCR CE-CERT (1997), chain-driven charbroilers account for 4% of restaurant PM emissions and 13% of VOC emissions. Proposed Regulation 6, Rule 2 requires that, within one year of adoption of the rule, all chain-driven charbroilers in the District be equipped and operated with a District-approved catalytic oxidizer or other certified control, as explained below.

Currently, three California air districts regulate chain-driven charbroiler emissions: SCAQMD, San Joaquin Valley Unified Air Pollution Control District, and Ventura County Air Pollution Control District. Each of these air districts requires chain-driven charbroilers to be equipped and operated with a catalytic oxidizer or equivalent control. As a result, the catalytic oxidizer has an established track record and has been proven capable of reliably reducing chain-driven charbroiler emissions of PM_{10} by 83% and VOC by 86%.

The proposed rule allows a restaurant operator the flexibility to install an alternative control device, provided the device has been approved by the District for use under the rule and certified by the manufacturer to reduce emissions to no more than 0.74 pounds (lbs.) of PM_{10} and 0.23 lbs. of organic compounds per 1,000 lbs. of meat cooked. Before a restaurant operator may install and operate an alternative control, the manufacturer of the control is required to perform a laboratory test, in accordance with specific procedures prescribed in the rule, to determine the ability of the control to meet the emission standards the rule requires. The manufacturer is required to submit all information pertaining to the test to the District for review. After completing review of the source test report, the District will approve, or deny approval of, the emission control device for use under the rule.

B. Proposed Standard for New Under-Fired Charbroiler Installations

Under-fired charbroilers account for 82% of PM emissions generated by restaurants, according to the UCR 1997 study. The focus of the proposed standard for new under-fired charbroiler installations is to reduce emissions from high-production restaurants that cook large quantities of meat on under-fired charbroilers and, consequently, are responsible for a large portion of commercial cooking emissions. The proposed standard calls for any owner or operator who, starting two years after adoption of this rule, installs any under-fired charbroiler in a restaurant such that the restaurant's under-fired charbroilers, taken together, have a total grill surface area of at least 10 square feet, to exhaust charbroiler emissions through a District-approved control device certified by the manufacturer to limit charbroiler emissions to no more than 1.9 lbs. of PM_{10} per 1,000 lbs. of meat cooked.

The standard recognizes that effective control equipment that meets these emission standards requires planning to install. Newly constructed restaurants can integrate the installation of the controls into their ventilation system to effectively reduce emissions. Owners of an existing restaurant who choose to install one or more additional under-fired charbroiler(s) in the restaurant and thereby become subject to the rule will have to install an approved control device. Alternatively, the restaurant owner may elect to install cooking equipment other than an under-fired charbroiler, such as a clamshell griddle or over-fired charbroiler, that emits much less PM than an under-fired charbroiler, and consequently, is not subject to the regulation. Also, cooking appliances such as clamshell griddles and over-fired charbroilers have the added benefit of using less energy than under-fired charbroilers.

Owners and operators of new installations subject to the rule will also be required to vent their emissions through a listed ventilation hood that has been tested against and meets the standards of Underwriters Laboratory (UL) Standard 710. Current building codes allow restaurants to install unlisted hoods that meet the prescribed material and design requirements of the local building and health code. UL 710 conforms to existing building and health code, and also more effectively captures and contains the thermal plume. As discussed more fully below, this may result in a cost savings to owners and operators given that approximately 28% of a restaurant's energy usage is for heating, cooling, and ventilation. A well designed hood system that is equipped with a UL 710 listed hood can reduce the volume of air needed for ventilation by almost 30%.

C. Proposed Standard for Existing Under-Fired Charbroilers

PM emissions from under-fired charbroilers can be reduced by 90% (up to 0.4 tpd) by regulating existing under-fired charbroilers. Approximately 82% of Bay Area PM emissions from commercial cooking are attributed to the approximately

5,000 under-fired charbroilers in use in the Bay Area, while new installations of under-fired charbroilers are responsible for 10% of the total of those emissions.

Starting five years after rule adoption, the proposed rule requires all restaurants with under-fired charbroilers with an aggregate grill surface area of 10 square feet or more to install a control technology approved by the District and certified by the control device manufacturer to emit no more than 1.9 lbs. of PM_{10} per 1,000 lbs. of meat cooked. This will reduce emissions by 90%.

Current control technologies are available that can be retrofitted into existing restaurants. However, some restaurants may require remodeling, additional plumbing, or additional structural support in order to install and operate currently available control devices. As a result, an extended implementation date for this standard is designed to allow time to advance the development of emerging control technologies or adapt existing technologies to be more suitable for existing restaurants.

D. Administrative Requirements

Chain-Driven Charbroilers

All operators of chain-driven charbroilers will be required to register with the District each chain-driven charbroiler and any emission control device operated with the charbroiler. The District will implement a web-based registration system to simplify the registration process. Controls that have already been approved for use in the District will be listed on the District web site. Restaurant owners will be assessed an initial registration fee and recurring annual fee to recover the District's costs of administering and enforcing the proposed rule. The proposed registration fee is $475 and the proposed annual fee is $135. The fees are to be adopted as part of the proposed amendments to Regulation 3: Fees. The proposed amendments to Regulation 3: Fees are currently scheduled to be first considered by the District Board of Directors at a May 2, 2007 hearing.

The proposed rule also has a recordkeeping provision that requires owners and operators to record the date of installation of, and any maintenance and repairs performed on, the control device. The repair logs will contain the date, time, and description of the work that was performed. The owner or operator must keep the records for at least five years. The purpose of this recordkeeping requirement is to ensure that the control is operated in accordance with the manufacturer's specifications.

The manufacturer of an emission control device other than a catalytic oxidizer must perform a laboratory test, in accordance with specific procedures prescribed in the rule, to determine the ability of the control to meet the emission standards the rule requires. The manufacturer is required to submit all information pertaining to the test to the District Source Test Section for review, and must verify under penalty of perjury that the information submitted is true and correct. After completing review of the source test report, the District will approve, or deny approval of, the emission control device for use under the rule.

Under-Fired Charbroilers

An operator of a restaurant with one or more under-fired charbroiler(s), with a grill surface area totaling at least 10 square feet will be required to register with the District the under-fired charbroiler(s) and any emission control device operated with the charbroiler(s) as specified in the proposed rule. The District will implement a web-based registration system that will include a list of certified controls for use in the Bay Area. At the time of registration, restaurant owners will be assessed a registration fee followed by an annual fee. The proposed registration fee is $475 and the proposed annual fee is $135. The fees are to be adopted as part of the proposed amendments to Regulation 3: Fees. The proposed amendments to Regulation 3: Fees are currently scheduled to be first considered by the District Board of Directors at a May 2, 2007 hearing.

The proposed rule requires that owners and/or operators of restaurants subject to the rule must keep records for not less than five years. The records must include date of installation of any control device operated to comply with the rule, the contract under which the control was purchased or any sales receipt from the purchase, and records of any maintenance or repairs performed on the control device. The maintenance and repair records must contain the date, time, and description of the work that was performed. The purpose of this recordkeeping requirement is to ensure that the control is operated in accordance with the manufacturer's specifications.

As with chain-driven charbroilers, manufacturers of control equipment for under-fired charbroilers will be required to certify that their control equipment meets the emission standards the rule requires and to provide verified results of a source test conducted in accordance with the procedures outlined in the rule.

V. EMISSION REDUCTIONS

Charbroilers produce PM and VOC through incomplete combustion of tenderizers, marinade, and fats in the meat cooked. The District estimates that chain-driven charbroilers in the Bay Area emit a total of 0.48 tons per day (tpd) of PM and 0.15 tpd of VOC. Under-fired charbroilers, which produce significantly more emissions and outnumber chain-driven charbroilers by roughly a ten to one ratio, collectively emit approximately 2.1 tpd of PM and 1.0 tpd of VOC in the Bay Area. A more detailed description of the emission estimates is presented in Appendix A.

Chain-Driven Charbroilers

The proposed standards for chain-driven charbroilers will become effective on

June 1, 2008. This standard is anticipated to reduce emissions of PM by 83% (0.40 tpd) and of VOC by 86% (0.13 tpd), reducing the combined PM and VOC emissions from chain-driven charbroilers to 0.11 tpd. Laboratory testing (UCR, 2002) conducted on catalytic oxidizers has verified that the control devices are capable of achieving these emission reductions.

New Under-Fired Charbroilers

The proposed standards for new installations of large under-fired charbroilers will become effective on June 1, 2009. Based on data provided by the county health departments, about 50 restaurants per year (10% of all permitted restaurants) will become subject to the requirements of this rule due to remodeling or new construction. Each year, these new installations will add an additional 0.045 tons of PM production per day that will be subject to the requirements of the rule, assuming that only hamburgers are grilled. If a mixture of meats (chicken, pork, seafood, steak, and hamburgers) are cooked proportional to the percentages listed in Table 1, these new installations will add an additional 0.027 tons of PM production per day that will be subject to the requirements of the rule. The proposed rule would reduce PM emissions from these new installations by 90% (0.041 tpd for restaurants cooking only hamburgers and 0.024 tpd for restaurants cooking a variety of meats).

Existing Under-Fired Charbroilers

The District estimates that there are currently 489 restaurants in the District operating one or more under-fired charbroilers with a total grill surface area of at least 10 square feet. The District is proposing to control emissions from restaurants with large under-fired grill capacities since they likely cook significant quantities of food and consequently, produce a considerable portion of the total emissions from restaurants. Based on data provided by the University of Minnesota study (Gerstler et al, 1999), approximately 0.033 tons per year (0.00009 tpd) of PM and 0.016 tons per year (0.00004 tpd) of VOC are produced from cooking hamburgers for each square foot of grill surface area on an under-fired charbroiler. The emissions are representative of cooking 190 lbs of hamburgers per day on an under-fired charbroiler, which is typical for a high production restaurant. Given this data, all existing under-fired charbroilers with an aggregate grill surface of at least 10 square feet generate approximately 0.44 tons per day of PM and 0.21 tons per day of VOC if these restaurants were solely cooking hamburgers. If restaurants with existing under-fired charbroilers of this size cook a combination of chicken, steak, pork, and seafood in amounts proportional to the percentages listed in Table 1, then the restaurants would emit about 0.26 tpd of PM and 0.12 tpd of VOC.

Effective June 1, 2012, these restaurants will become subject to the proposed rule, which would reduce PM emissions from these restaurants by 90%. This would result in an emission reduction of 0.40 tpd if restaurants cook only hamburgers. For restaurants that cook a variety of meat on these under-fired charbroilers, the rule would result in a reduction in PM emissions of approximately 0.23 tpd.

Table 3. Emission Reductions from Charbroilers

Type of Charbroiler	Type of Meat Cooked	Uncont-rolled PM_{10} Emissions (tpd)	PM_{10} Emission Reduction (tpd)	Uncont-rolled VOC Emissions (tpd)	VOC Emission Reduction (tpd)
Chain-Driven Charbroilers	Hamburgers	0.48	0.40	0.15	0.13
Existing Under-Fired Charbroilers >= 10 sq. feet	Hamburgers	0.44	0.40	0.21	---
	Hamburger, steak, chicken, pork, and seafood	0.26	0.23	0.12	---
TOTAL		**0.74 – 0.92**	**0.63 – 0.80**	**0.27 - 0.36**	**0.13**
New Under-Fired Charbroilers >= 10 sq. feet*	Hamburgers	0.045	0.041	0.021	---
	Hamburger, steak, chicken, pork, and seafood	0.027	0.024	0.012	---

* Note: new under-fired charbroilers estimated to increase at a rate of 10% per year.

Energy Efficiency

The proposal regarding new under-fired charbroilers has an added provision that may result in a reduction of energy usage and greenhouse gas generation. Commercial cooking equipment has a high energy demand for heating, cooling, and ventilation (approximately 28% of a restaurant's energy usage) that indirectly leads to production of greenhouse gases, primarily carbon dioxide from power generation. Often, restaurant ventilation systems operate at ventilation rates that are higher than necessary, resulting in higher construction costs and higher energy costs over the life of the system.

The District is proposing to require that restaurants with an under-fired charbroiler installed at least two years after rule adoption and with under-fired charbroiler grill surface area totaling at least 10 square feet also install UL listed ventilation hoods. County health departments prescribe basic standards for commercial kitchen exhaust hood construction. The standards dictate the exhaust rate for the ventilation system based on the usage of the appliance and the length, or open-face area, of the hood. The code-specific exhaust rate may be significantly greater than what is required for effective capture and containment of the cooking plume, in order to allow flexibility in the hood design and a diversity of appliances to be placed beneath the hood. This "safety factor" places an energy cost burden on commercial kitchen ventilation systems through its demand for more heated and cooled air.

The building codes allow exceptions to these exhaust rates if the hoods have been tested against a recognized standard such as UL Standard 710, Exhaust Hoods for Commercial Cooking Equipment. UL Standard 710 is a safety standard that a hood can meet only where the test yields no evidence that smoke or flame escapes outside of the exhaust hood. Hoods bearing a recognized laboratory mark are called "listed hoods" while those bearing no such mark are called "unlisted hoods".

Requiring the use of listed hoods may have the added benefit of reducing restaurant energy consumption, thereby lowering restaurant operating costs and the indirect emission of carbon dioxide associated with power generation. Generally, listed hoods can operate at a lower exhaust rate than an unlisted hood of comparable style and size over the same cook line. As illustrated in Table 4, listed hoods have the ability to operate at an exhaust rate 100 to 300 cfm lower than that required for unlisted hoods. As a result, listed hoods may use less energy, which would result in the emission of less carbon dioxide than unlisted hoods. An owner and operator using a listed hood may therefore experience lower operating costs due to direct energy savings. Estimates of the savings range from $1.00 to $3.00 per cubic foot of annual air costs. In addition, duct systems and building duct shafts using listed hoods are generally smaller, reducing the costs of construction.

Table 4. Minimum Exhaust Rates for Charbroilers

Type of Hood	Unlisted Hood (cfm per linear foot of hood)	Listed Hood (cfm per linear foot of hood)
Wall-mounted Canopy	400	200 – 400
Single Island Canopy	600	300 – 600
Double Island Canopy	400	250 – 400
Backshelf/Passover	400	300 – 400

Source: Energy Design Resources

VI. ECONOMIC IMPACTS

This section discusses the estimated costs associated with the proposed rule.

A. Cost Analysis for Charbroilers

The District investigated the technical feasibility, potential emission reductions, and costs of installing and operating the control strategies identified in Section III. The total annual costs for a control technology are calculated based on a ten year period and are comprised of the annualized capital costs and the annual recurring operation and maintenance (O & M) costs.

The District estimated capital costs using the capital recovery method, which accounts for depreciation and interest (i.e., inflation) costs over the useful life of the control. The District annualized the capital costs using the following equation:

Total Annualized Cost = (*Capital Recovery Factor*)×(*Capital Expenditure) + Annual O & M Costs*

Where:

Capital Expenditure is the equipment and installation costs
Capital Recovery Factor is 14.2% (7% per year over 10 years)
Annual O & M Costs are expenditures for utilities and equipment maintenance

The annual recurring O & M cost includes expenditures for cleaning the equipment and the duct work.

District staff also estimated a control technology's cost effectiveness by summing the total annual costs for the control technology installed at restaurants and dividing that sum by the total annual PM and VOC emissions reductions to be achieved.

Chain-driven Charbroilers

Costs associated with control devices for chain-driven charbroilers were derived from the SCAQMD Staff Report for Proposed Rule 1138 (1997) and San Joaquin Valley Unified Air Pollution Control District Draft Staff Report for Commercial Charbroiling (2001). The District verified and adjusted costs to 2007 dollars. Table 5 presents a summary of the total annual cost for installing and maintaining the equipment and Table 6 presents the cost-effectiveness.

Catalytic Oxidizer

<u>Capital Costs:</u> Manufacturers sell a catalytic oxidizer at a cost ranging from $1,500 to $4,700. For this analysis, the capital cost was assumed to be $9,000 for a new chain-driven charbroiler equipped with a catalytic oxidizer. The cost would essentially be the same if an existing broiler was retrofitted with a catalytic oxidizer. After five years, the catalyst will need to be replaced at a cost of $4,000. Installation of the equipment was assumed to not exceed $1,000, although typical installation costs ranges from $500 to $1,000.

<u>Operating Costs:</u> Annual O & M costs of cleaning the catalyst are expected to be $750, which includes the cost from cleaning the exhaust stack once a year. Cost savings associated with less frequent cleaning of the grease traps were not included in this cost estimate. The anticipated lifetime of the catalytic oxidizer is seven to eleven years with proper maintenance.

The total annualized cost of installing a catalytic oxidizer, including O & M, is

$2,028 (see Table 5). Based on the estimates of 0.48 tpd of PM emissions and 0.15 tpd of VOC emissions (Table 3) from chain-driven charbroilers, it is expected that 0.40 tpd of PM and 0.129 tpd of VOC (total of 190 tons per year) emission reductions can be achieved by installing a catalytic oxidizer, assuming an 83% removal efficiency for PM and 86% removal efficiency for VOC. The cost-effectiveness to reduce emissions from all chain-driven charbroilers in the Bay Area is $5,913 per ton of PM and VOC reduced.

Wet Scrubber

Capital Costs: A wet scrubber unit has a capital cost of $27,025 that includes an estimated installation cost of $2,000. The unit contains all the components and accessories to operate at 2,000 cfm, including surfactant feeder, controller, remote start/stop control, re-circulation pump, valves, and exhaust blower.

Operating Costs: Annual O & M costs are anticipated to not exceed $2,000. O & M includes the energy cost for operating the controller and exhaust blower as well as the monthly expense of purchasing non-foaming surfactants detergent.

The total annualized cost of installing this control, including O & M, is $5,838. PM removal efficiencies of 90% or higher have been achieved at restaurants in which wet scrubbers were installed as the control device. Based on the estimates of 0.48 tpd of PM emissions, it is expected that 0.43 tpd of PM (total of 157 tons per year) emission reductions can be achieved. The cost-effectiveness to reduce emissions by installing wet scrubber is $20,599 per ton of PM reduced.

Electrostatic Precipitators

Capital Costs: Manufacturers estimated a cost ranging from $10,000 to $40,000 for a single unit electrostatic precipitator including ducting and exhaust fan. For this assessment, a cost of $32,000 was used assuming a ventilation rate of 2,000 cfm. An additional installation cost of $2,000 was included.

Operating Costs: Annual O & M cost is anticipated to not exceed $2,000. The ESP unit itself uses minimal energy, equivalent to a 60 watt light bulb. However, industry representatives have stated that O & M costs will vary depending on the options that are installed in the unit at the time of purchase. For example, restaurant owners may purchase a self-cleaning ESP that automatically water washes the interior of the unit. In this case, the restaurant would have lower maintenance costs, but increased costs from purchasing manufacturer-approved detergents. In addition, restaurant owners may opt for purchasing a second set of plates for the ESP so that it can be used while the first set is washed. Restaurant owners may also purchase optional odor control units that will increase the cost of the unit by at least $4,000 and the operational cost by at least $10,000 per year. For this assessment, the District estimated costs for operating a single unit electrostatic precipitator without an odor control unit where the plates are removed nightly for cleaning.

The total annualized cost of installing this control, including O & M, is $6,544. An ESP has a tested collection efficiency for PM removal of 90%. Based on the estimates of 0.48 tpd of PM emissions, it is expected that 0.43 tpd of PM (total of 157 tons per year) emission reductions can be achieved. The cost-effectiveness to reduce emissions by installing an ESP is $23,092 per ton of PM reduced.

Fiber-Bed Filters

Capital Costs: Fiber bed filter system have a capital cost of $25,000 with an estimated installation cost of $2,500.

Operating Costs: Annual O & M costs of replacing the filter ($3.18 per cubic feet per minute flow) and utility costs for operating the equipment are $7,500.

The total annualized cost of installing this control, including O & M, is $11,405. The filters are capable of removing 90% of PM emissions. Based on the estimates of 0.48 tpd of PM emissions, it is expected that 0.43 tpd of PM (total of 157 tons per year) emission reductions can be achieved. The cost-effectiveness to reduce emissions by installing fiber-bed filters is $40,244 per ton of PM reduced.

Thermal or Direct-fired Incineration

Capital Costs: Manufacturers estimated a cost of $25,000 for the incineration unit plus an additional $6,350 for the installation.

Operating Costs: The unit requires 26 therms of natural gas per hour to operate. Using a rate of $0.63 cents per therm and assuming 16 hours of operation for 365 days per year, the annual O & M cost is $95,659.

The total annualized cost of installing this control including O & M is $100,111. PM and VOC removal efficiencies range from 95% to 99.9% depending upon the temperature, residence time, and mixing inside the incinerator. Assuming a removal efficiency of 95%, a total PM and VOC emission reduction of 0.60 tpd (216 tons per year) is expected. The cost-effectiveness is approximately $256,765 per ton of PM and VOC reduced.

Table 5. Annual Cost for Controls on Chain-driven Charbroilers

Control for Chain-driven Charbroiler	Capital Cost (Dollars)	Annualized Capital Cost (Dollars per year)	Annual Recurring O & M Costs (Dollars per year)	Total Annual Cost (Dollars per year over 10 years)
Catalytic Oxidizer	$9,000	$1,278	$750	$2,028
Wet Scrubber	$27,025	$3,838	$2,000	$5,838
Electrostatic Precipitators	$34,000	$4,828	$2,000	$6,828
Fiber Bed Filters	$27,500	$3,905	$7,500	$11,405
Thermal Incinerator	$31,350	$4,452	$95,659	$100,111

Table 6. Cost Effectiveness of Potential Controls on Chain-driven Charbroilers

Control for Chain-driven Charbroiler	Total Annual Cost (Dollars per year over 10 years)	Total PM and VOC Emission Reduction (Tons per year)	Number of Chain-Driven Charbroilers	Cost-Effectiveness (Dollars per ton of VOC and PM removed)
Catalytic Oxidizer	$2,028	190	554	$5,913
Wet Scrubber	$5,838	157	554	$20,599
Electrostatic Precipitators	$6,828	157	554	$24,094
Fiber Bed Filters	$11,405	157	554	$40,244
Thermal Incinerator	$100,111	216	554	$256,765

Under-fired Charbroilers

As described in Section III, the District evaluated the technical feasibility, potential emission reductions, and costs of installing an ESP, thermal incinerator, wet scrubber, or HEPA filter to control particulate matter emissions from under-fired charbroilers. Table 7 presents a summary of the total annual cost for installing and maintaining the equipment, and Table 8 presents the cost-effectiveness.

Electrostatic Precipitators

Capital Costs: Manufacturers provided a range of costs for a single unit electrostatic precipitator (ESP) with ducting and exhaust fan of $32,000 for a ventilation rate of 2,000 cfm to $40,152 for a ventilation rate of 5,000 cfm. For this assessment, a maximum ventilation rate of 3,000 cfm was used. The cost of an ESP that operates at a ventilation rate of 3,000 cfm is $35,000. Installation costs are site-specific and will vary depending on given local building codes. For a single floor restaurant where the control is located on the roof, the cost of installing the equipment is about $2,000. However, industry representatives have noted that costs for the control as well as the installation costs may be higher.

<u>Operating Costs:</u> The annual O & M cost is anticipated to not exceed $2,000. For more information regarding O & M costs for an ESP, see the discussion of electrostatic precipitator operating costs under the heading "Chain-Driven Charbroilers," above.

The total annualized cost of installing this control, including O & M, is $7,254. ESPs have a tested collection efficiency for PM removal of 90%. Based on the estimates of 0.48 tpd of PM emissions from cooking hamburgers, it is expected that 0.44 tpd of PM (total of 161 tons per year) emission reductions can be achieved. The cost-effectiveness to reduce emissions by installing ESP is $24,285 per ton of PM reduced.

For restaurants that cook a variety of meats, the cost effectiveness may be higher for installing and operating an ESP unit. Cooking other types of meat, including chicken, pork, and seafood, produces less PM emissions than cooking hamburgers. As a result, the cost-effectiveness of installing this control may decrease. The District estimates that the cost-effectiveness may decrease to as much as approximately $41,333 per ton of PM removed, depending on the amount and type of meats that are cooked on an under-fired charbroiler.

HEPA Filters

<u>Capital Costs:</u> HEPA filters have a capital cost of $35,000 for a 3,000 cfm unit and an estimated installation cost of $2,000.

<u>Operating Costs:</u> The annual O & M cost is anticipated to not exceed $3,000. HEPA filter units use a filter module that consists of three filters placed in series. The first filter is called a pre-filter that is fully disposable pleated filter that cost $6 per filter and must be replaced every four (4) weeks. The second filter is a medium filter that is a fully disposable bag filter that cost approximately $10 per filter and is replaced every eight (8) weeks. The final filter is a fully disposable 12 inch HEPA filter that costs $200 per filter and is replaced every six (6) months.

The total annualized cost of installing this control, including O & M, is $8,254. It is expected that 95% of PM may be captured using this control device. Based on estimate of 0.48 tpd of PM emissions from cooking hamburgers, the PM emission reduction is anticipated to be 0.46 tpd (total of 167 tons per year). The cost-effectiveness to reduce emissions by installing HEPA filters is $26,640 per ton of

PM reduced. The cost-effectiveness may decrease to as much as $44,705 if other meats in addition to hamburgers are cooked on the under-fired charbroiler.

Wet Scrubber

Capital Costs: A wet scrubber unit has a capital cost of $30,452 for a system that operates at 3,000 cfm, and an estimated installation cost of $6,266. The costs include all components and accessories necessary for the complete operation of the unit.

Operating Costs: The annual O & M cost is anticipated to not exceed $6,582. This O & M cost estimate includes the energy cost for operating the controller and exhaust blower, as well as the monthly expense of purchasing non-foaming surfactants detergent.
The total annualized cost of installing this control including O & M is $11,796. Although wet scrubbers have achieved PM removal efficiencies of 90% at restaurants in the South Coast Air Quality Management District, wet scrubbers are not commonly used in restaurants located in the Bay Area. Based on the estimates of 0.48 tpd of PM emissions from hamburgers, it is expected that 0.44 tpd of PM (total of 161 tons per year) emission reductions can be achieved. The cost-effectiveness to reduce emissions by installing a wet scrubber is $39,491 per ton of PM reduced. The cost-effectiveness may increase to as much as $67,639 if other meats in addition to hamburgers are cooked on the under-fired charbroiler.

Thermal or Direct-fired Incineration

Capital Costs: Manufacturers estimated a cost of $25,000 for the incineration unit plus an additional $6,350 for the installation.

Operating Costs: The unit requires 26 therms of natural gas per hour to operate. Using a rate of $0.63 cents per therm and assuming 16 hours of operation for 365 days per year, the annual O & M cost is $95,659.

The total annualized cost of installing this control including O & M is $100,111. PM and VOC removal efficiencies range from 95% to 99.9% depending upon the temperature, residence time, and mixing inside the incinerator. Assuming a removal efficiency of 95%, a total PM and VOC emission reduction of 0.68 tpd (248 tons per year) is expected from cooking hamburgers. The cost-effectiveness is approximately $217,580 per ton of PM and VOC reduced. The cost-effectiveness may increase to as much as $403,375 if other meats in addition to hamburgers are cooked on the under-fired charbroiler.

Table 7. Annual Cost for Controls on Under-Fired Charbroilers

Control for	Capital Cost	Annualized	Annual	Total Annual

Chain-driven Charbroiler	(Dollars)	Capital Cost (Dollars per year)	Recurring O & M Costs (Dollars per year)	Cost (Dollars per year over 10 years)
Electrostatic Precipitators	$37,000	$5,254	$2,000	$7,254
HEPA Filters	$37,000	$5,254	$3,000	$8,254
Wet Scrubber	$36,718	$5,214	$6,582	$11,796
Thermal Incinerator	$31,350	$4,452	$95,659	$100,111

Table 8. Cost Effectiveness of Proposed Controls on Under-Fired Charbroilers

Control for Chain-driven Charbroiler	Total Annual Cost (Dollars per year over 10 years)	Total PM and VOC Emission Reduction (Tons per year)	Number of Under-Fired Charbroilers	Cost-Effectiveness (Dollars per ton of VOC and PM removed)
Electrostatic Precipitator	$7,254	161	539	$24,285
HEPA Filters	$8,254	167	539	$26,640
Wet Scrubber	$11,796	161	539	$39,491
Thermal Incinerator	$100,111	248	539	$217,580

B. Energy Savings

The District is proposing to require that any restaurant that installs an under-fired charbroiler such that, after the installation, the restaurant has under-fired charbroilers totaling at least 10 square feet in grill surface area, install a listed ventilation hood. This requirement would go into effect two years after rule adoption. Listed hoods are tested against UL Standard 710 that attests to the hood's efficiency in capturing and containing cooking appliance exhaust. Listed hoods cost approximately $500 to $6,000 more than unlisted hoods at the time of purchase, but are allowed to operate at a lower ventilation rate than unlisted hoods. The advantage of the listed hood is that it can be operated in a manner that uses less energy which may, in turn, result in lower energy bills over the lifetime of the hood.

Based on the range of minimum exhaust rates presented in Table 4, a listed hood can operate, on average, at a rate of 187.5 cfm per linear foot of hood length lower than an unlisted hood. For an under-fired charbroiler with 10 square foot grill surface area and 0.5 foot overhang on each side, the lower exhaust rate would equate to a reduction in ventilation rate of 1,125 cfm. At this exhaust rate, the exhaust fan uses 981 kilowatts less energy per year than if an unlisted hood were installed. Assuming electricity costs of $0.168 per kilowatt-hour this would result in a cost savings of $165 per year over the lifetime of the hood. The cost savings does not account for additional savings associated with less cooling and heating of make-up air required to replace the air exhausted by the hood and is thus a conservative estimate. As an example, the "Up Your Stack" web site (www.upyourstack.com), a resource web page dedicated to commercial kitchen ventilation, estimates a savings of $1.00 to $3.00 per cubic foot of annual air costs based on installation of unlisted hood. In a 10 foot by 10 foot kitchen with 10 foot ceiling, the restaurant owner might expect a lower energy cost of $100 to $300 annually.

In order to incorporate this cost savings into the cost analysis presented in Section VI–A, the incremental additional capital cost of installing a listed hood was included. Because listed hoods may operate at a lower ventilation rate, a smaller duct shaft may be used that lowers the overall construction costs in new restaurant buildings. The $2,000 incremental capital cost of installing a listed hood was reduced by $200 to account for a reduction in the necessary duct shaft size and attendant reduction in constructions costs. The final incremental capital cost that was used in this report is $1,000. The O & M costs were reduced by $165 to take in to account the annual energy savings realized from operating a listed hood.

Tables 9 and 10 present, respectively, the annual costs and cost-effectiveness associated with each control technology, taking into account the energy savings described above that result from use of a listed hood. These costs are only presented for restaurants that install one or more under-fired charbroilers totaling at least 10 square feet grill surface area.

Table 9. Annual Cost for Installing Listed Hoods with Controls

Control for Chain-driven Charbroiler	Capital Cost (Dollars)	Annualized Capital Cost (Dollars per year)	Annual Recurring O & M Costs (Dollars per year)	Total Annual Cost (Dollars per year over 10 years)
Electrostatic Precipitators	$38,800	$5,510	$1,835	$7,345
HEPA Filters	$38,800	$5,510	$2,835	$8,345
Wet Scrubber	$38,518	$5,470	$6,417	$11,887
Thermal Incinerator	$33,150	$4,707	$95,494	$100,201

Table 10. Cost Effectiveness of Installing Listed Hoods with Controls

Control for Chain-driven Charbroiler	Total Annual Cost (Dollars per year over 10 years)	Total PM and VOC Emission Reduction (Tons per year)	Number of Under-Fired Charbroilers	Cost-Effectiveness (Dollars per ton of VOC and PM removed)
Electrostatic Precipitator	$7,231	161	539	$24,208
HEPA Filters	$8,231	167	539	$26,566
Wet Scrubber	$11,773	161	539	$39,414
Thermal Incinerator	$100,088	248	539	$217,529

C. Incremental Cost Effectiveness

Section 40920.6 of the California Health and Safety Code requires an air district to perform an incremental cost analysis for any proposed Best Available Retrofit Control Technology rule or feasible measure. The air district must: (1) identify one or more control options achieving the emission reduction objectives for the proposed rule, (2) determine the cost effectiveness for each option, and (3) calculate the incremental cost effectiveness for each option. To determine incremental costs, the air district must "calculate the difference in the dollar costs divided by the difference in the emission reduction potentials between each progressively more stringent potential control option as compared to the next less expensive control option."

To determine incremental costs, the District compared the cost-effectiveness of each control device presented in Table 6 for chain-driven charbroilers and Table 8 for under-fired charbroilers. Table 11 presents a summary of the incremental cost-effectiveness associated with the proposed regulation.

As shown in Table 11, the catalytic oxidizer is the most cost-effective control device for chain-driven charbroiler. The other control technologies have an increased cost-effectiveness that ranges from $14,686 to $250,852 over the cost of purchasing and operating a catalytic oxidizer. In addition, the catalytic oxidizer operates without an external energy supply since it uses the heat generated from the cooking process to activate the catalyst. The catalyst also radiates heat back to the charbroiler, and as a result, less energy is required to operate the charbroiler. Although the proposed standard essentially allows the use of any of the control technologies listed in Table11, the proposed standard is based on the effectiveness of a catalytic oxidizer.

For under-fired charbroilers, ESP and HEPA filters are the most cost-effective control devices for controlling PM emissions. The wet scrubber is also a viable control option to restaurant owners given its proven control efficiencies in other industries. The thermal incinerator has substantially higher costs to operate.

Table 11. Incremental Cost Effectiveness of Proposed Controls on Under-Fired Charbroiler

Type of Charbroiler	Control	Cost-Effectiveness (Dollars per ton of VOC and PM removed)	Incremental Cost Effectiveness
Chain-Driven Charbroiler	Catalytic Oxidizer	$5,913	$0.0
	Wet Scrubber	$20,599	$14,686
	Electrostatic Precipitator	$24,094	$18,181
	Fiber Bed Filters	$40,244	$34,331
	Thermal Incinerator	$256,765	$250,852
Under-Fired Charbroiler	Electrostatic Precipitator	$24,285	$0.0
	HEPA Filters	$26,640	$2,355
	Wet Scrubber	$39,491	$15,206
	Thermal Incinerator	$217,580	$193,295

D. District Staff Impacts

Currently, the District does not regulate emissions from restaurants. Implementing this rule will require District resources from all divisions including enforcement, engineering, source test, and administration. The actual personnel involved will likely involve an air quality inspector assigned to restaurants; an air quality technician to coordinate development of the web-based registration system, review registrations, and answers questions from the public; Source Test engineers to review the manufacturer's certification and testing procedures; a program analyst to design the web-based registration and maintain the registration database; and an accountant to process registration and annual fees.

In the first year after adoption, the proposal calls for all owners and operators of chain-driven charbroilers to install a catalytic oxidizer or equivalent control device approved for use under the rule. There are approximately 554 chain-driven charbroilers currently operating in the Bay Area. The District anticipates that an inspection should require no more than 130 minutes for each restaurant. Given the number of restaurants, inspection time would be about 1,200 hours in the first year which is equivalent to 0.60 full-time employees (FTE), at a cost of $128,000 for an air quality inspector.

This proposal is also the first District rule to offer web-based registration. In order to develop this system, total of 500 hours, or 0.25 FTE, of a program analyst and air quality engineer are required to develop the registration form, maintain the registration database, review registrations, and respond to public inquiries. Both a program analyst position and an engineer costs $53,500 for combined 0.25 FTE. Because many catalytic oxidizers have already been approved by other air districts, the District is anticipating that no more than 80 hours (0.05 FTE) would be required to review the manufacturer's certification and testing protocol. A Principal Engineer's time costs $13,000 at 0.05 FTE.

New installations of under-fired charbroilers totaling at least ten square feet of grill surface area would be subject to the proposal, starting two years after the rule is adopted. In five years, all restaurants with under-fired charbroilers totaling at least ten square feet of grill surface area would be required to install a control device. There are currently 489 restaurants in the Bay Area that have under-fired charbroilers totaling at least 10 square feet of grill surface area. Inspections are anticipated to require no more than 1,060 hours per year or 0.53 FTE, costing $113,420. To maintain the web-based registration, the District estimates that 0.13 FTE of an engineer will be required at a cost of $27,300. A Principal Engineer will be required to review the source test data provided by the manufacturer for each control device submitted to the District for approval under the rule. The District estimates that 720 hours will be required to review 30 certifications at a cost of 0.36 FTE ($94,320).

The District is anticipated to incur a cost of approximately 1.0 FTE in the first five years of implementing this regulation based on the estimation presented above. To recover costs, the cost of administrating the regulation corresponds to a registration fee of $475 and annual recurring fee of $135. The fee schedule for restaurants is proposed to be contained in Regulation 3 under Schedule R.

E. Socioeconomic Impacts

Section 40728.5 of the Health and Safety Code requires an air district to assess the socioeconomic impacts of the adoption, amendment, or repeal of a rule if the rule is one that “will significantly affect air quality or emissions limitations.” Applied Economic Development, Berkeley, California, has prepared a socioeconomic analysis. The analysis concludes that the affected restaurants should be able to absorb the costs of compliance with the proposed rule without significant economic dislocation or loss of jobs. The socioeconomic analysis is attached as Appendix B.

VII. ENVIRONMENTAL IMPACTS

Pursuant to the California Environmental Quality Act, the District has had an initial study for the proposed amendments prepared by Environmental Audit, Inc. The initial study concludes that there are no potential significant adverse environmental impacts associated with the proposed amendments. A negative declaration is proposed for adoption by the District Board of Directors. The initial study and negative declaration is to be circulated for public comment during the period from April 2, 2007 to April 23, 2007.

VIII. REGULATORY IMPACTS

Section 40727.2 of the Health and Safety Code requires an air district, in adopting, amending, or repealing an air district regulation, to identify existing federal and district air pollution control requirements for the equipment or source type affected by the proposed change in district rules. The district must then note any differences between these existing requirements and the requirements imposed by the proposed change.

Adoption of this rule would not conflict with any existing federal or District requirement. Under the federal air pollution requirements, there is no rule that limits emissions from restaurants. The District also does not have any rules that are applicable to restaurants except those of general applicability such as Regulation 6: Particulate Matter and Visible Emissions, and Regulation 7: Odorous Substances.

IX. RULE DEVELOPMENT PROCESS

The District staff has undertaken a comprehensive public outreach program to involve all stakeholders in developing this proposal, including individual restaurant owners, hood manufacturers, restaurant trade organizations and industry representatives, county health departments, and vendors and installers of commercial kitchen appliances.

The District started the rule development process in January 2005. At that time, the District contacted the SCAQMD to receive copies of all research documents and staff reports that were produced in support of SCAQMD Regulation 1138. The District then contacted the health departments of all the counties in the District in March 2005 and December 2005, to request an inventory of currently permitted restaurants and to apprise the counties of the District's intent to consider restaurant controls. The District held two meetings with county health officials, one on January 19, 2006, and another on July 28, 2006. The purpose of the meetings was to discuss the current emission inventory, solicit suggestions for ways to control emissions, and development of a cooperative enforcement strategy between the District and the various counties.

The District also initiated contacted with the Golden Gate Restaurant Association in February 2006 to invite their participation in the rule development process. The District met with representatives of the Golden Gate Restaurant Association on February 24, 2006, and had follow-on telephone discussions as the rule evolved.

District contacted the PG&E Food Service Technology Center in San Ramon, California in May 2006 regarding emission factors for specific types of commercial cooking equipment. After conducting a site walk of their facility, the District has been in continuous discussions with representatives from the Food

Service Technology Center in developing this proposal. The Center represents the interests of the restaurant industry and kitchen ventilation hood manufacturers. The Center is also a clearing house for commercial kitchen equipment performance and has expertise in commercial kitchen ventilation and building energy efficiency.

The District also verified the emission inventory by conducting source tests on four restaurants in the Bay Area. The District tested two restaurants that operated either a chain-driven charbroiler or under-fired charbroiler that exhausted their emissions through a control device. For comparison purposes, the District also collected particulate matter samples from two restaurants that operated either a chain-driven charbroiler or under-fired charbroiler without any control device. The emission estimates were used to determine emission standards in the proposed rule.

In October 2006, in advance of public workshops held in November 2006, District staff published the draft regulation and provided a workshop report explaining the proposed regulation. The first draft of Regulation 6, Rule 2, and the workshop report were posted on the District web site and e-mailed to stakeholders on October 16, 2006. Simultaneous to the posting on the District web site, the District sent out approximately 17,000 postcards to individual restaurant owners, hood vendors, and installers informing them of the rule and the then-upcoming public workshop. The District also developed a rule summary fact sheet that was translated to Chinese and Spanish and made available on the District web site.

Once the regulation was posted, the District received and responded to more than 20 telephone inquiries and e-mails regarding specific topics and issues about the draft rule and workshop report.

The District held four (4) public workshops on November 14 and 15, 2006, in San Francisco, San Jose, Oakland, and Vallejo to solicit comments from public, members of county health departments, industry organizations, and other interested parties on the proposed rule. A total of approximately 20 people attended these workshops, with most of the interested parties being hood manufacturers, a restaurant organization, and independent local restaurants. The District received written comments from hood manufacturers that were identical to comments provided by the restaurant organization.

Overall, the public comments supported the standard for chain-driven charbroilers. Input from the first workshop raised concerns about the technical feasibility and costs of installing high efficiency filters, a modest control, in all restaurants that operate a Type I hood. There was disagreement within the industry regarding the effectiveness of high efficiency filters. The trade organization did not support the installation of controls on restaurants that utilize low emission cooking equipment. Another comment suggested that the rule would result in more energy consumption and additional greenhouse gas emissions.

After the November public workshops, the District continued discussions with hood manufacturers and trade organizations regarding ways to revise the proposal. These interactions lead directly to developing a second draft of Regulation 6, Rule 2 to address emissions from only charbroilers. A supplement to the workshop report was generated to summarize the differences from the original proposal. The District presented the revised proposal before the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Technical Committee 5.10 Kitchen Ventilation on January 27, 2007. The second workshop notice and revised rule were posted on the District website and e-mailed to all interested parties. The second workshop was held on March 6, 2007.

Input from the second workshop was focused primarily on removing certain requirements intended to promote energy efficiency and on the cost-effectiveness of control technologies. One set of comments requested that the District lower the effective grill size from 10 square feet to six (6) square feet and include a provision to regulate emissions from griddles. Staff used input received from the second workshop to develop the final draft of the proposed regulation that is published as a companion to this Staff Report for comments on April 2, 2007. The proposed regulation is scheduled for a public hearing by the Board of Directors on May 2, 2007.

The District will continue to follow the development of cost effective control technologies for existing under-fired charbroilers and provide technical updates to members of the Board of Directors.

X. FUTURE RESEARCH

Emissions from restaurant operations currently make up over 6% of all PM_{10} emissions in the Bay Area. This rule is an important first step in achieving emission reductions from a source category that has not been regulated in the past. District staff is committed to working with industry representatives and to provide the Board of Directors with periodic updates on the development of control technology for under-fired charbroilers. This rule is an opportunity for hood manufacturers, abatement equipment manufacturers, and cooking equipment manufacturers and vendors to work together in developing new and adapting existing technologies.

Catalytic oxidizers, a highly cost-effective and virtually maintenance-free control device for chain-driven charbroilers were developed in response to the SCAQMD Regulation 1138, adopted in 1997. Because the SCAQMD rule did not regulate under-fired charbroilers, there has been limited research and development directed at control technologies for these cooking devices. A regulatory mandate will help to create a market for under-fired charbroiler abatement technology. For this reason, the compliance date for existing under-fired charbroilers is set five years in the future, to allow time for development of better, more cost-effective technologies.

The proposed rule is only the first step in an ongoing commitment to reduce emissions from commercial cooking appliances. As additional data becomes available, District staff will be evaluating possible controls on other types of cooking equipment, including griddles, woks, and wood-fired cooking appliances. There are over 7,000 griddles that operate in the Bay Area that, collectively, are responsible for about 14% of commercial cooking emissions. Studies conducted on wok cooking indicate woks emit a number of toxic compounds from volatilization and partial combustion of the cooking oils. Combustion of wood in wood-fired cooking appliances produces the same emissions as wood stoves and fireplaces and occurs much more frequently than residential wood burning. District investigation into possible controls on these and other types of cooking equipment will be part of efforts to reduce PM emissions in order to achieve state PM standards and (if necessary) the new federal 24-hour PM standard.

Staff is interested in further research in this field to support further development of data on emissions from griddles, woks, wood-fired cooking appliances, and other types of cooking appliances. The District will closely monitor research which could be used to refine the emission inventory, assess risk factors, and identify whether additional rule making should be conducted.

In addition to reducing PM and VOC emissions, this proposed rule also may reduce restaurant energy costs and reduce the emissions of greenhouse gases in the Bay Area. The Foodservice Consultants Society International (FCSI) of North America has a “Best Practice” design and specification guideline for restaurant owners that provides practical ways to reduce heating and cooling costs. Staff will evaluate whether there are additional standards that may be adopted to improve performance in commercial kitchen ventilation systems, and thus, reduce energy use, energy costs, and greenhouse gas emissions.

XI. CONCLUSION

Pursuant to Section 40727 of the California Health and Safety Code, the proposed rule must meet findings of necessity, authority, clarity, consistency, non-duplication, and reference. The proposed regulation is:

- Necessary to protect public health by reducing ozone precursors and particulate matter emissions to meet the requirements of Senate Bill 656 Particulate Matter Implementation Schedule and further study commitment of the Bay Area 2005 Ozone Strategy;
- Authorized by California Health and Safety Code Sections 40000, 40001, 40702, and 40725 through 40728;

- Clear, in that the new regulation specifically delineates the affected industry, compliance options, and administrative requirements for industry subject to this rule, so that its meaning can be easily understood by the persons directly affected by it;
- Consistent with other District rules, and not in conflict with state or federal law;
- Non-duplicative of other statutes, rules, or regulations; and
- Implementing, interpreting and making specific the provisions of the California Health and Safety Code sections 40000 and 40702.

The proposed rule has met all legal noticing requirements, has been discussed with the regulated community and other interested parties, and reflects the input and comments of many affected and interested parties. District staff recommends adoption of proposed Regulation 6, Rule 2: Commercial Cooking Equipment and adoption of the CEQA Negative Declaration.

XII. REFERENCES

1. England, G.C., Wien, S., Chang, M.C., Gurney, M. D., and Loos, K., 2001. Fine Particle and Precursor Emissions from Power, Oil, and Gas Industry Combustion Sources.

2. Foodservice Consultants Society International North America (FCSI), 2006. FCSI White Paper, Commercial Kitchen Ventilation, “Best Practice” Design and Specification Guidelines, September 2006.

3. Food Service Technology Center. Design Guide 1: Improving Commercial Kitchen Ventilation System Performance. Selecting and Sizing Exhaust Hoods.

4. Hildemann, L.M., Cass, G.R., Markowski, G.R., 1989. A Dilution Stack Sampler for Collection of Organic Aerosol Emissions: Design, Characterization and Field Tests. Aerosol Sci. Technol. 10: 193-204.

5. Gerstler, W.D., Kuehn, T.H., Pui, D.Y., Ramsey, J.W., Doerr, M.P., 1996. Identification and Characterization of Effluents from Various Cooking Appliances and Processes as Related to Optimum Design of Kitchen Ventilation Systems. ASHRAE 745-RP, Phase I, Final Report. Dated June 13, 1996.

6. Gerstler, W.D., Kuehn, T.H., Pui, D.Y., Ramsey, J.W., Rosen, M., Carlson, R.R., and Petersen, S.D., 1999. Identification and Characterization of Effluents from Various Cooking Appliances and Processes as Related to Optimum Design of Kitchen Ventilation Systems. ASHRAE 745-RP, Phase II, Final Report. Dated February 9, 1999.

7. Gerstler, W.D., 2002. New Rules for Kitchen Exhaust. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) Journal. Downloaded from www.ashraejournal.org. Dated November 2002.

8. Kuehn, T.H., Olson, B.A., Ramsey, J.W., Friell, J., and Rocklage, J., 2004. Development of a Standard Method of Test for Commercial Kitchen Effluent Grease Removal Systems. Draft Final Report. Reported conducted by the University of Minnesota, Department of Mechanical Engineering, Minneapolis, MN for Nickel-Fisher, Inc. Food Service Technology Center, San Ramon, CA. Dated July 31, 2004.

9. MacDonald, J.D., Zielinska, B., Fujita, E.M., Sagabiel, J.C., Chow, J.C., and Watson, J.G., 2003. Emissions from Charbroiling and Grilling of Chicken and Beef. J. Air & Waste Manage. Assoc. 53: 185-184. February 2003.

10. National Fire Protection Association, Inc. (NFPA), 2004. NFPA 96 Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations. 2004 Edition.

11. Pacific Environmental Services, Inc., 1999. Final Report. A Detailed Survey of Restaurant Operations in the South Coast Air Basin. Submitted to South Coast Air Quality Management District on February 5, 1999. Contract No. 98089.

12. Public Research Institute, 2001. Charbroiling Activity Estimation. Prepared for the California Air Resources Board and the California Environmental Protection Agency. Dated June 30, 2001.

13. San Joaquin Valley Unified Air Pollution Control District, 2001. Draft Staff Report. Commercial Charbroiling. Dated October 27, 2001.

14. Sherer, M., 2003. Special Report: Clearing the Air. New Hood and Fan Technologies are Doing a Better Job for Less. Foodservice Equipment Reports. Downloaded from www.fermag.com./sr/v7i6_sr_hood.htm. Dated June 2003.

15. South Coast Air Quality Management District, 2000. Status Report on Controlling Particulate Matter and Volatile Organic Compound Emissions from Restaurant Operations. Board Meeting Date: August 18, 2000. Agenda No. 20.

16. South Coast Air Quality Management District, 2004. Staff Recommendations Regarding Controlling Emissions from Restaurant Operations. Board Meeting Date: December 3, 2004. Agenda No. 39.

17. University of California Riverside, College of Engineering, Center for Environmental Research and Technology, (CE-CERT) 1999. Development and Demonstration of Emission Control Technologies for Commercial Underfired Broilers. Contract No. 98015, February 1999.

18. University of California Riverside, College of Engineering, Center for Environmental Research and Technology, (CE-CERT) 1997. Further Development of Emission Test Methods and Development of Emission Factors for Various Commercial Cooking Operations. Contract No. 96027, July 1997.

19. University of California Riverside, College of Engineering, Center for Environmental Research and Technology, (CE-CERT) 2002. Assessment of Emissions from a Chain-Driven Charbroiler (Nieco Model 9025, Golden West Equipment, Inc) Using a Catalytic Control Device (Model 7-193), Final Report, for Engelhard Corporation. Dated September 13, 2002.

APPENDIX A
EMISSIONS CALCULATIONS

The following sections describe the method used to quantify PM and VOC emissions from broilers for the nine Bay Area counties.

A. Estimated Number of Restaurants with Broilers

To obtain an accurate estimate of the total number of commercial restaurants in the District, staff contacted the health and environmental departments from each of the nine Bay Area counties: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Solano, and Sonoma. County health agencies maintain lists of restaurants and other facilities in order to inspect and regulate food handling practices within the county's jurisdiction. Table A-1 presents the results of the survey. Restaurants situated in the City of Berkeley are under the jurisdiction of the local health department and not regulated by the Alameda County health department. The number of restaurants in the City of Berkeley is included in Table A-1.

Table A-1. Commercial Restaurants by County

County/City	Total Number of Restaurants	Adjusted Total for Commercial Restaurants
Alameda County	3,700	2,651
Contra Costa County	1,989	1,425
City of Berkeley	468	336
Marin County	607	435
Napa County	345	248
San Francisco County	3,997	2,863
San Mateo County	2,018	1,446
Santa Clara County	4,933	3,534
Solano County*	1,146	821
Sonoma County*	1,504	1,078
TOTAL	**20,707**	**14,838**

Note: * - The number of restaurants for Solano and Sonoma counties was adjusted based on the percentage of the total population within the District jurisdiction (71.2% for Solano County and 87.7% for Sonoma County).

The initial estimate of 20,707 restaurants in the District includes establishments that do not cook (i.e., delicatessens, ice cream parlors, juice bars, etc), institutional eating facilities (i.e., school cafeterias, lodges, retirement homes), and restaurants that have gone out of business. Because the restaurant names and addresses were not requested as part of the survey, the exact number of facilities that would normally be excluded as "noncommercial" restaurants could not be determined. Pacific Environmental Services (PES) conducted a similar study for the South Coast Air Quality Management District (SCAQMD) in 1999 to determine the number of commercial restaurants under its jurisdiction and found that on average, approximately 77% of the facilities classified as restaurants were commercial facilities that served food to the general public. The study was based on a restaurant survey conducted in the City of Pasadena, the City of Vernon, and Riverside County where 19.4, 16.7 and 23.9 percent, respectively, of the facilities were not commercial restaurants. In addition, PES also determined that approximately 6.97% of the restaurants have gone out of business since the health department lists were compiled.

Using the results of the PES study, a factor of 0.7163 (0.77 for commercial restaurants multiplied by 0.9303 for open business) was then applied to the total number of restaurants in the District to exclude those facilities from the survey that did not serve food, were not open to the public, or have gone out of business. Rounding all estimates to the next whole number, the final number of commercial restaurants in the District was projected at 14,838.

The PES study further surveyed the type of equipment that was used in the cooking operations of the commercial restaurants. Based on the SCAQMD report, the majority of emissions (87% of PM and 82% of VOC) from cooking operations are generated from chain-driven and under-fired broilers.

Chain-driven broilers consist of conveyorized belts that carry meat to a flame area that broils the meat on the top and bottom simultaneously. Under-fired broilers have three components: a heating source, high temperature radiant surface, and slotted grill. The grill holds the meat while it is cooked from radiant heat. The study found that the fraction of facilities in the SCAQMD that operated chain-driven and under-fired broilers based on 95th percent confidence limits (in parenthesis) was:

Under-fired broilers:	0.330 (0.29 – 0.37), or 33%
Chain-driven broilers:	0.0373 (0.0212 – 0.0534), or 4%

A state-wide study conducted by Public Research Institute (PRI) in 2001 for the California Air Resources Board and the California Environmental Protection Agency found that approximately 8% of the restaurants had chain-driven broilers while 45% of the restaurants had under-fired broilers. The PRI study determined a higher average percentage of broilers per restaurant than the PES study mainly due to the fact that the PRI study focused on restaurants thought to conduct more broiling activities than other types of restaurants. Given this bias, District staff considered the PES study results more reflective of the likely representation of broilers in the Bay Area.

Multiplying by the fraction of broilers determined in the PES study, the estimated number of broilers in the District is (rounding up to the nearest whole number):

Under-fired broilers:	4,897
Chain-driven broilers:	554

B. Amount and Type of Meat Cooked on Broilers

The PES study asked the restaurants to report their average weekly use of hamburger, steaks, poultry (with and without skin), pork and seafood, based on the type of cooking equipment used. The average food throughput for chain-driven broiler and under-fired broiler restaurants is presented in Table A-2.

Table A-2. Average Pounds of Meat Cooked Per Year (PES Study)

Type of Food	Chain-driven Broiler (lbs/year)	Under-Fired Broiler (lbs/year)
Hamburger	108,846	7,795
Steaks	9,443	6,474
Poultry with Skin	5,200	15,226
Poultry without Skin	18,413	6,027
Pork	6,932	1,404
Seafood	7,457	5,673
TOTAL	**156,291**	**42,599**

In a state-wide phone survey conducted by PRI, the average amount of meat cooked per year varied significantly from the results of the PES study. Table 3 presents the results of the PRI study.

Table A-3. Average Pounds of Meat Cooked Per Year (PRI Survey)

Type of Food	Chain-driven Broiler (lbs/year)	Under-Fired Broiler (lbs/year)
Hamburger	41,486	14,049
Steaks	12,281	9,363
Poultry with Skin	7,651	7,485
Poultry without Skin	13,842	9,311
Pork	2,997	7,699
Seafood	6,179	7,416
TOTAL	**84,436**	**55,323**

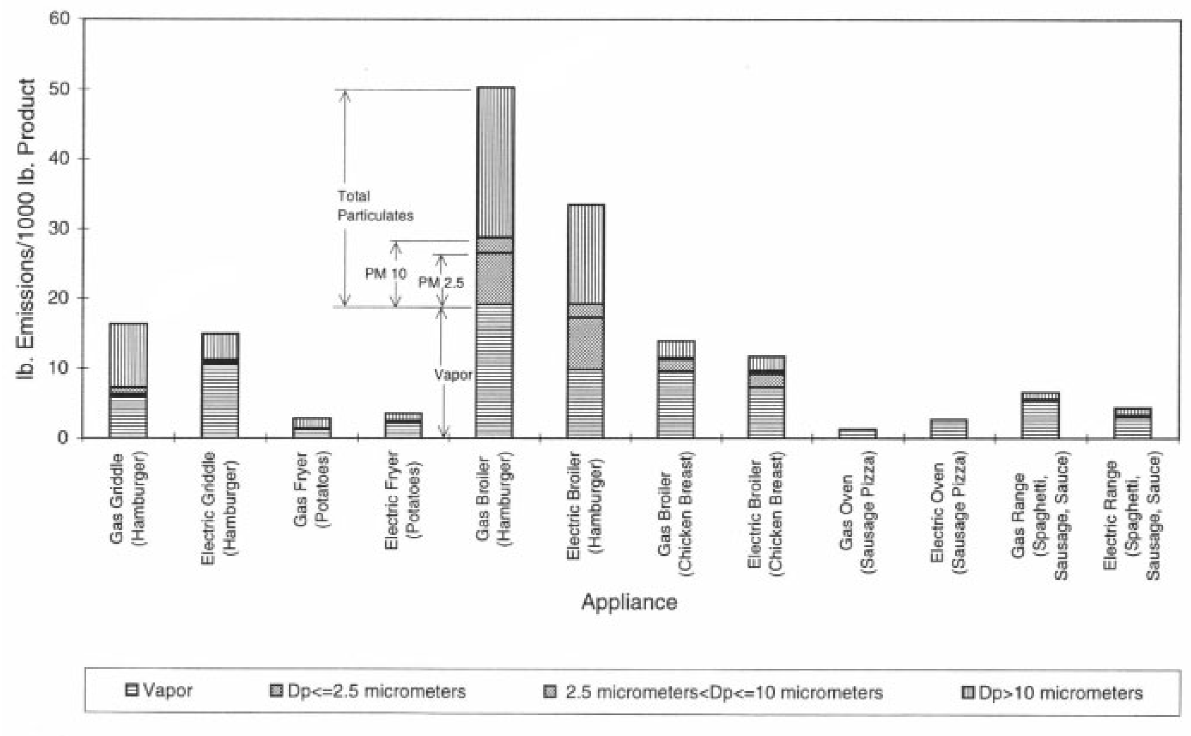
Although both studies had comparable a number of responders (543 for PES and 655 for PRI), the major differences between the PES and PRI studies were: (1) the PRI study used computer-assisted telephone interviews instead of PES's use of a self-administered (mail-out) questionnaire; (2) PRI used a more detailed restaurant classification scheme and not all categories of restaurants were surveyed; (3) the PRI study focused on restaurants most likely to use broilers; and (4) PRI surveyed restaurants throughout California while PES investigated restaurants within SCAQMD. Overall, PES had a low response rate with only 12.9% of the restaurants responding to the survey while PRI had a response rate of 41%. Given that PES did not receive any responses from the 210 national chain restaurants in its study area, it is unknown if this would significantly impact their estimated amount of hamburger cooked on chain-driven broilers. (A majority of this type of equipment is utilized by fast food restaurants). It should be noted that PES did receive responses from local chain and fast food restaurants that were not considered “national” chains. PRI received responses from 157 fast food restaurants, which equated to 23.9% of the responders. Based on the broader geographic coverage of the responders and the inclusion of cooking practices from fast food restaurants, District staff considered the results of the PRI study (Table A-3) a more representative estimate of the amount of meat cooked on broilers per year.

C. Emission Factors from Broilers

SCAQMD contracted the University of California Riverside, College of Engineering – Center for Environmental Research and Technology (CE-CERT) in 1997 to develop a test method that estimates emission factors for PM_{10} and VOC released from various restaurant cooking operations. The resulting study (the “CE-CERT study”) included tests conducted for hamburger cooked on under-fired and chain-driven broilers. A subsequent study sponsored by ASHRAE, published in 1999 by Gerstler, et al., from the University of Minnesota, Department of Mechanical Engineering (the “Gerstler study”) characterized the effluent emissions from various grease producing cooking processes. The study measured grease particulate and vapor emissions and real time particulate size distributions within the exhaust duct using a sample probe and following US EPA Method 5.

Figure A-1 shows the average grease distribution emitted from each appliance as determined by the Gerstler study. The actual composition of the emitted products is complex and it is difficult to determine the portion of the emissions that are particulates. That is because condensable vapors such as water and grease are present in vapor as well as liquid form. Generally, condensables are vapors in gaseous form at entry into the ventilation hood, but may condense into particulate form (i.e., liquid or solid state) in the duct works, on exiting the exhaust fan, or in the atmosphere. The CE-CERT study included the emissions from condensable vapors into its total particulate emission factor. Because these vapors behave as gases, they cannot be removed through mechanical filtration. Particulates greater than 10 microns in size are generally not emitted into the atmosphere, the CE-CERT study confirmed. Standard baffle filters and the exhaust fan prevent the release of particles greater than 10 microns in size. Based on the emission factors from the Gerstler study, it is estimated that Type 1 hoods (hoods with fire suppression built into the exhaust system, required for all cooking appliances in restaurants) capture 1,573 tons per year (4.3 tons per day) of PM greater than 10 micron in size from the nine Bay Area counties. For this report, emissions were estimated for particulates less than PM_{10} and for VOC.

Figure A-1. Average Grease Distribution by Appliance



Source: Gerstler et al, 1999

A total of 50 lbs. of emissions is generated from a gas broiler for every 1000 lbs. of hamburger cooked. Based on the Gerstler study, approximately 39% (19 lbs. for every 1000 lbs. of meat cooked) of the total grease emitted from cooking hamburgers on an under-fired broiler is in the form of condensable vapors. Of the remaining 61% (31 lbs) of grease emissions, 42% (21.5 lbs) of the particulates are greater than 10 microns and 15% (7.3 lbs) of the emissions are less than 2.5 microns in size. Significantly lower emissions are generated from cooking chicken on under-fired broilers due to the very low fat content. The Gerstler study measured only 14 lbs of total grease emissions for every 1000 lbs. of chicken breast cooked. Approximately 69% of the emissions from chicken are in the form of condensable vapors while the remaining 31% are particulates. Table A-4 presents a summary of the emissions factors produced from the Gerstler study.

Table A-4. PM Emission Factors for Under-Fired Broilers (lbs/1000 lbs of food cooked)

Type of Food	Under-Fired Broiler	
	PM >10 micron	PM < 10 micron
Hamburger	21.5	9.5
Chicken breast	2.5	2.0

Source: Gerstler et al, 1999

The emission factors for both types of meats from the Gerstler study compared well with previous emission factors determined by the CE-CERT study. It should be noted that the impinger methods used by both studies may create positive mass artifacts that result in higher emissions rates (Hildemann et al., 1999).

A study conducted in 2003 by MacDonald et al., from the Desert Research Institute (DRI) (the “DRI study”), used the same cooking equipment as at CE-CERT to estimate emissions of particulate matter less than 2.5 microns. The DRI study collected samples from a stainless steel dilution tube, rather than an impinger, because: (1) doing so allowed a broader range of sampling media and methods to be employed; and (2) the conditions experienced by the sample more closely match those experienced by the exhaust gas leaving the vent as they mix with the atmosphere (England et al., 2001). Hildemann et al., (1989) found that run-to-run variability is typically large using traditional impinger test methods due to the presence of random non-combustion generated particles that lead to artifact formation in the liquid impingers. Artifacts result in a large positive bias in the condensable particle measurement using traditional methods (England et al., 2001). Unfortunately, the DRI study only quantified emissions for particulates less than 2.5 micron and a portion of condensable vapors that solidified in the dilution tube. For this reason, the DRI emission factors are not directly comparable to either those of the CE-CERT study or the Gerstler study.

Thus, District staff used the emission factors from the Gerstler study to estimate emissions of PM_{10} from under-fired charbroilers. Because the Gerstler study did not test chain-driven charbroilers or determine emissions factors for VOC, District staff used emission factors developed in the CE-CERT study to estimate PM and VOC emissions from chain-driven charbroilers, and VOC emissions from under-fired charbroilers. Hamburger emissions estimated using chain-driven broilers were applied to all meats cooked on chain-driven broilers, because other types of meat were not tested on chain-driven broilers. Under-fired emission factors for chicken breast were used to estimate emissions from pork and chicken with and without skin cooked on under-fired broilers. District staff used emission factors for seafood developed in the CE-CERT study, because the Gerstler study did not develop any such emission factors. The final emission factors used in this study are presented in Table A-5.

Table A-5. Emission Factors (lbs/1000 lbs of food cooked)

Type of Food	Chain-driven Broiler		Under-Fired Broiler	
	PM10 (b)	VOC (b)	PM10 (a)	VOC (b)
Hamburger	7.42	2.27	9.5	3.94
Steaks	7.42 (c)	2.27 (c)	9.5 (c)	3.94 (c)
Poultry with Skin	7.42 (c)	2.27 (c)	2	1.82
Poultry without Skin	7.42 (c)	2.27 (c)	2 (d)	1.82 (d)

Type of Food	Chain-driven Broiler		Under-Fired Broiler	
	PM10 (b)	**VOC (b)**	**PM10 (a)**	**VOC (b)**
Pork	7.42 (c)	2.27 (c)	2 (d)	1.82 (d)
Seafood	7.42 (c)	2.27 (c)	3.3 (b)	0.38

Note:
a: Emission factors are taken from Gerstler et al study.
b: Emission factors are taken from CE-CERT study.
c: Emissions factors for hamburger were applied to all other meats since these meats were not tested on this equipment.
d: Emission factors for chicken breast were applied to chicken with/without skin, and pork

D. Emissions from Broilers

The emission inventory for chain-driven and under-fired broilers is estimated by multiplying the number of broilers by the average amount of meat cooked and the emission rates using the following relationship:

$$EM = \frac{EF \times Eall \times M}{2000 \text{ lbs/ton}}$$

Where:
EM = Emission inventory from broilers (tons/year);
EF = Emission factor (lbs of PM10 or VOC/1000 lbs of meat cooked);
Eall = Total number of broilers in District (unitless); and
M = Average pounds per year of meat cooked on one broiler.

Table A-6 presents the final estimated emissions of PM_{10} and VOC for broilers.

Table A-6. Emissions from Broilers

Type of Food	Chain-driven Broiler		Under-Fired Broiler	
	PM10 (tons/yr)	**VOC (tons/yr)**	**PM10 (tons/yr)**	**VOC (tons/yr)**
Hamburger	85.3	26.1	327	135
Steaks	25.2	7.72	286	118
Poultry with Skin	15.7	4.81	37.5	34.1
Poultry without Skin	28.5	8.70	67.8	61.7
Pork	6.16	1.88	14.7	13.3
Seafood	12.7	3.89	49.9	5.75
Total (tons/year)	174	53	782	369
Total (tons/day)	0.48	0.15	2.1	1.0