INDOOR AIR QUALITY: RESIDENTIAL COOKING EXPOSURES

FINAL REPORT

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ABSTRACT

A study was performed in a Test House in California to collect data that will provide a better understanding of the impact of residential cooking activities on exposure to particles and gaseous Toxic Air Contaminants. Particulate matter (PM), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), polycyclic aromatic hydrocarbons (PAHs), elements, and aldehydes were measured. Thirty-two tests were performed to measure the impact of cooking during typical cooking activities with gas and electric ranges and to evaluate variables that might impact emissions. The study also included tests of worst-case cooking conditions and of potential exposure reduction methods. The study demonstrated that cooking can produce high concentrations of particles and gases. $PM_{2.5}$ concentrations were over 1000 $\mu g/m^3$ during stovetop stir-frying, frying of tortillas in oil on the range top burner, and baking lasagna in the gas oven. PM_{10} concentrations measured in the kitchen, living room, and bedroom ranged from below the detection limit to 3660 $\mu g/m^3$ in the 32 tests. Combustion pollutants were elevated in the house primarily during use of the gas range. CO concentrations during cooking periods were generally less than 4 ppm, but exceeded 9 ppm during preparation of a full meal and during oven cleaning. NO_2 concentrations were greater than 50 ppb during some tests with the gas range and averaged 400 ppb during the 5-hr oven cleaning test, exceeding the ARB Indoor Air Quality (IAQ) Guideline of 250 ppb over one hour, and representing a significant source of exposure. Formaldehyde concentrations exceeded the ARB action level of 0.1 ppm (124 $\mu g/m^3$) during oven cleaning and broiling of fish. Several PAH compounds were found in the fresh cooking oils used in the study, but the concentrations were low in the house during cooking. The data, however, suggest that additional study is warranted to fully evaluate the impact of cooking on PAH exposure. The results of the study demonstrated the significance of cooking as a source of exposure to particles and Toxic Air Contaminants. Because of the high variability of the emissions during cooking, it was difficult, however, to quantitatively determine the impact of variables such as food type, cooking method, pan material, or the impact of simple exposure reduction methods.

EXECUTIVE SUMMARY

Background

Cooking has been identified as a potentially significant source of indoor air pollution and personal exposure to Toxic Air Contaminants. Results of a number studies suggest that cooking may be a major source of exposure to particulate matter (PM), combustion pollutants, polycyclic aromatic hydrocarbons (PAHs), and other organic compounds. Epidemiological studies have found significant associations between increased respiratory symptoms and the presence of, or cooking with, a gas range. Despite the recognition that cooking may be an important source of air contaminants in residential dwellings, emissions from cooking and the resultant exposures have not been well characterized.

The current study was performed for the California Air Resources Board (ARB) to gain a better understanding of the impact of cooking on indoor air concentrations and personal exposures to air contaminants generated by cooking in residences. This study represents the first large-scale study of cooking emissions and the resultant exposures in a residential setting under semi-controlled conditions. The study included thirty-two cooking tests with a variety of cooking methods and foods. It addressed various factors that may impact emissions from cooking and evaluated simple exposure reduction methods.

Methods

To meet the study objectives, a test house was rented in Rohnert Park, California. The house was a small single-story ranch style home constructed in the 1970s. The small size of the house (less than 1000 ft^2) and the layout of the rooms, consisting of a kitchen, adjacent living room, and three bedrooms, resulted in good air mixing in the house even though the house air handler was not operated during testing. The house had an attached garage where a laboratory was set up. The test house was instrumented for the following measurements:

- CO, NO, and NO_2 with continuous pollutant monitors,
- Real-time PM concentrations and size distributions (12 size fractions from 0.04 to 8.4 μm, aerodynamic mean diameter) with an electrical low pressure impactor (ELPI) that recorded data continuously,
- $PM_{2.5}$ and PM_{10} mass, collected on Teflon® filters with size selective inlets,
- Air exchange rates,
- Temperature and relative humidity (RH) indoors and outdoors,
- Range top burner and oven temperatures,
- Gas or electric use during cooking, and
- PAHs, elements, and aldehydes, in a subset of tests.

Following a pre-test and refinement of the study design and test protocols, a main study was performed that consisted of 32 cooking tests at the test house. The tests involved cooking with an electric range, gas range, and microwave oven. The electric range was used for seven cooking tests. These same seven cooking activities were performed with the gas range for comparison.

The microwave was used in three tests to compare emissions with the gas and electric ranges. All other tests were performed with the gas range.

Realistic cooking activities were performed during the study. They involved cooking activities such as stovetop stir-frying on the range top burner, frying tortillas in oil, broiling fish in the oven, and baking a pre-packaged frozen lasagna in the oven. The amount of food cooked was larger than would be typical in a residential setting, and the duration of cooking was generally longer than typical in order to obtain sufficient pollutant mass for analysis.

Results

Average $PM_{2.5}$ mass concentrations in the kitchen, living room, and bedroom ranged from 2.9 to 3,880 $\mu g/m^3$ during 32 cooking tests. PM_{10} concentrations ranged from 0.4 to 3660 $\mu g/m^3$. Indoor concentrations during cooking were substantially higher than the outdoor concentrations, which ranged from 0.6 to 13.6 $\mu g/m^3$ during the study. The highest concentrations occurred during operation of the self-cleaning feature of an intentionally dirtied gas oven. During routine cooking, the concentrations of $PM_{2.5}$ were over 1000 $\mu g/m^3$ during stovetop stir-frying, frying of tortillas in oil on the range top burner, and baking lasagna in the gas oven. Continuous, real-time PM measurements with an electrical low-pressure impactor (ELPI) showed that the particles emitted during cooking were primarily in the size fractions of less than 1 μm.

The median and average $PM_{2.5}$ concentrations during the six standard (typical) cooking tests, which ranged from approximately 1.5 to 5 hours in duration, exceeded the pending Federal National Ambient Air Quality Standard (NAAQS) of 65 $\mu g/m^3$ (24 hour average). The median and average PM_{10} concentrations exceeded the ARB IAQ Guideline of 50 $\mu g/m^3$ over 24 hours. The data indicated that cooking can be a significant source of exposure to PM.

Element concentrations measured in indoor air PM_{10} samples during the cooking tests exceeded outdoor concentrations for most elements. Of potential importance were elevated concentrations of chromium, titanium, nickel, and zinc during the oven self-cleaning tests. Due to the short test periods and low mass levels in the samples, element measurements were below the method detection limit in many samples.

As expected, combustion pollutants were elevated in the house primarily during use of the gas range. Average CO concentrations during cooking periods were generally less than 4 ppm, although concentrations higher than 9 ppm were measured during preparation of a full meal and during oven cleaning. NO_2 concentrations were greater than 50 ppb during four of six standard cooking tests with the gas range and averaged over 400 ppb in all three rooms during the 5-hr oven cleaning test, exceeding the ARB IAQ Guideline of 250 ppb (1 hour).

A number of PAHs, which ARB has identified as Toxic Air Contaminants under the grouping of Polycyclic Organic Matter, were identified by gas chromatography/mass spectrometry analyses of bulk samples of cooking oils used in the study. During cooking tests with these oils, PAHs were measured in air samples collected in the kitchen. However, there was not a clear relationship between the presence of PAHs in the oils and the concentrations of the PAHs in the air samples. The concentrations of PAHs in the air samples collected in the kitchen during the

cooking tests were within the range of concentrations measured in other indoor air studies. The indoor concentrations were generally higher than concurrent outdoor concentrations indicating that cooking was a source of PAHs. The data suggest that additional testing and analyses are warranted to more fully evaluate the impact of cooking on exposure to PAHs.

Formaldehyde and acetaldehyde, Toxic Air Contaminants identified by the ARB, were present in air samples collected during oven cleaning, broiling fish, and oven pork roast tests. During the 5-hr oven cleaning tests, the formaldehyde concentrations of 417 and 224 $\mu g/m^3$ with the gas and electric ranges, respectively, substantially exceeded the Acute Reference Exposure Level (REL) of 94 $\mu g/m^3$ (1 hour) (OEHHA, 1999) and the Action Level of 0.10 ppm (124 $\mu g/m^3$) from the ARB IAQ Guideline (CARB, 1991). During the broiling fish test, the formaldehyde concentration of 129 $\mu g/m^3$ also exceeded the action level. Acetaldehyde concentrations of 434 and 92 $\mu g/m^3$ were measured during oven cleaning and fish broiling tests with the gas range. Although the aldehyde measurements were limited in scope, they indicated that cooking might have a significant impact on aldehyde exposures.

Oven cleaning resulted in the highest concentrations of the measured air contaminants in the house during the study. Of the six standard cooking tests performed with both the gas and electric range, the highest emissions of PM occurred during frying of tortillas in oil on the electric range and baking a frozen lasagna in the gas oven. Broiling fish also produced high PM emissions.

In worst-case tests that involved realistic activities such as heating cooking oils too hot or slightly burning food, indoor air concentrations and emission rates were generally higher than in the standard tests. With the exception of the oven-cleaning tests, the highest PM concentrations were measured during the worst-case stovetop stir-frying test.

The impact of variables such as type of cooking method, type of food, or pan material could not be determined quantitatively in this study. The concentrations of the air contaminants measured in the rooms and the emission rates calculated with the mass balance model were too variable to determine the significance of differences between different cooking activities. Adjusting the emission rates for the food mass lost or the energy used during cooking did not change the observed trends.

Tests with the microwave demonstrated that emissions of PM and combustion pollutants were lowest with this cooking method. It was the most effective exposure reduction method evaluated in the study. Tests with the range hood exhaust and range hood side shields resulted in lower concentrations of some of the air contaminants, but there was not a dramatic reduction in indoor air pollutant concentrations.

Conclusions

The data collected in the study successfully addressed the project objectives. The results provide a better understanding of the impact of cooking on indoor air pollutant concentrations and exposure. The data indicated that cooking is a significant, although highly variable, source of PM indoors. Exposure to PM due to cooking may be substantial for many individuals, depending on the amount of cooking that is done and the duration of time spent in the home following cooking. With a gas range, exposure to CO and NO_2 is increased substantially.

Oven cleaning was identified as the most significant source of emissions of PM, CO, NO, NO_2, formaldehyde, and acetaldehyde. Data from the oven cleaning tests suggest that guidance should be developed to help reduce exposure to air contaminants during operation of the self-cleaning feature of gas and electric ovens.

The results of the study cannot be used to quantitatively assess the impact of different types of cooking methods, different foods, or other parameters related to cooking methods and utensils due to the high variability in the emissions. To evaluate the impact of these parameters, a much larger number of tests would need to be performed. These tests could be performed under highly controlled conditions in environment test chambers or in field studies under realistic cooking conditions.

The results of the study suggest that additional research is warranted to more fully characterize the impact of cooking on exposure to Toxic Air Contaminants, such as PAHs and aldehydes and to evaluate exposure reduction techniques under realistic conditions in residences.

1.0 INTRODUCTION

1.1 Background

The California Air Resources Board (ARB) Indoor Air Quality and Personal Exposure Assessment Program is working to identify and reduce Californian's indoor and personal exposure to air pollutants. To meet this goal, the ARB requires data on emissions from various air pollutant sources and the resultant personal exposure and indoor air concentrations in selected microenvironments. Data collected by the ARB can be used to improve estimates of human exposure to selected Toxic Air Contaminants in a variety of microenvironments and to develop guidance for Californians to help them reduce their exposure to air contaminants.

Various studies have identified cooking as a potentially significant source of indoor air pollution and personal exposures. Cooking has been reported to be a major source of particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), and other organic compounds in ambient air due to emissions from commercial cooking operations (Rogge et al., 1991; Schauer et al., 1998; and Schauer et al., 1996). Cooking has also been identified as a significant source of PM in residential dwellings (Brauer et al., 2000; Brauer et al., 1996; Ozkaynak et al., 1996; Ross et al., 1999; Wallace, 1998, 1996a, and 1996b). PAHs have been reported in fumes from cooking oils (Chiang et al., 1997; Shields et al., 1995; Shuguang et al., 1994; and Wu et al., 1998). Measurements in residences have shown increases in levels of PAHs associated with cooking (Chuang et al., 1991; Dubowsky et al., 1999; and Sheldon et al., 1993). Air contaminants may be emitted from the cooking appliance (Rogge et al., 1993; Rogge et al., 1997) and the cooking process (Annis and Annis, 1989; Rogge et al., 1991; Gerstler et al., 1998). Epidemiological studies have found significant associations between increased respiratory symptoms and the presence of, or cooking with, a gas range (Pope et al., 1995; Zhong et al., 1999).

Despite the recognition that cooking may be an important source of air contaminants in residential dwellings, emissions from cooking and the resultant exposures have not been well characterized. To meet its goals, the ARB required data to gain a better understanding of the impact of cooking on indoor air concentrations and personal exposures to air contaminants generated by cooking in residences. The current study was initiated to address those data needs. The ARB developed a design for a study to collect data on pollutant emissions and exposures from a wide range of cooking activities. The study objectives and design are described below. The current study represents the first large-scale study of various cooking emissions and exposures in a residential setting under semi-controlled conditions. Results from the study will provide a better understanding of the impact of cooking and will be useful for developing further research in this area of exposure.

1.2 Study Objectives

The goal of the project was to characterize the pollutant emissions and the potential human exposure impact from a range of residential cooking activities. The specific objectives of the project were the following:

- Characterize emission rates and resultant indoor air concentrations and personal exposures for particulate matter (PM), carbon monoxide (CO), nitric oxide (NO), and nitrogen dioxide (NO_2) produced by residential cooking under typical and realistic worst-case conditions
- Characterize emission rates and resultant indoor air concentrations for other cooking pollutants such as PAHs, elements, and other potential marker compounds
- Measure the effectiveness of selected exposure reduction practices

1.3 Study Design and Project Overview

The project objectives were addressed in an original study design submitted to the ARB in the ARCADIS Geraghty & Miller (ARCADIS) Technical Proposal. The plan was subsequently refined in consultation with ARB staff and members of a Technical Review Group (TRG, listed in Appendix B) that was formed to provide technical input to the study. The study design is outlined in the *Revised Study Design and Test Plan for Indoor Air Quality: Residential Cooking Exposures*, dated November 12, 1998. The project consisted of the following ten tasks:

- Task 1 – Review the literature and study design
- Task 2 – Meet and consult with the Technical Review Group and the ARB to finalize the study design
- Task 3 – Obtain a Test House in California where the tests will be performed
- Task 4 – Prepare the Test House for the study and perform a pre-test
- Task 5 – Conduct testing of cooking activities
- Task 6 – Test exposure reduction methods
- Task 7 – Perform data processing and analysis
- Task 8 – Prepare draft final report
- Task 9 – Prepare final report
- Task 10 – Present project seminar

A literature review was performed at the start of the project in an attempt to identify additional information that could be used to refine the study design, test protocols, or measurement methods. The ARB had already performed a literature review and identified the major peer-reviewed literature on the subject in their request for proposal. The literature review was performed using both computerized and manual search methods. At the time of the review (Fall, 1998), there was little information identified by ARCADIS beyond that already identified by the ARB. The bibliography for the literature review is included as Appendix A of the report.

The literature review did not result in any significant changes to the study design. Minor modifications were made to the study design based on discussions with the TRG and ARB staff. These modifications were incorporated in the study design referenced above. The following is a brief overview of the project. More detailed information is presented in the following sections of the report.

A test house was rented in Rohnert Park, California for the study. The house was a small single-story ranch style home constructed in the 1970s. It met a large number of the criteria for selection of the test house, as described in Section 2.0. The small size of the house (less than 1000 ft^2) and the layout of the rooms resulted in good air mixing in the house even though the house air handler was not operated during testing. The house had an attached garage where a laboratory was located. The test house was specially instrumented for the study. Temperature and relative humidity (RH) sensors were placed in selected rooms and outdoors. Temperature sensors, a power transducer, and a dry gas meter were installed on the ranges to collect data during cooking tests. Teflon® sampling lines were routed to the kitchen (K), living room (LR), master bedroom (MBR), and outdoors (OA) for collection of air contaminants. A second set of sampling lines was routed to the same rooms for collection of SF_6, the tracer gas measured to calculate air exchange rates. A laboratory was set up in the garage with pollutant monitoring instrumentation, a data acquisition system, and support hardware for instrument calibrations.

A pre-test was performed in May 1999 to test the instrumentation, sampling methods, and test protocols. The pre-test involved initial measurements of CO, NO, and NO_2 to characterize the performance of the gas range before and after tuning. The methods and results for the tuning are included in Appendix D.

Four cooking tests were then performed. Duplicate tests were performed that involved frying loose ground beef in a pan on the range top burner. A second set of duplicate tests was performed that involved preparation of a pork roast in the oven of the gas range. Results of the pre-test are summarized below and included in an electronic database accompanying the report.

The main cooking study was performed in February 2000, when the temperatures were moderate, to avoid the need for operation of an air conditioner during the cooking tests. The main study involved 32 cooking tests at the house in Rohnert Park. The tests involved cooking with an electric range, gas range, and microwave oven. The microwave was used in three of the tests and measurements were performed only with real-time monitoring methods (continuous monitors for CO, NO, NO_2 and PM). The electric range was used for seven cooking tests. These same seven cooking activities were performed with the gas range for comparison. All other tests were performed with the gas range. Parameters measured during all tests, except with the microwave, included the following:

- CO, NO, and NO_2 with continuous pollutant monitors
- PM concentrations and size distributions (12 size fractions from 0.04 to 8.4 μm, aerodynamic mean diameter) with an electrical low pressure impactor (ELPI) that recorded data continuously
- $PM_{2.5}$ and PM_{10} mass, collected on Teflon® filters with size selective inlets,
- Air exchange rates
- Temperature and RH indoors and outdoors
- Range top burner and oven temperatures
- Gas or electric use during cooking

During selected tests, additional samples were collected for other air contaminants. These included samples for PAHs, elements, and aldehydes. Although fatty acids were originally proposed for measurement during the project, they were dropped from the main study. Samples were collected for aldehyde measurements instead because results from other studies (Theibaud et al., 1994, Schauer et al., 1998 and Kelly, 2000) suggested that cooking with the oven and broiler resulted in substantial emissions of carbonyl compounds.

The 32 tests were designed to collect information on the following factors:

- Appliance type (gas, electric, and microwave)
- Cooking method (frying, baking, broiling, range-top burner, oven)
- Food type (variety of foods cooked)
- Cooking vessel (pan material, lids)
- Exposure reduction methods (exhaust fan, hood shields)

1.4 Pre-Test Summary

The pre-test involved a set of four tests during which all measurements were performed and samples were collected for all target parameters. The tests, which involved relatively short duration cooking events, were designed to determine the performance of the sampling and analytical methods. The tests were performed in duplicate to assess the variability and method precision. The results of the pre-test are presented in the electronic database accompanying the report. Results of the pre-test and issues identified in the pre-test included the following:

- $PM_{2.5}$ mass concentrations ranged from below the minimum detection limit (MDL) in one outdoor sample to 1040 $\mu g/m^3$ in the kitchen during one of the tests with pan frying of loose ground beef
- PM_{10} mass concentrations ranged from 9.9 to 11.8 $\mu g/m^3$ outdoors and 25 to 144 $\mu g/m^3$ indoors during the four cooking tests
- Results of the pre-tests indicated that the cooking protocol should be changed to increase the amount of PM mass that could be collected by the integrated sampling methods. The average mass of PM on the filters for all samples collected during the pre-test was only 100 μg. Mass on the filter samples collected outdoors was near the limit of detection due to the short sampling periods. This was because the cooking period for pan-frying of ground beef lasted only 20 minutes, and the total exposure duration during which the samples were collected was only 2 hours long. Although the sampling period was longer for the pork roast in the oven (4.3 hours), the total mass collected was still low because of the lower emissions during this cooking activity.
- Real-time measurements of particle concentrations in the 12 size fractions with the ELPI indicated that the particles were predominantly in the smaller size fractions (less than 0.5 μm). This observation suggested that additional measurement methods, such as a scanning mobility particle sizer (SMPS), would be required to characterize the particle size distribution. An SMPS was not available for the study, and the ELPI represented the best single piece of instrumentation for measurements over a wide range of particle sizes.

- PAH concentrations were low and below the limit of detection in many of the samples. Few compounds were detected in samples collected during the short beef pan-frying tests. PAH levels were generally higher indoors than outdoors. PAH concentrations in the living room were not substantially different from those in the kitchen, suggesting that sampling should be limited to the kitchen. Precision was poor for duplicate samples. The poor precision and large number of samples with non-detectable PAHs suggested that the cooking periods and sampling durations should be longer.
- The elements measured by X-ray fluorescence (XRF) in PM_{10} samples were typical of ambient air particles, predominantly comprised of silicon, aluminum, sulfur, calcium, and iron. Chlorine was also detected frequently at this location, which was near the ocean. Although copper and zinc were detected in over two-thirds of the samples, there was no clear trend of higher indoor concentrations. Due to low mass levels on the filters, there was poor precision for the duplicates. As for the other parameters measured by collection of integrated samples, the data suggested that the data quality would be improved if cooking protocols were modified to facilitate collection of higher levels of PM mass.
- CO, NO, and NO_2 emissions were consistent with published results for gas ranges
- Indoor temperatures in the house ranged from 17.0 to 26.8 °C. Indoor relative humidity during the pretest ranged from 32.4 to 61.7%. Air exchange rates ranged from 0.31 to 1.07 air changes per hour

Results from the pre-test were used to refine the study design. The primary change was to develop cooking protocols that incorporated either cooking of multiple batches of food during a single cooking event or performing two sequential cooking events during which a single set of integrated air samples were collected.

2.0 MATERIALS AND METHODS

2.1 Overview

The test house was procured for use in April 1999 and configured for use in the study. Teflon® sampling lines were routed from the attached garage laboratory to the house for collection of gaseous pollutants (CO, NO, and NO_2). A second set of polypropylene sampling lines was installed for collection of the SF_6 that was measured to calculate air exchange rates. The sampling lines were approximately 15 m long. Signal lines were routed from the laboratory to the house for collection of data from the room temperature sensors, RH probes, thermocouples, and the power transducer. Lines were also routed for collection of outdoor temperature and RH. Pollutant monitors, the data acquisition system (DAS), and support hardware were set up in the garage laboratory.

Following set up and calibration of the instrumentation, testing began in the house. A used gas range was procured for the study, and a gas line was installed for the range. An electric range was also procured because the one in the house when rented did not have a self-cleaning feature. Preliminary measurements were performed to validate performance of the monitoring instrumentation. Air exchange rates were measured over a few days to validate performance of the method. The pollutant monitors were operated to measure background CO, NO, and NO_2 concentrations indoors and outdoors. Tests were then performed to measure baseline CO, NO, and NO_2 concentrations during operation of the gas range top burner and the oven without food cooking. Following the initial measurements, adjustments were made to the gas range burners, and additional measurements were performed.

The pre-test was performed in May 1999. It involved measurements of all parameters during two types of cooking activities – frying of loose ground beef in an un-covered pan on the gas range top burner and baking a pork roast in the gas oven. Both types of cooking were performed in duplicate in order to evaluate the variability between tests. Duplicate samples were collected during the tests to determine method precision. Results of the tests were used to refine the study design.

The main study was performed in February 2000. Thirty-two cooking tests were performed. Additional tests were performed to measure baseline concentrations of pollutants generated by the gas range top burner and the oven. The following sub-sections describe the main study.

2.2 Description of the Test House and Appliances

A test house was rented in Rohnert Park, California for use in the project. Rohnert Park, located approximately 60 miles north of San Francisco and 20 miles from the Pacific Ocean has a relatively moderate climate. During February and March 2000, while the tests in the main study were being performed, the average high temperatures were 61.6 °F (16.4 °C) and 64.4 °F (18 °C), respectively. Average lows were 40.2 and 41.4 °F (4.6 and 5.3 °C), respectively for February and March 2000. The average heating degree-days for February is 15 (base 65 °F) for the years 1931 to 2000.

The house, built in 1983, was a single story ranch style home on a crawl space. The floor plan of the house is depicted in Figure 2-1, which also depicts the sampling locations in the kitchen, living room, and master bedroom. The front elevation of the house is depicted in Figure 2-2. There were a number of criteria defined for selection of the house including the following:

- Single family residence of typical California construction
- Built after 1988
- Two to three bedrooms
- Single story
- Floor area of 1300 to 2000 ft^2
- Double glazed windows and adequate insulation to have air exchange rates representative of California residences
- Central heating and air conditioning system
- Located in moderate climate (to minimize the need for operating the heating or air conditioning system during testing
- Located in a residential area away from major industrial sources of PM and SVOC contaminants
- No fugitive dust sources nearby (gravel driveways or roadways)
- Located at least one mile away from establishments that emit cooking fumes,
- Range top exhaust that vents to outdoors
- Attached garage (to facilitate set up of the laboratory)

Figure 2-1. Floor Plan of the Test House (Not to Scale)

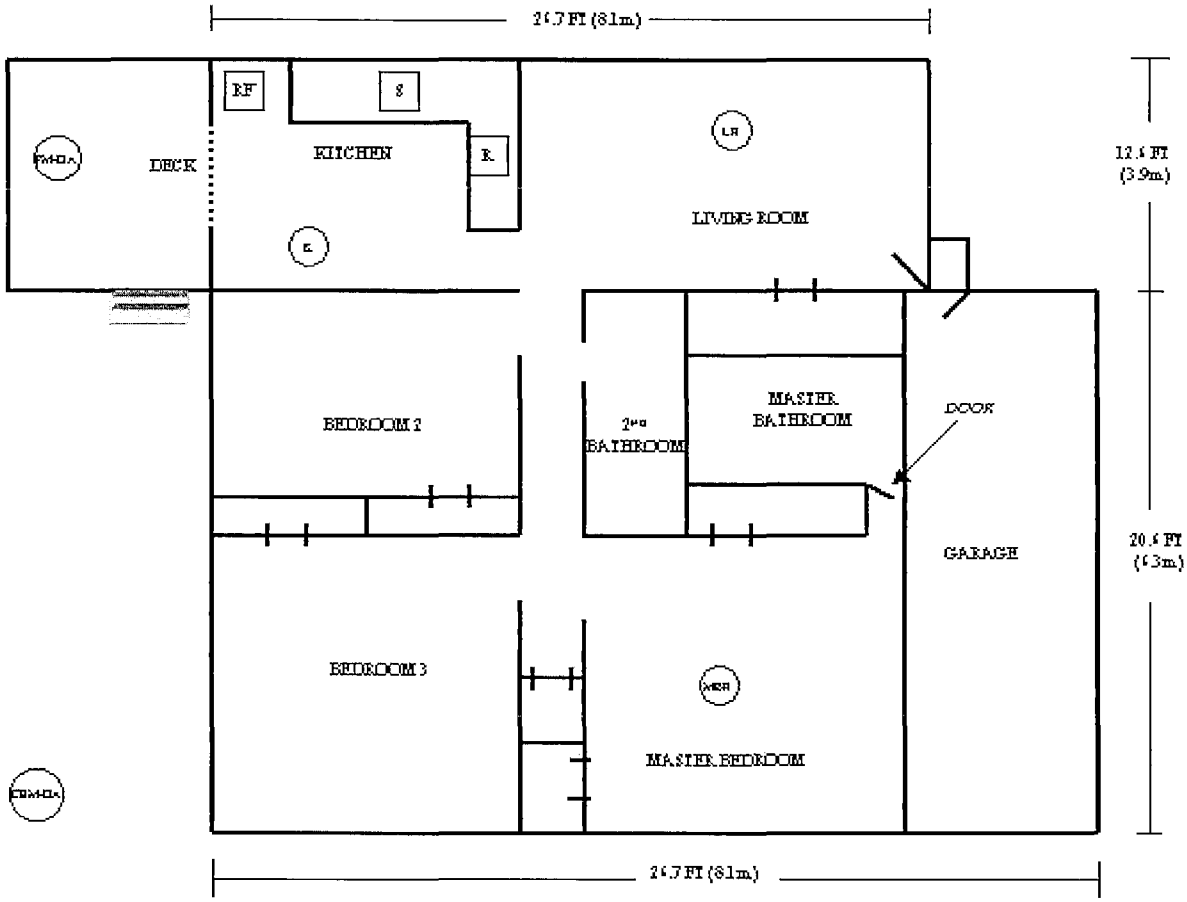


Figure 2-2. Front Elevation of the Test House

Many of the criteria were met. However, some criteria were not met due to difficulty finding a rental home at the time that the study was performed. At the time of the study, there was an extremely limited rental home market in the area selected for the study. It was necessary to locate the test house in an area with a relatively moderate climate because the intention was not to operate a ducted heating and cooling system while tests were being performed. Operation of an air handler would likely result in substantial particle loss in the ductwork. There was difficulty finding homes that could meet the selection criteria. There was also reluctance by landlords to rent a house for a one-year period for use as a test house. As a result of these complications, the search for an appropriate house that would meet the criteria lasted over five months.

The house that was rented was a single story home typical of California housing stock, but it was somewhat older and smaller than desired. The best available information is that it was built in 1983. The house had a floor area of 824 ft^2 (76.56 m^2) and a volume of 187 m^3. The size of the house was smaller than the original selection criterion. The rental company advised us that the house had a floor area of approximately 1100 ft^2, which turned out to be incorrect. However, as the data indicate, the small size and the layout of the house apparently resulted in good air mixing and relatively uniform air contaminant concentrations in the different rooms, most likely improving the accuracy of the source emission rate calculations. The house had three bedrooms, a living room, and kitchen separated by walls from the other rooms in the house (Figure 2-1). It had central heating, but no air conditioning. The furnace was fitted with a standard disposable high performance filter that was replaced at the start of the tests. The air exchange rate measurements showed that the house was relatively well insulated and sealed. Air exchange rates measured in

February 2000 ranged from 0.18 to 1.08 hr^{-1} and were typically 0.22 to 0.30 hr^{-1} (Table 3-25, Section 3). The range hood exhaust was vented to the outdoors. There were no major sources of particles from cooking activities located near the house. There was some wood burning in the residential neighborhood during the period of the main study.

The house was minimally furnished. There was a refrigerator in the kitchen, which was operating during the study. The furnishings in the adjacent living room consisted of an upholstered couch, upholstered loveseat, plastic chairs, and a coffee table. There were beds, but no dressers in two of the three bedrooms. There were plastic vertical blinds on all windows, but no curtains. The entire house, except for the bathrooms and kitchen, was carpeted. Therefore, although minimally furnished, there was a fairly substantial amount of surface area that could serve as reversible or non-reversible "sinks" for deposition of gaseous and particulate air contaminants. Plastic runners were placed over carpets in the main walkways of the living room and hallway in order to minimize particle resuspension by the technicians.

The house was equipped with an electric range when rented, but the oven did not include a self-cleaning feature. Therefore, a used electric range was obtained from a local appliance dealer. Gas piping was installed to the kitchen, and a gas range was purchased for the study. A microwave was also rented. All appliances were used and were at least five years old. The appliances were typical of those that would be found in a rental home of this size and age. All cooking appliances were cleaned prior to the start of testing. The only available information on the appliances was the following:

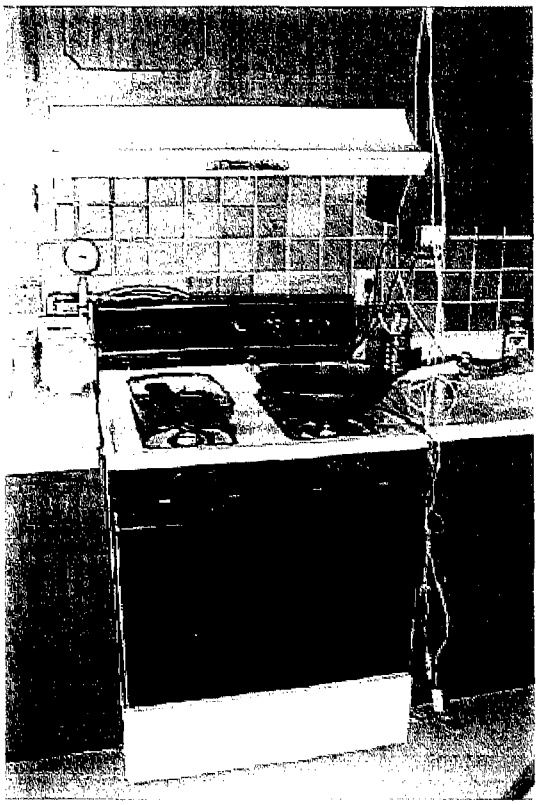
- Magic Chef Gas Range with self-cleaning oven, broiler in oven, and 4 equal-size, stovetop burners, Model # 34428RA (Figure 2-3). The right front burner was used for all range top burner tests. All of the burners were used in the full meal-cooking test.
- Whirlpool Electric Range with self-cleaning oven, 2 large burners, 2 small burners, Model No. RF385PXPW, Serial No. F62602406. The right front burner was used for all tests.
- Quasar Microwave Oven, Model No. MQ5540WW, Serial No. NM33409260, manufacture date of Dec. 1993, Output Frequency = 2450 MHz, Input = 110 volts, 13 amps.

During the main study, the main gas valve on the gas range failed after the first four tests. The valve was replaced. No other adjustments or changes were made to the gas range. The change of the valve did not impact the performance of the gas range top burners or oven.

A limited number of cooking utensils were purchased from local retail outlets in Rohnert Park, CA. They consisted of the following:

- Frying pan – Ecko Endura. 12-inch diameter, non-stick stainless steel skillet
- Baking dish – Pyrex, 9-in X 12-in
- Baking pan – Disposable aluminum baking pan, 8-in X 11-in
- Deep fat frying – Cast iron pan with aluminum frying basket (for French fries)
- Stir-frying–wok, carbon steel, 12 in. diameter
- Vegetable steaming and water boiling – 4 quart stainless steel steamers

Figure 2-3. Test House Gas Range and Cooking Utensils



2.3 Description of the Tests and Cooking Protocols

The main study consisted of the 32 cooking tests listed in Table 2-1. The tests involved cooking with a gas range, electric range, and microwave oven. Tests were performed to measure emissions for a variety of types of cooking, including frying of foods on the range top burners, broiling foods in the oven, and cooking meat in the oven. The tests addressed emissions from cooking of a variety of foods.

During the development of the study design, an attempt was made to obtain data on the predominant food types and cooking methods used in California. Population-based surveys of cooking method frequencies in California or the U.S. were not publicly available. Data on the dietary intake of the U.S. population is available from The U.S. Department of Agriculture (USDA) Continuing Survey of Food Intake of Individuals (CSFII) studies (USDA, 2000). But data on the dietary intake of Californians would be difficult to obtain from the CSFII database cost-effectively and within the time frame of this study. The CSFII studies show that beef, pork, and chicken are the most commonly consumed meats, and that vegetable and seed oils are a significant portion of the dietary fat intake in the U.S. Other information that was available suggested that, after baking or roasting meat, frying was the most common cooking method for meat (Mitchell, 1998). There was a high frequency of frying in fat and oils. Results reported by Rogge (1997) and Gerstler et al. (1998) showed that frying of food and broiling meat and fish resulted in high emissions.

Table 2-1. List of Cooking Tests

Test No.	Type	Range	Conditions	Notes/Comments[a]
1	Oven Cleaning	Gas	Standard	Oven problem; data not reported
1R	Oven Cleaning	Gas	Standard	Repeated test 1
2	Stovetop Stir Fry	Gas	Standard	Two batches cooked in one event
3A	Bacon	Gas	Standard	Two event cooking test
3B	Bacon			Second event
4	Tortillas	Gas	Standard	
5	French Fries	Gas	Standard	Two batches cooked in one event
6A	Broil Fish	Gas	Standard	Two event cooking test
6B	Broil Fish			Second event
7	Bake Lasagna	Gas	Standard	
8	Oven Cleaning	Electric	Standard	Tests 1–7 and 8–14 = same cooking protocols
9	Stovetop Stir Fry	Electric	Standard	Two batches cooked in one event
10A	Bacon	Electric	Standard	Two event cooking test
10B	Bacon			Second event
11	Tortillas	Electric	Standard	
12	French Fries	Electric	Standard	Two batches cooked in one event
13A	Broil Fish	Electric	Standard	Two event cooking test
13B	Broil Fish			Second event
14	Bake Lasagna	Electric	Standard	
15	Bacon	Microwave	Standard	Two event cooking test
15A	Bacon			Second event
16	Bake Lasagna	Microwave	Standard	
17A	Stovetop Stir Fry	Gas	Worst Case	Oil hotter; food cooked longer
17B	Stovetop Stir Fry			Second event in the test
18A	Bacon	Gas	Worst Case	Extra crisp bacon
18B	Bacon			Second event in the test
19A	Broil Fish	Gas	Worst Case	Burned
19B	Broil Fish			Second event in the test
20	Full Meal	Gas	Standard	Large meal with multiple foods; oven and range top burner used
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	Not true replicate – changed to two event test
21B	Stovetop Stir Fry			Second event in the test
22	French Fries	Gas	Test 5 Replicate	
23	Bake Lasagna	Gas	Test 7 Replicate	
24	Fry Beef	Gas	Cast Iron Pan	Data logger failed
24RA	Fry Beef	Gas	Cast Iron Pan	Repeated Test 24 to evaluate pan type
24RB				Second event in the test
25	Pork Roast	Gas	Aluminum Pan	Compare pan types

Table 2-1. List of Cooking Tests Cont.

Test No.	Type	Range	Conditions	Notes/Comments[a]
26	Fry Beef	Gas	Range Hood	Operated on high
27	Pork Roast	Gas	Range Hood	Operated on high
28	Fry Beef	Gas	Range Side Shields	Exhaust on high with side shields
29	Pork Roast	Gas	Range Side Shields	Exhaust on high with side shields
30A	Stovetop Stir Fry	Gas	Vegetable Oil	Compare oils
30B				Second event in the test
31A	Fry Beef	Gas	Pan Lid	Impact of pan lid
31B				Second event in the test
32A	Popcorn	Microwave	Standard	Two event test
32B				Second event in the test
33	Burner Baseline	Gas		Range top burner with pot of water only
34	Oven Baseline	Gas		No food in oven
35	Instrument Comparison	Gas		No food in oven
36	Instrument Comparison	Gas		No food in oven
37	Instrument Comparison	Gas		No food in oven
38	Oven Dirtying	Gas		Bake off food and oil used to dirty oven
38R	Oven Dirtying	Gas		Bake off food and oil used to dirty oven
39	Oven Dirtying	Electric		Bake off food and oil used to dirty oven

[a] See text for definition of "test," "event," and "batches."

Based on the limited available information, discussions with the ARB, and teleconferences with members of the TRG, the matrix of tests presented in Table 2-1 was developed. The types of cooking included frying of foods on the range top because of the continued widespread use of frying for food preparation and the expected high emissions. Stir-frying of chicken and vegetables and frying of tortillas were expected to be common in the ethnically diverse cuisine and population of California. One type of cooking involved frying of loose ground beef in a pan on the range top burner because this food item can be used in a wide variety of food dishes. Broiling of fish in the oven was selected because it is a relatively simple food preparation method and likely to be common in California. A fish with high oil content, Salmon, was selected for the broiling tests. The primary oven baking method involved cooking a large (2.5 lb) pre-packaged lasagna, representing another easy type of cooking. Selection of the pre-packaged lasagna also allowed comparison of the emissions from gas and electric ovens with those from the microwave. Similarly, bacon was selected for the tests because it is a popular food item, and a comparison could be made between the microwave cooking method and standard frying on the range top. In a limited number of tests, a pork roast was cooked in the gas oven, allowing comparison of emissions from the meat with emissions from the lasagna. French fries were prepared by frying in oil because of the popularity of the food item and anticipation of high emissions from the heated oil. Two different cooking oils, vegetable and peanut oil, were used in the tests for comparison of

emissions, particularly the PAH emissions. The oils were analyzed for PAH content prior to the main study.

The first 14 tests consisted of seven tests with the gas range for comparison to an identical set of seven tests with the electric range. Identical cooking protocols were used for the comparisons. Three tests were performed with the microwave. Two of the tests compared cooking of the same foods (bacon and lasagna) that were prepared with the gas and electric ranges. The other test was with a popular microwave food – popcorn. Three tests (Nos. 21, 22, and 23) were performed with the gas range as replicates of test numbers 2, 5, and 7, respectively.

The other tests were designed to evaluate factors that might impact emissions and indoor air concentrations during cooking. Tests 24 and 25 compared cooking with different pan materials. Test 24 was repeated as 24R because of a problem with the DAS during the first test. Tests 26 through 31 evaluated simple exposure reduction methods.

All tests involved preparation of a single food item, except test 20, which involved preparation of a full meal. All tests, except Test 20, were performed using either a range top burner or the oven, but not both at the same time. Each test, except Test 20, was performed for only a single type of cooking activity (e.g., broiling fish, stovetop stir-frying, baking a lasagna). In Test 20, preparation of the full meal involved cooking a number of different foods, using both the range top burners and the oven.

Also shown in the table are eight other tests that were performed. The gas range top burner was operated for one hour to obtain the baseline concentrations of combustion pollutants in Test 33. The oven was operated for two hours in Test 34 to obtain baseline concentrations. Tests 35, 36, and 37 were performed to evaluate sampling instrumentation in the kitchen. The last three tests listed (38, 38R, and 39) were not actually tests. For oven cleaning tests, the oven was first "dirtied" by applying a mixture of tomato puree and cherry pie filling to the bottom of the oven and cooking oil on the walls of the oven. After dirtying the oven, the oven was operated for a one-hour period at 350 °F to bake the material onto the surfaces in preparation for the test with the self-cleaning oven.

Tests 1 and 8 were performed to measure emissions during the self-cleaning cycles of the gas and electric ovens, respectively. Although oven cleaning is not performed frequently, the self-cleaning feature of both gas and electric ovens involves baking the surfaces at high temperatures (~450 °F). Therefore, this feature may result in high emissions from very dirty ovens. The Underwriters Laboratory (Underwriters Laboratory, 1993) has a method for dirtying an oven for measuring emissions of CO that involves application of 5-ounce of a beef gravy and vegetable oil shortening mixture. In January 2000, the Consumers Union reported a method for dirtying ovens during their performance tests of self-cleaning ovens (Consumers Reports, 2000). It involved a mixture of cherry pie filling, egg yolks, cheese, lard, tapioca, and tomato puree, but the quantities and test protocol could not be obtained in time for the tests. A modified protocol using five oz. of tomato puree, oil, and cherry pie filling was used in the first test, but the amount of material was too high, resulting in excessively high emissions. The amount was reduced to 3 oz. for tests 1R and 8. The protocol for dirtying the oven used a mixture of 28 g of tomato puree, 28 g of cherry pie filling, and 28 g of vegetable oil. The tomato puree and pie filling were wiped on the floor of the oven to

represent spills. The oil was wiped on the walls of the oven with a brush. After application, the oven was operated at 350 °F for one hour to bake the material onto the surface. The self-cleaning test was performed on the following day.

To the extent possible, cooking was performed following published recipes and routine cooking practices that would be performed in a residence. When available, as for the pre-packaged lasagna, the instructions on the package were followed. The cook, an ARCADIS chemist, was an experienced cook, but not a professional. He did much of the cooking in his own home and was considered to be representative of an "average" cook. By design, a professional cook was not used for the tests. During tests with the same food and cooking method, protocols were followed to insure that the food preparation methods, cooking methods, and cooking times were as consistent as possible to facilitate comparisons between tests.

As shown in Table 2-1, there were four types of cooking protocols implemented during the study:

1. Single event cooking tests with one batch of food - The simplest type of cooking protocol was a single event with a single batch of food cooked, as in Test Nos. 7 and 14 in which a single, large, pre-packaged frozen lasagna was baked in the oven. The cooking period was approximately two hours, and the post-exposure period was one hour, for a total exposure period of three hours.
2. Single event cooking tests during which two batches of food were prepared - In the second type of cooking protocol, there was a single event during which two batches of food were cooked sequentially. After all of the food was cooked, there was a one-hour post-cooking exposure period. This protocol was used in Test Nos. 5 and 12 during which a basket of French fries was cooked in oil, removed, and then a second batch was placed in the same oil to cook. It took approximately one hour to complete the cooking event, including the initial heating of the oil. After both batches of French fries were cooked, there was a one-hour post-cooking period, resulting in a total exposure period of approximately two hours.
3. Two event cooking tests - The third type of cooking protocol involved two cooking events separated by one hour. The protocol was used, for example, in Test Nos. 6 and 13. The test started by turning on the oven, then broiling a large salmon steak. At the end of the cooking period, the fish was removed and the oven was turned off. This cooking event, denoted as 6A in Table 2-1, was followed by a one-hour post-cooking period to simulate eating and clean-up. Then the oven was turned on again; a second salmon steak was broiled, and the oven was turned off. This cooking event was followed by another one-hour post-cooking period. The total duration of the test was 3.25 hours. The $PM_{2.5}$ and PM_{10} samples for gravimetric analysis were collected throughout the entire two-event cooking test. Continuous monitoring with the ELPI and other pollutant monitors provided concentration data over the entire test.
4. Exposure reduction tests consisted of replicate cooking experiments conducted with the addition of pan lid, range hood fan and side shields.

The need to perform these different protocols was demonstrated in the pre-test. During the pre-test, a single batch of loose ground beef was fried in a pan on the range-top burner. Due to the small amount of food cooked and the short duration of the test, there was insufficient $PM_{2.5}$ and PM_{10} mass on the filters for accurate gravimetric analysis. To increase the amount of mass collected, these protocols were implemented.

The durations of the cooking events are presented in Table 2-2. The table lists the start time for background measurements, the cooking times, and the duration of the cooking time and the total exposure period. The total exposure period represents the total duration of the test. The test durations ranged from 1 hour and 30 minutes (Test 2) to 5 hours and 8 minutes for oven cleaning (Test 1R). The cooking period started when the range top burner or the oven was turned on. The cooking period ended when the burner or oven was turned off. Therefore, cooking periods included the time required to pre-heat the oven, pan, or cooking oil. The total exposure period was the total period in which the cook or occupants would be exposed to emissions from the cooking. The total exposure period included the cooking period plus a one-hour post-cooking period during which the meal would be eaten and cleanup would be performed. The assumption was that the cook and occupants would be in the residence for at least one hour after cooking. For the first two types of cooking protocols, the total exposure period included one hour of post-cooking exposure. In two event tests, the third type of protocol, there were two hour-long post-cooking exposure periods. A single $PM_{2.5}$ and PM_{10} mass measurement was made for each test regardless of the number of batches of food cooked or the number of cooking events within the test. During two event tests, data collected with the continuous monitors (CO, NO, NO_2, and PM with the ELPI) are reported as Test XA and XB in the results tables. The two event tests facilitated additional replication of cooking events, as recommended by the TRG, for measurements of CO, NO, NO_2, and PM with the ELPI.

Multiple cooking tests were performed on many days during the main study. Because of the amount of time necessary for zero and span checks of the continuous monitors, ELPI, and gas chromatograph used for SF_6 measurements, as well as set up of the instrumentation, performance of multiple tests on a day improved efficiency.

In order to obtain sufficient sample mass for PM, PAHs, and elements, a single set of outdoor air samples was collected on each day of testing. If only a single test was performed, for example with a total exposure period duration of 4 hours, the outdoor sample was collected during the same 4-hr period. If three tests were performed over a 9-hr period during the day, the outdoor air sample was integrated over the entire nine hours. This protocol was used because the mass of PM collected during short cooking tests would be inadequate for accurate gravimetric analysis.

On days with multiple tests, the house was flushed with outdoor air between tests to exhaust the air pollutants generated during the test and to re-establish the indoor background pollutant concentrations to reasonable levels prior to the start of the next test. The flush out was accomplished with the central air handler fan operating in conjunction with window fans and open doors. Because of this protocol, data was collected during most tests for only one hour after the source was turned off.

Cooking protocols were developed that involved reasonable and representative cooking scenarios. The detailed cooking protocols are included in Appendix C of the report. Table 2-3 presents a brief description of the cooking protocols. To the extent possible, cooking was performed to be representative of typical residential cooking. All foods were purchased from local grocery stores in Rohnert Park. The foods to be used in multiple tests were purchased in large quantities and stored in the freezer to insure comparability between the tests. All pans, foods, and oils were weighed prior to, and following cooking, in order to determine the weight loss during the cooking event. Food weights are reported in Section 3.0. All cooking tests, except Test No. 20, involved cooking a single meal item. The stovetop stir-fry cooking protocol, for example, involved cooking both the vegetables and chicken for the dish, but involved use of only a single stovetop pan and burner. Most other cooking protocols involved a single food.

Table 2-2. Cooking Times and Test Durations

Test No.	Date	Test Type	Range Type	Cooking Event	Background Start Time	Cooking Start Time	Cooking End Time	Exposure End Time	Cooking Duration (Hr:Min)	Exposure Duration (Hr:Min)
1	2/3/00	Oven Cleaning	Gas	Total	12:44	12:54	16:54	18:24	4:00	5:30
1R	2/24/00	Oven Cleaning	Gas	Total	12:08	12:18	16:18	17:26	4:00	5:08
2	2/5/00	Stovetop Stir Fry	Gas	Total	13:59	14:09	14:30	15:39	0:21	1:30
3	2/5/00	Bacon	Gas	Total	9:08	10:08	11:57	13:06	0:42	2:58
3A	02/05/00	Bacon	Gas	1st event	9:08	10:08	10:30	11:36	0:22	1:28
3B	02/05/00	Bacon	Gas	2nd event	11:27	11:37	11:57	13:06	0:20	1:29
4	2/4/00	Tortillas	Gas	Total	10:31	10:41	11:26	12:38	0:45	1:57
5	2/4/00	French Fries	Gas	Total	13:31	13:41	14:49	16:13	1:08	2:32
6	2/6/00	Broil Fish	Gas	Total	10:54	11:04	12:55	14:05	0:44	3:01
6A	02/06/00	Broil Fish	Gas	1st event	10:54	11:04	11:28	12:34	0:24	1:30
6B	02/06/00	Broil Fish	Gas	2nd event	12:25	12:35	12:55	14:05	0:20	1:30
7	2/9/00	Bake Lasagna	Gas	Total	9:52	10:02	12:08	13:11	2:06	3:09
8	2/10/00	Oven Cleaning	Electric	Total	10:06	10:16	14:16	15:23	4:00	5:07
9	2/14/00	Stovetop Stir Fry	Electric	Total	14:02	14:12	14:33	15:44	0:21	1:32
10	2/11/00	Bacon	Electric	Total	15:06	15:23	17:14	18:25	0:51	3:02
10A	02/11/00	Bacon	Electric	1st event	15:06	15:23	15:46	16:45	0:23	1:22
10B	02/11/00	Bacon	Electric	2nd event	16:36	16:46	17:14	18:25	0:28	1:39
11	2/11/00	Tortillas	Electric	Total	9:52	10:02	10:45	11:54	0:43	1:52
12	2/11/00	French Fries	Electric	Total	12:47	12:57	13:22	14:35	0:25	1:38

Table 2-2. Cooking Times and Test Durations Cont.

Test No.	Date	Test Type	Range Type	Cooking Event	Background Start Time	Cooking Start Time	Cooking End Time	Exposure End Time	Cooking Duration (Hr:Min)	Exposure Duration (Hr:Min)
13	2/14/00	Broil Fish	Electric	Total	9:43	9:53	11:51	13:08	0:36	3:15
13A	02/14/00	Broil Fish	Electric	1st event	9:43	9:53	10:11	11:32	0:18	1:39
13B	02/14/00	Broil Fish	Electric	2nd event	11:23	11:33	11:51	13:08	0:18	1:35
14	2/13/00	Bake Lasagna	Electric	Total	15:26	15:36	17:37	18:58	2:01	3:22
15	2/8/00	Bacon	Microwave	Total	17:34	17:44	20:16	21:23	0:81	3:39
15A	02/08/00	Bacon	Microwave	1st event	17:34	17:44	18:28	19:38	0:44	1:54
15B	02/08/00	Bacon	Microwave	2nd event	19:29	19:39	20:16	21:23	0:37	1:44
16	2/8/00	Bake Lasagna	Microwave	Total	14:22	14:32	15:07	16:08	0:35	1:36
17	2/29/00	Stovetop Stir Fry	Gas	Total	14:50	15:00	16:56	18:38	0:51	3:38
17A	02/29/00	Stovetop Stir Fry	Gas	1st event	14:50	15:00	15:26	16:30	0:26	1:30
17B	02/29/00	Stovetop Stir Fry	Gas	2nd event	16:21	16:31	16:56	18:38	0:25	2:07
18	2/27/00	Bacon	Gas	Total	10:53	11:03	13:04	14:10	0:57	3:07
18A	02/27/00	Bacon	Gas	1st event	10:53	11:03	11:29	12:32	0:26	1:29
18B	02/27/00	Bacon	Gas	2nd event	12:23	12:33	13:04	14:10	0:31	1:37
19	2/27/00	Broil Fish	Gas	Total	18:45	18:55	20:49	21:57	0:50	3:02
19A	02/27/00	Broil Fish	Gas	1st event	18:45	18:55	19:20	20:23	0:25	1:28
19B	02/27/00	Broil Fish	Gas	2nd event	20:14	20:24	20:49	21:57	0:25	1:33
20	2/28/00	Full Meal	Gas	Total	8:38	8:48	11:08	15:53	2:20	7:05

Table 2-2. Cooking Times and Test Durations Cont.

Test No.	Date	Test Type	Range Type	Cooking Event	Background Start Time	Cooking Start Time	Cooking End Time	Exposure End Time	Cooking Duration (Hr:Min)	Exposure Duration (Hr:Min)
21	2/27/00	Stovetop Stir Fry	Gas	Total	15:02	15:12	16:51	18:00	0:39	2:48
21A	02/27/00	Stovetop Stir Fry	Gas	1st event	15:02	15:12	15:31	16:30	0:19	1:18
21B	02/27/00	Stovetop Stir Fry	Gas	2nd event	16:21	16:31	16:51	18:00	0:20	1:29
22	2/26/00	French Fries	Gas	Total	12:27	12:37	14:05	15:32	1:28	2:55
23	2/23/00	Bake Lasagna	Gas	Total	16:11	16:21	18:22	19:30	2:01	3:09
24	2/17/00	Fry Beef	Gas	Total	9:59	10:09	10:30	11:47	0:21	1:38
24R	2/25/00	Fry Beef	Gas	Total	10:20	10:30	12:13	13:25	0:42	2:55
24RA	2/25/00	Fry Beef	Gas	1st event	10:20	10:30	10:51	11:51	0:21	1:21
24RB	2/25/00	Fry Beef	Gas	2nd event	11:42	11:52	12:13	13:25	0:21	1:33
25	2/17/00	Pork Roast	Gas	Total	12:52	13:02	16:02	17:16	3:00	4:14
26	2/15/00	Fry Beef	Gas	Total	11:55	12:05	12:26	13:33	0:21	1:28
27	2/15/00	Pork Roast	Gas	Total	14:47	14:57	17:58	19:09	3:01	4:12
28	2/16/00	Fry Beef	Gas	Total	12:13	12:23	12:44	13:50	0:21	1:27
29	2/16/00	Pork Roast	Gas	Total	14:28	14:38	17:38	18:45	3:00	4:07
30	2/29/00	Stovetop Stir Fry	Gas	Total	10:32	10:42	12:17	13:29	0:35	2:47
30A	02/29/00	Stovetop Stir Fry	Gas	1st event	10:32	10:42	11:00	11:59	0:18	1:17
30B	02/29/00	Stovetop Stir Fry	Gas	2nd event	11:50	12:00	12:17	13:29	0:17	1:29
31	2/23/00	Fry Beef	Gas	Total	11:56	12:06	13:50	14:58	0:39	2:52
31A	02/23/00	Fry Beef	Gas	1st event	11:56	12:06	12:27	13:31	0:21	1:25

Table 2-2. Cooking Times and Test Durations Cont.

Test No.	Date	Test Type	Range Type	Cooking Event	Background Start Time	Cooking Start Time	Cooking End Time	Exposure End Time	Cooking Duration (Hr:Min)	Exposure Duration (Hr:Min)
31B	02/23/00	Fry Beef	Gas	2nd event	13:22	13:32	13:50	14:58	0:18	1:26
32	2/15/00	Popcorn	Microwave	Standard	20:05	20:15	21:18	22:19	0:08	2:04
32A	2/15/00	Popcorn	Microwave	1st batch	20:05	20:15	20:19	21:13	0:04	0:58
32B	2/15/00	Popcorn	Microwave	2nd batch	21:03	21:13	21:17	22:19	0:04	1:06
33	2/24/00	Range Baseline	Gas	Total	8:51	9:01	10:01	11:05	1:00	2:04
34	2/24/00	Oven Baseline	Gas	Total	18:15	18:25	20:25	21:33	2:00	3:08
35	2/28/00	Instrument Comparison	Gas	Total	17:25	17:35	18:05	18:49	0:30	1:14
36	2/28/00	Instrument Comparison	Gas	Total	19:20	19:30	20:01	20:58	0:31	1:28
37	2/29/00	Instrument Comparison	Gas	Total	--	18:38	19:41	--	1:03	1:03
38	2/2/00	Oven Dirtying	Gas	Total	20:23	20:33	22:03	23:04	1:30	2:31
38R	2/23/00	Oven Dirtying	Gas	Total	20:06	20:16	21:16	22:18	1:00	2:02
39	2/9/00	Oven Dirtying	Electric	Total	14:14	14:31	15:31	16:35	1:00	2:04

Table 2-3. Summary of the Cooking Protocols

Test Number	Summary Description of Cooking Protocols
1R	Oven Cleaning – Test was performed by running test 38R prior to this test. Oven lock was engaged and the oven was set to the clean setting. The oven was operated for 4 hours.
2, 9, 17, 21	Stovetop Stir Fry – Using a stovetop, 16 g of peanut oil was added and heated for one minute on high. Two batches of pre-packaged frozen vegetables were fried in peanut oil sequentially in two batches and removed. Boneless skinless chicken breasts cut into 2-inch pieces were fried in peanut oil sequentially in two batches, removed, and weighed. In total, 65 g of peanut oil was used.
3, 10, 18,	Bacon – Using the skillet, 6 to 8 pieces of sliced bacon were placed into the pan and cooked turning once. Cooked bacon was removed, and 6 to 8 pieces of bacon was added to pan and cooked in drippings from first batch. Cooking continued until the pound of bacon was cooked. Bacon was removed and served.
4, 11	Tortillas – Using the skillet, 1075 g of vegetable oil was added to the pan and heated for 10 minutes on medium high. Individual white corn flour tortillas were cooked in oil for 1 to 2 minutes each, until golden brown. A total of 24 tortillas were cooked.
5, 12, 22	French Fries – Using cast iron kettle with fryer basket, 3045 g of vegetable oil was added and heated on high until oil temperature reached 190 °C. The contents of one 2-lb bag of steak cut French fires were put into the basket and cooked for 9 minutes. After the first batch of French fries was cooked, a second bag of French fries was cooked.
6, 13, 19	Broil Fish – Using the Pyrex baking dish, one Atlantic salmon steak was placed in the center and brushed with 15 g of extra virgin olive oil. The broiler was heated for 5 minutes, and the steak was placed under the broiler. The steak was cooked for 5 minutes, then removed, turned over, and brushed with 15 g of oil. The steak was cooked for an additional 5 minutes, removed, and served.
7, 14	Bake Lasagna – Using the pan provided by the packaging, one frozen pre-packaged lasagna was removed from the freezer. The oven was turned on to 375 °F and pre-heated for 30 minutes. The lasagna was placed in the center of the oven and cooked for 1.5 hours, removed, and served.
15	Microwave Bacon – Using the Pyrex baking dish and paper towels, 6 strips of sliced bacon was placed on two paper towels in the dish and covered with 2 paper towels. The dish was placed in the microwave and cooked on the highest setting for 15 minutes. The bacon and towels were removed and the test repeated with 6 more strips of bacon.
16	Microwave Lasagna – Using the pan provided by the packaging, one frozen pre-packaged lasagna was removed from the freezer. The lasagna was placed in the center of the microwave and cooked on the highest setting for 30 minutes, turning 90 degrees every 10 minutes.
20	Full Meal – Consisted of baked potatoes, fried chicken, boiled vegetables, boiled broccoli, brown gravy, and rolls. Oven was pre-heated to 400 °F for 30 minutes. Potatoes were poked with knife and placed in Pyrex baking dish. The potatoes were cooked for 1 hour 50 minutes. Yellow squash was prepared by slicing the squash into ½ inch slices and adding one diced yellow onion to the 4-quart pot. Water was added to cover the vegetables. The squash and onions were covered and simmered for 50 minutes. Broccoli was prepared by cutting the florets from the stem, placing them in a 4-quart pot and covering with water. The broccoli was covered and simmered for 50 minutes. The fried chicken was prepared by covering the chicken pieces with a fryer breading mix and cooking in 3390 g of vegetable oil in the cast iron kettle with fryer basket. One half of the chicken was cooked at a time for 20 minutes. The gravy was prepared from a pre-packaged dehydrated brown gravy mix. One cup of water was added to a 4-quart pan and heated for one minute. The gravy mix was added and cooked while stirring for 1 minute. The biscuits were prepared by heating a package of frozen rolls for 23 minutes in the oven during the end of the potatoes cooking time. Food cooking was timed to have all of the food cooking end times within a few minutes of each other.
24, 26, 28, 31	Fry Beef – Using the skillet, ground beef was browned. The skillet was pre-heated for 1 minute; the ground beef was added to the pan and stirred for 1 minute. The ground beef was cooked for 20 minutes, stirring every 5 minutes.
25,27,29	Pork Roast – Using the Pyrex baking dish, the center cut pork roast was placed fat side up in the dish. The oven was pre-heated to 275 °F for 30 minutes, and the roast was placed in the center of the oven. The roast was cooked for 2.5 hours
30	Stovetop Stir Fry – Same as test 2 except used vegetable oil rather than peanut oil.
32	Microwave Popcorn – This test was performed by taking one bag of microwave popcorn and placing it in the center of the microwave oven. The oven was operated on maximum power for 4 minutes
33	Burner Background – Performed by boiling water for 1 hour in a 4-quart pot.
34	Oven Background – Performed by setting oven to bake at 375 deg F for 2 hours.
38R, 39	Oven Dirtying – These tests were performed by spreading a tomato puree and cherry pie filling mixture on the bottom of the oven and cooking oil was spread on the walls, top and bottom of the oven. A total of 90 grams of material was used to dirty the oven prior to oven cleaning. The oven was set to 350 °F for 1 hour to allow the material to bake on.

Note: No spices were used in these preparations.

2.4 Measurement Methods and Performance

2.4.1 Test House and Appliance Measurement Parameters

A laboratory was set up in the garage of the test house. Signal lines were routed from the DAS to temperature and relative humidity probes located in the rooms of the house and outdoors. Signal lines were also routed from the appliances (e.g. for thermocouples in the oven) to the DAS. Tubing for collection of air samples was routed from the garage laboratory to the rooms. Sampling and monitoring inlets were at a standing breathing height of approximately 1.5 m (60 inches). An enclosure was set up in the back yard for temperature and RH sensors.

The Test House was set up for continuous measurements of temperature and RH indoor and outdoors, continuous CO and NO_2 monitoring indoors and outdoors (described in a following section), and automated measurements of air exchange rates by the SF_6 tracer gas decay method. Automated sampling systems were used for collection of air samples from multiple locations. A DAS was used for recording data from the monitors.

The test house and appliance measurement parameters and instrumentation are summarized in Tables 2-4 and 2-5.

Temperature and RH were measured continuously in the kitchen, living room, and master bedroom. Probes consisting of resistance temperature detectors (RTDs) were used for temperature measurements. Thin-film capacitance sensors were used for RH. Temperature and RH were also measured outdoors at the location indicated on Figure 2-1. The outdoor probe was appropriately shielded.

Air exchange rates were measured using an automated SF_6 tracer gas decay method. The method was based on ASTM method E-741 (ASTM, 1999). The tracer gas was introduced into the house manually by releasing 50 mL of pure SF_6 throughout the house, with the volume introduced into each room weighed for the room volume. Dosing was performed approximately 30 minutes before the start of each test. Air was sampled sequentially from the kitchen, living room, master bedroom, and outdoors with an automated system to obtain an average air exchange rate for the house. Analysis was performed with a Hewlett Packard gas chromatograph (GC) with an electron capture detector (ECD). The GC was calibrated with SF_6 standards over a range of 0.5 to 100 ppb. Zero and span checks were performed prior to the start of each day of testing.

Temperatures were measured with thermocouples interfaced to the DAS. Temperatures measured during the tests included the temperature of the flame of the stovetop burner, oven flame temperature and oven compartment temperature, and temperature of cooking oils and/or temperature of foods (e.g., roasts). Placement of the probes in the foods and the flame was difficult to reproduce, making it difficult to compare temperatures between the tests. The volume of gas used in each cooking test was measured with a dry gas meter. The local natural gas supplier reported the BTU content of the gas as 1000 ± 20 Btu/ft^3. During tests with the electric stove, a similar set of temperatures was measured. Electric power was measured with a power transducer (lights and clocks were disabled). Temperature was not measured in the microwave.

Table 2-4. Test House Environmental Measurement Parameters and Instrumentation

Parameter	Instrument	Measurement Principle/Method	Measurement Range	Locations[a]
Temperature	HyCal HT-2W-C-D9-TT-B	Resistance Temperature Detector	-17 to 37.7 °C	K, LR, MBR, OA
Relative Humidity	HyCal HT-2W-C-D9-TT-B	Thin Film Capacitance	0-100 %	K, LR, MBR, OA
Air Exchange	Hewlett-Packard 5890	Tracer Gas (SF_6) Decay w/ GC/ECD	0-100 ppbv	K, LR, MBR, OA
Air Flow Rates	Shortridge ADM 860	Pitot tube	25-10,000 fpm	Air handler
Exhaust Air Flow Rates	Solomat MPM 500	Anemometer (hot wire or vane)	30 - 2500 fpm	Range hood
Data Acquisition				
LabTech Notebook for Win '95	DAS computer	12 bit A/D	Hardware dependent	Inputs from all locations
8-channel A/D board	CyberResearch CYDAS 8	8 channel, 12 bit A/D, 20 kHz	±5 V, 0-10 V	DAS
32-channel multiplexing panel	CyberResearch CYEXP 32	Voltage, current, or thermocouple	switchable gains	DAS
Dosing & Sample Acquisition				
SF_6 Dosing		Manual release of pure SF_6	Not applicable	All rooms with weighted release volumes
SF_6 Sampling System	ARCADIS-configured - poly-line, valves/manifold	Sequential sampling	Not applicable	K, LR, MBR, OA
NO_2/CO Sampling System	ARCADIS-configured - Teflon® line, valves/manifold	Sequential sampling	Not applicable	K, LR, MBR, OA

[a] Locations: Kitchen (K), Living Room (LR), Master Bedroom (MBR), Outdoor Air (OA)

Table 2-5. Appliance Measurement Parameters and Instrumentation

Parameter	Instrument	Measurement Principle/Method	Measurement Range	Locations
Cooking Oil or Food Temperature	K type thermocouple	emf, Seebeck Effect	-200 to 1250 °C	Range top
Flame Temperature	K type thermocouple	emf, Seebeck Effect	-200 to 1250 °C	Range-top burner
Food Temperature	K type thermocouple	EMF, Seebeck Effect	-200 to 1250 °C	Oven
Oven Temperature	K type thermocouple	EMF, Seebeck Effect	-200 to 1250 °C	Oven
Natural Gas Volume	Dry Gas Meter	Positive displacement		Gas range
Electrical Power	Power Transducer	Hall Effect		Electric range

2.4.2 Pollutant Measurement Parameters and Instrumentation

The pollutant sampling and analysis methods are summarized in Table 2-6 and described below. The performance of the measurement methods and instrumentation is summarized in Section 3.10 and highlighted below.

2.4.2.1 Carbon Monoxide (CO) Monitoring

CO was monitored with a Thermo Environmental Instruments Model 48 non-dispersive infrared (NDIR) monitor located in the garage laboratory. The monitor is a bench top sized instrument that is an approved Federal Reference Method (FRM) monitor for National Ambient Air Quality Standards (NAAQS) ambient air monitoring. The monitor was set up to sample from an automated sampling valve and manifold system to sequentially measure CO in air samples from the outdoors (OA), kitchen (K), living room (LR), and master bedroom (MBR). Teflon® sample collection tubes were plumbed from the garage laboratory to each sampling location in the house. To allow for sufficient instrument rise time, the sampling time for each location was 3.75 minutes, which resulted in four measurements at each location per hour. Data from the monitor were recorded with the DAS. Data were processed with a routine that averaged the monitor readings only for the last minute of the measurement cycle. The average during the minute period was saved to the DAS.

Certified gas standards in gas cylinders were used with a dilution system to perform weekly multi-point calibrations over a range from 0 to 20 ppm. Zero and span checks were performed at the start of each day of testing.

The CO monitor, being an FRM, was appropriate for measurements during this study. The detection limit of 0.1 ppm was adequate for the study. The performance of the instruments was excellent based on daily zero and span checks. The bias was less than 2.1 % for all 18 span checks. The relative standard deviation for the span checks performed with a 19.4 ppm standard was 1.0 %.

2.4.2.2 Nitric Oxide (NO) and Nitrogen Dioxide (NO_2) Monitoring

NO and NO_2 were measured with a Thermo Environmental Instruments Model 42 chemiluminescent monitor located in the garage. The instrument is also a FRM. The monitor was set up in the same manner as the CO monitor, with samples supplied to one instrument with the sampling system that alternated between locations. Teflon® sampling lines were used for transferring the sample to the instrument. The instrument was calibrated over a range of 0 to 1000 ppb with certified gas standards in gas cylinders and a dilution system. Zero and span checks were performed at the start of each day of testing. Measurements for NO may be truncated to 1000 ppb due to scale limitations during monitoring.

Table 2-6. Pollutant Measurement Parameters and Instrumentation

Parameter	Instrument	Measurement Principle/Method	Measurement Range	Minimum Detection Limits	Locations[a]
Gases - Continuous					
Carbon Monoxide - Area Monitor	Thermo-Environmental Instruments, Inc. Model 48	Non-dispersive Infra-red (NDIR)	1-20 ppm	0.1 ppm	K, LR, MBR, OA (Sequential)
Nitric Oxide (NO_x) - Area Monitor	Thermo-Environmental Instruments, Inc. Model 42	Chemiluminescence Detector	0-1,000 ppb	0.50 ppb	K, LR, MBR, OA (Sequential)
PM (Continuous) - Range from 0.03 μm to 10 μm)	Dekati Electrical Low Pressure Impactor	Multi-stage impactors with multi-channel electrometers	Size range dependent	0.56/cm^3 (6.5 μm) 381/cm^3 (0.047μm)	Kitchen
$PM_{2.5}$ (Integrated) - Personal	Personal Environmental Monitor (PEM)	Impactor/ Gravimetric	Not applicable	17 μg/m^3	Kitchen
$PM_{2.5}$ (Integrated) - Indoor rooms, outdoors	MS&T Sampler	Impactor/ Gravimetric	Not applicable	3 μg/m^3	LR, MBR, OA
PM_{10} (Integrated) - Personal	Personal Environmental Monitor (PEM)	Impactor/ Gravimetric	Not applicable	17 μg/m^3	Kitchen
PM_{10} (Integrated) - Indoor rooms, outdoors	MS&T Area Sampler	Impactor/ Gravimetric		3 μg/m^3	LR, MBR, OA
Polyaromatic Hydrocarbons (PAHs)	Low Flow SKC Pump	Quartz filter/GC/MS[b]	Not applicable	0.4 ng/m^3	K, OA
Elements (PM_{10})	Same as Particles, Integrated	Filter/XRF[c]	Not applicable	Element dependent	K, OA
Aldehydes	Low Flow SKC Pump	DNPH-Silica gel/HPLC[d]	Not applicable	0.5 μg/m^3	K, OA

[a] Locations: Kitchen (K), Living Room (LR), Master Bedroom (MBR), Outdoor Air (OA)
[b] Gas chromatography/mass spectrometry
[c] X-ray fluorescence
[d] High performance liquid chromatography

The chemiluminescent monitor, being a FRM, was appropriate for measurements during this study. The instrument was operated on the 0 – 1000 ppb range. The detection limit of 0.5 ppb was adequate for the study. The performance of the instrument used to measure the concentrations from the four locations was excellent based on daily zero and span checks. The bias measured with the 1000 ppb standard was less than 3% for NO and 8% for NO_2 for all span checks. The relative standard deviation for the span checks was 1.6 % for NO and 4.3% for NO_2.

2.4.2.3 Real-Time Particle Monitoring

Real-time measurements of particle concentrations were performed during the cooking tests using a Dekati Electrical Low Pressure Impactor (ELPI) that is distributed by TSI Particle Instrument Division (St. Paul, MN). The instrument was well suited for the project because it enables real time particle size distribution (particle counts) and concentration measurement ($\mu g/m^3$) in the size range from 30 nm up 10 μm. The instrument has been used in recent studies of PM emissions from commercial kitchen cooking appliances (Gerstler et al., 1998) and indoor sources such as candles and incense (Guo et al., 2000). The ELPI is based on combining electrical detection principle with low-pressure impactor size classification. The electric current carried by charged particles into each of the 12 impactor stages is measured in real-time by a multichannel electrometer. The mid-points of the size fractions measured are 0.04, 0.08, 0.13, 0.21, 0.32, 0.51, 0.81, 1.3, 2.0, 3.2, 5.2, and 8.4 μm.

The ELPI is a bench top size instrument that requires a large vacuum pump for operation. The exhaust of the ELPI vacuum pump was filtered through a high efficiency particulate air (HEPA) filter. The instrument and pump were placed on a cart so that the ELPI could be moved between the kitchen and outdoors. However, the instrument is not very portable. The ELPI was generally located in the kitchen at a location immediately adjacent to the inlets of the integrated PM samplers. The inlet was at the approximate cook breathing height at 3 feet from the front of the stove. To avoid additional air mixing in the kitchen, the ELPI exhaust was ducted in a plastic tube through a gap in the rear sliding door to the outdoors; the gap was filled with a foam strip. The instrument was moved onto the back deck of the house prior to each day's tests and at the end of the tests to perform short term outdoor air measurements. The only location measured indoors was in the kitchen. The instrument was calibrated by the manufacturer. No additional calibrations or performance checks could be performed with the instrument in the field. The instrument was zeroed at the start of each day of testing. The impactor stages were cleaned according to manufacturers instructions.

Data were collected as one-minute averages. Data were collected for at least ten minutes prior to the start of each test to measure the background in the kitchen.

Although there were few operational problems with the instrument, there were short periods during some tests when the electrometers did not appear to operate properly, despite routine cleaning and zeroing of the instrument. Most of the apparent electrometer problems occurred for the larger impactor stages. These problems may have been related to the nature of the aerosol (grease droplets) or due to the elevated moisture levels in the kitchen during cooking of some foods. There were few particles in the three largest size fractions, further reducing the accuracy of the measurements.

The ELPI manufacturer provides an internal algorithm for estimating the mass concentrations for each measurement channel. The mass was estimated using a density of 1.0 g/cm^3. Mass estimates were reasonable for smaller particles based on comparisons to the $PM_{2.5}$ gravimetric data. But the mass estimates for the three channels measuring the larger particles were generally in poor agreement with the PM_{10} gravimetric mass data and were frequently unrealistically high. This may have been due to the low number of large particles and poor counting statistics for these size fractions with a one-minute averaging time.

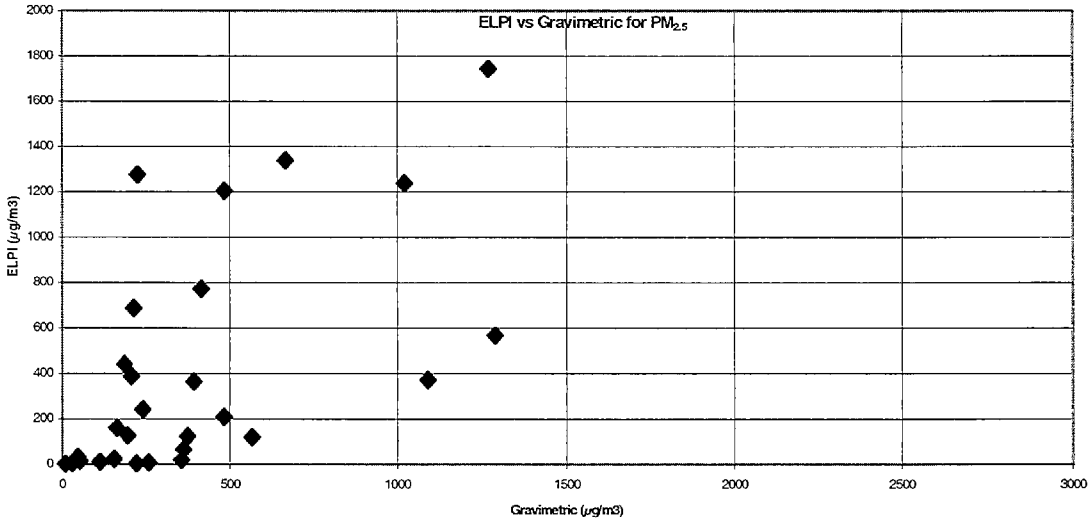
Guo et al. (2000) reported that mass estimated by the ELPI for the size fractions representing $PM_{2.5}$ could be related to $PM_{2.5}$ gravimetric mass measurements for tests measuring emissions from candles in the EPA Indoor Air Research House. They reported that the correlation could be determined empirically as:

$$\ln C_{grav} = 0.829 \ln C_{ELPI} - 0.475,$$

where C_{grav} is the gravimetric measurement and C_{ELPI} is the estimated $PM_{2.5}$ mass from the ELPI measurement. They reported an R^2 of 0.967 for N = 14.

An attempt was made to determine a relationship between ELPI and gravimetric measurements during the cooking tests in this study, but there was no correlation between the methods. During some tests, the ELPI concentrations were higher than gravimetric. But in other tests, the gravimetric concentrations were higher. The relationship between the gravimetric measurements and the ELPI mass estimates for particles in the $PM_{2.5}$ size fraction are depicted in Figure 2-4.

Figure 2-4. Relationship Between $PM_{2.5}$ Gravimetric Measurements and ELPI Measurements



2.4.2.4 Integrated Sampling for $PM_{2.5}$ and PM_{10}

Particle mass in the $PM_{2.5}$ and PM_{10} size fractions was collected with the personal environmental monitors (PEMs) previously used in PTEAM (Thomas et al, 1993) and the MS&T size selective impactor that has been used in the EPA Large Building Studies (EPA, 1994), the EPA Duct Cleaning Study (Fortmann et al, 1997) and other indoor air studies. Both sampling inlets have been described in the literature (Ozkaynak et al., 1996; Turner et al., 2000). The PEM is a small personal sampler that operates at either 4 or 10 L/min. The inlets of the 4 L/min version used in this study have 10 holes that direct the flow toward an oil-coated, sintered metal impactor ring. After impaction, the remaining particles are drawn to the membrane filter in the inlet base. The MS&T Area Sampler draws the air sample through an inlet and nozzle. After the air passes through the nozzle, sized for either $PM_{2.5}$ or PM_{10} cutpoints, the air impacts on an oiled sintered metal impactor plate. For both inlets, the samples were collected on tared Teflo® membrane filters.

$PM_{2.5}$ and PM_{10} were collected with the PEMs in the kitchen. The MS&T samplers were used in the LR, MBR, and outdoors where the concentrations were expected to be lower. The MS&T samplers operated at 20 L/min. Following sampling, filters were stored in a freezer at –10 °C. To minimize volatilization of PM, samples were transported to the lab in coolers using ice packs.

Particle mass was determined gravimetrically. Weighing was performed in a controlled environment weighing facility using a microbalance with a 1 μg resolution. Filters were conditioned in the facility for 48 hours prior to weighing, which was performed according to the protocol developed for the EPA Large Building Study (U.S. EPA, 1993). The method detection limit (MDL) for the ARCADIS weighing protocol with the microbalance in a controlled environment facility is 8 μg mass on the filter, which results in a MDL of 3 $\mu g/m^3$ for a 2-hour sample collected at 20 L/min.

2.4.2.5 PAH Sampling and Analysis Method

PAHs were collected in a subset of tests. Samples were collected outdoors and in the kitchen. The pre-test results indicated that the concentrations in the living room were not substantially different than the kitchen concentrations. The sample collection method involved collection with the PM_{10} size selective inlet containing a quartz filter for collection of particulate matter, followed by an in-line sampler (between the filter and pump) containing XAD-4/PUF. Samplers were operated at the required flow rate for the size cutpoint (4 L/min for the PEM in the kitchen and 20 L/min for the MS&T sampler outdoors). Following sampling, filters and sampling media were stored in a freezer at –10 °C. To minimize volatilization of material, samples were shipped to the lab in ice-packed coolers.

PAH analyses were performed by the Desert Research Institute (DRI) using a Gas Chromatography/Mass Spectrometry (GC/MS) method (Zielinska et al., 1998). Prior to extraction, the following deuterated internal standards were added to each filter-sorbent pair: naphthalene-d_8, acenaphthylene-d_8, phenanthrene-d_{10}, anthracene-d_{10}, chrysene-d_{12}, pyrene-d_{10}, benz[a]anthracene-d_{12}, benzo[a]pyrene-d_{12}, benzo[e]pyrene-d_{12}, benzo[k]fluoranthene-d-$_{12}$,

benzo[g,h,i]perylene-d_{12}, coronene - d_{12}, and 1-nitropyrene-d_{11}. The filter-XAD pairs were microwave extracted with dichloromethane. The extracts were then concentrated by rotary evaporation at 20 °C under gentle vacuum to ~1 ml and filtered through 0.45 mm Acrodiscs (Gelman Scientific), rinsing the sample flask twice with 1 ml CH_2Cl_2 each time. Approximately 100 µl of acetonitrile was added to the sample, and CH_2Cl_2 was evaporated under a gentle stream of nitrogen. The final volume was adjusted to 100 μl.

The samples were analyzed by the EI (electron impact) GC/MS technique. A Varian Star 3400CX GC equipped with an 8200CX Automatic Sampler and interfaced to a Varian Saturn 2000 Ion Trap was used for these analyses. Injections (1 μL) were made in the splitless mode onto a 30 m 5% phenylmethylsilicone fused-silica capillary column (DB-5ms, J&W Scientific). Quantification of the individual compounds was obtained by selective ion storage (SIS) technique, monitoring the molecular ion of each compound of interest and the corresponding deuterated internal standard, added prior to extraction.

Calibration curves for the GC/MS quantification were made for the most abundant and characteristic ion peaks of the PAH compounds using the deuterated species most closely matched in volatility and retention characteristics as internal standards. Authentic PAH standards (purchased from Aldrich, Inc.) plus National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 1647 (certified PAH) with the addition of deuterated internal standards were used to make calibration solutions.

A three-level calibration was performed for each compound of interest, and the calibration check (using median calibration standards) was run every ten samples to check for accuracy of analyses. If the relative accuracy of measurement (defined as a percentage difference from the standard value) was less than 20%, the instrument was recalibrated.

MDLs for the PAHs were estimated to range from 3 ng/m^3 for naphthalene to 6 ng/m^3 for coronene assuming a 1 L sample volume. Sample volumes in this study ranged from 0.75 to 1.9 m^3. The DRI laboratory does not include the MDL for each PAH in each sample, but calculates an uncertainty level for each compound in the sample. The uncertainty is calculated as follows:

1. Determine the replicate precision by comparing the same compound result (ng/sample) in replicate injections. The replicate precision is calculated as a fraction (difference/mean of the two values) and averaged over all replicates.
2. Then compute the root-mean-square of (A) the replicate precision from step 1 multiplied by the value for which the uncertainty is being determined, and (B) the analytical detection limit.

The effect of this calculation is that the uncertainty is equal to the MDL if the measured value is zero, and the uncertainty becomes increasingly small as the sample concentration gets very high. In this report, all concentrations are reported, but the values below the uncertainty level calculated by DRI are italicized.

2.4.2.6 Elemental Analyses

Elemental analyses were performed for particles collected in the PM_{10} fraction during a subset of tests. Samples were analyzed by Desert Research Institute with XRF using a Kevex Corporation Model 700/8000 energy dispersive x-ray fluorescence (EDXRF) analyzer. Analyses were performed following the DRI Standard Procedure No. 2-205.2. The method is the same as used in the previous ARB study of air pollutants inside California vehicles (Rodes et al., 1998). The estimated detection limits for a 2.4 m^3 volume sample (20 L/min for 120 minutes) are listed in Table 2-7. The MDL for samples collected with the PEMs would be five times higher. As was the case for PAHs, DRI no longer reports the MDL, but they report the uncertainty associated with each measurement instead. Therefore, all element concentrations are presented in this report, with concentrations below the uncertainty level presented in italics.

2.4.2.7 Aldehydes

Samples were collected during a limited number of tests for determination of selected aldehydes. Air samples were collected on silica gel cartridges coated with acidified 2,4-dinitrophenylhydrazine (DNPH). The method is described in the *EPA Compendium of Methods for the Determination of Air Pollutants in Indoor Air* (U.S. EPA, 1999). The commercially available cartridges (Waters Sep-Pak DNPH Silica Gel Cartridge, Waters Associates, Milford, PA) contain 2.9 grams of a 55 to 105 μm chromatographic-grade silica gel. Samples of 40 to 140 L volume were collected with a vacuum pump and mass flow controller at nominal sampling rates of 0.2 to 0.3L/min. The sampling volumes were well below the maximum volumes recommended in the EPA Compendium Method TO-11A (U.S. EPA, 1999). The sampling flow rates were measured at the start and end of each collection period.

Samples collected on DNPH-coated silica gel cartridge were extracted with 5 mL of acetonitrile (UV grade). Twenty-five μL of the extract was then analyzed with a HP 1090 HPLC equipped with a diode array detector. Chromatography was performed with a C-18 reverse phase column (Zorbax ODS, 4.6 x 250 mm) using a gradient program [0 - 10 min at 60 % acetonitrile (ACN) and 40% water, 10 - 20 min at 70% ACN and 30% water, 20-25 min at 100% ACN, and 25-41 min at 60 % ACN and 40% water].

Table 2-7. Minimum Detection Limits for Elements Analyzed by XRF

Element	ng/m^{3a}	Element	ng/m^{3a}
Al	44.8	Br	4.5
Si	28.2	Rb	4.5
P	25.1	Sr	4.9
S	22.4	Y	5.8
Cl	44.8	Zr	7.6
K	27.3	Mo	12.1
Ca	20.2	Pd	49.3
Ti	13.0	Ag	53.8
V	11.2	Cd	53.8
Cr	8.5	In	58.2
Mn	7.2	Sn	76.1
Fe	6.7	Sb	80.6
Co	3.9	Ba	232.9
Ni	4.0	La	277.7
Cu	4.9	Au	13.9
Zn	4.9	Hg	11.6
Ga	8.5	Tl	11.2
As	7.2	Pb	13.4
Se	5.4	U	10.3

[a] Based on a 2.4 m^3 sample volume on a 37 mm filter

The HPLC was calibrated for seven carbonyl compounds: formaldehyde, acetaldehyde, propanal, butanal, benzaldehyde, pentanal, and hexanal. The target compounds were identified by comparison of their chromatographic retention times with those of the derivatized standards. Quantification was performed using an external standard method with a five-point calibration based on peak area of derivatized standards. Standards were prepared at five concentration levels (between 0.04 and 1.50 ng/μL), and a calibration curve was generated by linear regression treatment of the concentration and chromatographic response data. Performance of the instrument was verified on each day of analysis by analysis of a calibration check sample prior to analysis of samples. The practical quantitation limit, which was based on the lowest calibration standard was 3.9 μg/m^3 for a nominal 45 L sample volume. The MDL was 0.5 μg/m^3 for a 40 L sample. None of the target compounds were detected in the field blanks.

2.5 Data Analysis and Emission Rate Calculation

2.5.1 Analysis Objectives and Analysis Plan

The major analysis objectives for the study are summarized in Table 2-8. Although there were 32 cooking tests performed in the main study, there was a minimal amount of replicate testing. The design of the study was such that it addressed many different variables to characterize the range of the resultant emission rates and exposures. Due to the limited number of replicates, the significance of differences between the tests is difficult to determine. It should be recognized

that the analysis of the data consists almost exclusively of preparation of the summary statistics and comparison of summary data from different tests or groups of tests. The data set was too small to perform more complicated analyses. Much of the discussion in Section 4.0 is descriptive.

2.5.2 Summary Statistics

The summary statistics presented in this report are the basic statistical techniques and include the calculation of averages, standard deviations, medians, minimums, and maximums.

For real-time data on CO and NO_2, the data were analyzed to obtain peak and average concentrations during the cooking period and the total exposure period (duration of cooking plus time period after termination of cooking, as specified in the cooking protocol).

Table 2-8. Data Analysis Objectives and Plan

Program Objective	Analysis Plan
Measure personal exposures and indoor concentrations for $PM_{2.5}$ and PM_{10} during cooking	Calculate average and variance of concentrations during cooking exposure period at all locations in the house
Measure personal exposures and indoor concentrations for CO and NO_2 during cooking	Compute peak, average, and standard deviation of concentrations of pollutants at all locations
Measure personal exposures and indoor concentrations for PM in size fractions from 0.1 to 10 μm	
Measure personal exposure and indoor concentrations of PAHs, elements, and aldehydes during cooking	Compute peak, average, standard deviation, and median concentrations during cooking and exposure periods
Compare personal exposures and indoor concentrations under typical and worst-case conditions during cooking	Determine differences between indoor concentrations and emission rates
Determine emission rates of PM, CO, and NO_2 produced by cooking under typical conditions	Calculate emission rates using mass balance model
Determine emission rates of PM, CO, and NO_2 produced by cooking under worst-case conditions	Calculate emission rates using mass balance model
Evaluate impact of appliance type (gas range, electric range, microwave) on pollutant emission rates	Determine differences in indoor concentrations and emission rates
Evaluate impact of the type of cooking method on pollutant emission rates	Determine differences in indoor concentrations and emission rates
Evaluate impact of food type on pollutant emission rates	Determine differences in indoor concentrations and emission rates
Evaluate impact of cooking utensil material (iron or aluminum) on pollutant emission rates	Determine differences in indoor concentrations and emission rates
Evaluate impact of exposure reduction methods on cook exposure and indoor concentrations	Determine differences in indoor concentrations and emission rates

2.5.3 Emission Rates

Although the primary objective of the study was to measure exposures to air contaminants due to cooking in the test house, the technical approach was developed such that emission rates and source strengths could be calculated using a dynamic mass balance model. Emission rates were calculated for $PM_{2.5}$ and PM_{10}, measured by the gravimetric method, CO, NO, and NO_2, and for selected size fractions measured with the ELPI. A dynamic mass balance model was used, as follows:

$$ER = \frac{V(a+k)T_e\left(C_i - \frac{fa}{a+k}C_o\right)}{T_c - \frac{1}{(k+a)}\left[\left(e^{(-(k+a)(T_e-T_c))}\right) - \left(e^{(-(k+a)T_e)}\right)\right]}$$

Where:

ER = emission rate (μg/hr)
V = house volume (m^3)
a = air exchange rate (hr^{-1})
k = pollutant deposition or decay rate (hr^{-1})
C_i = indoor kitchen concentration ($\mu g/m^3$)
f = penetration factor (unitless)
C_0 = outdoor concentration ($\mu g/m^3$)
T_e = total exposure time (hr)
T_c = total cooking time (hr)

Parameters in the model that were measured included C_i, C_0, air exchange rate, and house volume. The value f was set to one, assuming complete mixing in the house. The penetration factor was set to 1 for all parameters. The deposition rates were set equal to 0.0 hr^{-1} for CO and NO. A deposition rate of 0.8 hr^{-1} was used for NO_2, based on data collected previously for ARB model development (Koontz et al., 1998) and published data compiled by Traynor (1999) for the California Department of Health Services Indoor Air Quality Section.

The deposition velocity for $PM_{2.5}$ was set to 0.31 hr^{-1}. This rate was determined based on the differences in the decay rates of $PM_{2.5}$ mass concentrations measured with the ELPI data and SF_6 decay rates measured to calculate air exchange rates in 14 representative tests that covered a range of cooking activities. The rate was in reasonable agreement with the rate of 0.39 hr^{-1} reported by Wallace (1996) from PTEAM. The rate of 1.01 hr^{-1} reported by Wallace from PTEAM was used for the PM_{10} and elemental deposition rate because the ELPI data for the larger size fractions were inadequate to estimate the deposition rate during the cooking tests in this study. A deposition velocity of 1.01 hr^{-1} was also used for the elements analyzed in samples of PM_{10}.

Data on deposition velocity for PAHs, aldehydes, and elements were not available. A deposition velocity of 0.0 was used for calculating the emission rates of PAHs, consistent with that used by Sheldon et al. (1992) in a previous ARB project. Due to the lack of data, a deposition velocity of 0.0 was also used for aldehydes.

Source strengths were calculated as μg of pollutant emitted per g of food cooked and per unit of energy (μg/BTU). Emission rates were also calculated as μg of pollutant emitted per g of food per hour (μg/g/h).

Some mass balance model calculations resulted in negative values because the outdoor concentration was higher than in the kitchen. The primary cause of this was environmental effects. For example - outdoor samples were integrated over a full day's operation while indoor samples were taken only during each cooking test. The outdoor sample tended to be more accurate because the longer sampling period provided a larger sample, while the shorter period indoor samples yielded smaller catches or values closer to the method detection or quantification limits. In addition, for some constituents, there was no measurable difference between outdoor and indoor samples because the indoor cooking emissions were balanced by the effects of multiple traffic rush hours, woodstove heating cycles, surrounding residential cooking, etc. on the day-long, average ambient pollutant levels. A related experimental error occurred when very low measured concentrations were reduced to zero or negative values when corrected for media blank data. Because it is a possibility that outdoor concentrations would exceed indoor concentrations of these pollutants, all resulting negative values are entered into the data tables as flagged zeros.

Peak concentrations for the gaseous emissions were computed using the peak kitchen concentrations and peak outdoor concentrations. This may have resulted in an underestimation of the peak concentrations due to a peak outdoor concentrations possibly not occurring at the same time as the indoor peak concentration. This is seen in only a few cases for CO and NO.

3.0 RESULTS

Data are presented in this section that summarize the results of the project. Summary data, including averages, standard deviations, medians, maximum, and minimum concentrations are reported for all parameters. The averages and medians are provided as reference values and are useful for comparing the emissions and resultant exposures for the different tests. However, it should be noted that the 32 tests do not represent a statistical sample of different types of cooking. The 32 tests include replicates and tests performed with the same foods or cooking methods but with different pans or oils. The 32 tests also include tests of simple exposure reduction methods. The averages, standard deviations, and medians should not be interpreted as representative for cooking in this test house or any other house.

Results from the pre-test were reported previously and are included in a complete database, which will be submitted to the ARB in electronic format.

This section contains limited discussion of the data. The results are further summarized and discussed in Section 4.0.

3.1 Test Descriptions

A total of 32 cooking tests were performed during the study. The tests are summarized in Table 3-1. In addition to the 32 cooking tests, eight other tests were performed. These eight additional tests included baseline measurements of CO, NO, and NO_2 concentrations during operation of the gas range burner (Test 33) and oven (Test 34) and evaluation of the impact of the URG sampling pumps in the kitchen on pollutant measurements (Tests 35, 36, and 37). Results are also presented for three test periods when the oven was operated at 350 °F following application of the oven-dirtying foods (Tests 38, 38R, and 39). The results from tests 33 through 39 were not included in the calculation of the summary statistics because these were not cooking tests.

As discussed in Section 2.0 and shown in Table 3-1, both the types of cooking and the foods varied. Some foods were cooked in pans on the range top burner, including bacon, tortillas, and stovetop stir frying. French fries were prepared in oil in a pan on the range top. The oven was used to broil fish and bake lasagna. Most of the cooking involved some type of frying or use of cooking oil. None of the foods in this study was prepared by boiling in water or by steaming, except during Test 20 when a full meal was prepared. The mass of food at the start of the cooking event is listed in the table. The mass includes the cooking oil if required for the food preparation. The final column presents the mass lost during the cooking event. This will include both particulate matter and vapor-phase emissions, including water from the foods. The mass lost during the cooking events ranged from 10 g during preparation of popcorn in the microwave to 1830 g during preparation of the full meal.

Cooking oils were used during preparation of a number of the foods. The type of cooking oil used is also listed in Table 3-1. Peanut oil, vegetable oil, and olive oil were used in the cooking activities. Prior to the tests, the oils were extracted and analyzed to determine the PAH concentrations. Results of the analyses of the bulk oils are presented in Table 3-2. PAHs were

detected in all five oils tested. The PAH concentrations were generally higher in the olive and peanut oils than in the canola, corn, or vegetable oils. Twenty-one of the 22 PAHs targeted for quantitation were measured in the olive oil. But, the peanut oil had higher concentrations of most of the PAHs. The peanut oil was used for stovetop stir-frying. The PAH emissions during the stir-fry cooking with peanut oil were compared to stir-fry cooking using vegetable oil in Test 30.

Table 3-1. Summary of the Cooking Tests

Test No.	Range Type	Test	Food Description/Notes	Starting Food Mass (g)	Mass Loss (g)
1	Gas	Oven Cleaning	Test aborted due to oven problem	--	--
1R	Gas	Oven Cleaning	Self-cleaning feature	90	90
2	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil	1015	135
3	Gas	Bacon	Extra lean bacon – Total	975	290
3A	Gas	Bacon	Extra lean bacon – First event	495	145
3B	Gas	Bacon	Extra lean bacon – Second event	480	145
4	Gas	Tortillas	White corn tortillas fried in vegetable oil	1840	295
5	Gas	French Fries	Steak cut French fries in 1 gal of vegetable oil	4870	695
6	Gas	Broil Fish	Atlantic salmon steaks with olive oil – Total	1040	155
6A	Gas	Broil Fish	Atlantic salmon steaks with olive oil – 1st event	525	70
6B	Gas	Broil Fish	Atlantic salmon steaks with olive oil – 2nd event	515	85
7	Gas	Bake Lasagna	Frozen lasagna with meat sauce	1165	45
8	Electric	Oven Cleaning	Self-cleaning feature	90	90
9	Electric	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil	1060	195
10	Electric	Bacon	Extra lean bacon – Total	890	385
10A	Electric	Bacon	Extra lean bacon – First event	435	170
10B	Electric	Bacon	Extra lean bacon – Second event	455	215
11	Electric	Tortillas	White corn tortillas fried in vegetable oil	1905	380
12	Electric	French Fries	Steak cut French fries in 1 gal of vegetable oil	4875	1120
13	Electric	Broil Fish	Atlantic salmon steaks with olive oil – Total	835	90
13A	Electric	Broil Fish	Atlantic salmon steaks with olive oil – 1st event	420	45
13B	Electric	Broil Fish	Atlantic salmon steaks with olive oil – 2nd event	445	45
14	Electric	Lasagna	Frozen lasagna with meat sauce	1170	145
15	Microwave	Bacon	Extra lean bacon – Total	940	470
15A	Microwave	Bacon	Extra lean bacon – First event	535	265
15B	Microwave	Bacon	Extra lean bacon – Second event	405	205
16	Microwave	Lasagna	Frozen lasagna with meat sauce	1160	165
17	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – Total	1805	555
17A	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 1st event	905	290

Table 3-1. Summary of the Cooking Tests Cont.

Test No.	Range Type	Test	Food Description/Notes	Starting Food Mass (g)	Mass Loss (g)
17B	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 2nd event	900	265
18	Gas	Bacon	Extra lean bacon – Total	910	390
18A	Gas	Bacon	Extra lean bacon – First event	445	190
18B	Gas	Bacon	Extra lean bacon – Second event	465	200
19	Gas	Broil Fish	Atlantic salmon steaks with olive oil – Total	810	180
19A	Gas	Broil Fish	Atlantic salmon steaks with olive oil – 1st event	390	70
19B	Gas	Broil Fish	Atlantic salmon steaks with olive oil – 2nd event	420	110
20	Gas	Full Meal	Fried chicken, yellow squash, broccoli, gravy	13145	1830
21	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – Total	1800	370
21A	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 1st event	885	175
21B	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 2nd event	915	195
22	Gas	French Fries	Steak cut French fries in 1 gal of vegetable oil	5215	795
23	Gas	Bake Lasagna	Frozen lasagna with meat sauce	1170	200
24	Gas	Fry Beef	Less than 30% fat ground beef, browned	915	175
24R	Gas	Fry Beef	Less than 30% fat ground beef, browned	910	190
25	Gas	Pork Roast	Roasted center cut pork loin rib roast	1920	195
26	Gas	Fry Beef	Less than 30% fat ground beef, browned	905	225
27	Gas	Pork Roast	Roasted center cut pork loin rib roast	1960	305
28	Gas	Fry Beef	Less than 30% fat ground beef, browned	915	140
29	Gas	Pork Roast	Roasted center cut pork loin rib roast	2405	140
30	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – Total	1795	310
30A	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 1st event	885	150
30B	Gas	Stovetop Stir Fry	Chicken, frozen vegetables, peanut oil – 2nd event	910	160
31	Gas	Fry Beef	Less than 30% fat ground beef, browned – Total	1820	210
31A	Gas	Fry Beef	Less than 30% fat ground beef, browned – 1st event	910	120
31B	Gas	Fry Beef	Less than 30% fat ground beef, browned – 2nd event	910	90
32	Microwave	Popcorn	Movie theatre butter flavor popcorn – Total	220	20
32A	Microwave	Popcorn	Movie theatre butter flavor popcorn – 1st event	110	10
32B	Microwave	Popcorn	Movie theatre butter flavor popcorn – 2nd event	110	10
33	Gas	Range Baseline (with pan of water)		0	
34	Gas	Oven Baseline		0	

Table 3-2. Concentrations (ηg/g) of PAHs in Cooking Oils[a]

Compound	Olive	Peanut	Canola	Corn	Vegetable
Acenaphtylene	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]
Acenaphthene	19.88	ND[b]	ND[b]	ND[b]	ND[b]
Phenanthrene [c,m]	10.67	ND[b]	ND[b]	0.72	ND[b]
Anthracene [c,m]	1.12	2.60	1.12	1.54	0.56
Fluoranthene [m,t]	4.07	1.28	0.71	0.65	1.64
Pyrene [c,m]	7.10	10.23	1.79	ND[b]	ND[b]
Benz(a)anthracene [c,m]	4.49	13.57	6.51	ND[b]	2.22
Chrysene [c]	3.29	14.73	ND[b]	ND[b]	2.22
Benzo(b+j+k)fluoranthene	77.33	72.82	ND[b]	4.68	5.28
Benzo(e)pyrene [c,m]	0.26	19.44	ND[b]	2.70	3.66
Benzo(a)pyrene) [c,m]	8.32	24.48	ND[b]	10.96	4.22
Indeno[1,2,3-cd]pyrene [c]	16.25	30.34	2.67	2.03	9.84
Benzo(g,h,i)perylene	5.31	26.58	18.72	3.20	8.40
Fluorene	1.73	ND[b]	0.21	0.28	0.30
1-methylphenanthrene	4.25	0.74	3.56	3.59	4.38
Perylene	1.50	15.53	ND[b]	1.90	3.06
Dibenzo(ah+ac)anthracene	9.26	27.10	ND[b]	0.59	9.20
Naphthalene	31.70	13.93	15.53	13.29	17.58
1-methylnaphthalene	10.11	ND[b]	ND[b]	ND[b]	0.66
Biphenyl	2.99	0.12	0.72	0.26	ND[b]
2,6+2,7-dimethylnaphthalene	8.63	ND[b]	ND[b]	ND[b]	ND[b]
2,3,5+1-trimethylnaphthalene	4.63	0.16	0.63	ND[b]	0.32

[a] Data are corrected for the analytical blank
[b] ND: Not detected at a concentration higher than the analytical blank
[c] Designated as a carcinogen or probable carcinogen
[m] Designated as a mutagen
[t] Designated as a teratogen

Designations from: U.S. Environmental Protection Agency (USEPA), 1989a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume I, Part A. Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December.

PAH concentrations in bulk cooking oils have not been reported previously. Benzo(a)pyrene and dibenzo(a,h)anthracene have been reported previously in fumes from refined vegetable, soybean, and vegetable oil (Shuguang et al., 1994), but the concentrations in the oil were not reported. Wu et al. (1998) also reported PAHs in fumes from cooking oils, but did not determine the concentration of the PAHs in the oils.

During each test, cooking temperatures were recorded on a continuous basis. Depending on the type of cooking activity, temperatures measured included the temperature of the food, the oven temperature, and the flame temperature (oven or range top burner). The average

temperatures during each cooking event are listed in Table 3-3 for the oven and burner. The maximum temperature is listed for the food. There was difficulty placing the thermocouple into the burner flame at exactly the same location, making it difficult to compare flame temperatures between tests. It was also difficult to place the thermocouple into the meat and fish at the start of the test. The thermocouple could not be inserted into the Salmon steaks used for the broiling tests. The temperature data should be used to evaluate relative differences between tests, rather than absolute differences.

Although it was difficult to accurately measure the temperatures in the food or the range-top burner flame temperature due to the difficultly of achieving a consistent probe placement relative to the flame, the oven temperature measurements were more repeatable. During the two replicate tests (Nos. 7 and 23) that involved baking of lasagna in the gas oven, the average oven temperatures were 190 and 198 °C and the oven burner flame temperatures averaged 225 and 243°C during the 2-hr cooking events. During two tests (Nos. 27 and 29) in which a pork roast was cooked in the oven, the average oven temperatures were 153 and 146 °C and oven burner flame temperatures were 180 and 176 °C. For both types of cooking, the variation between cooking temperatures was small. As shown in Table 3-3, similar repeatability could not be obtained for the range-top burner flame temperatures during replicate tests.

The gas or electric use during the cooking test was recorded with either a dry gas meter or a wattmeter. Results of these measurements are also included in Table 3-3. Values for gas use are based on heating content of 1000 btu/ft^3 of gas. The local gas company reported that the gas supplied to the test house was 1000 ± 20 btu/ft^3.

Table 3-3. Cooking Temperatures and Energy Use during Cooking Tests

Test No.	Type	Range	Conditions	Temperature (°C)[a]				Cooking		
				Food	Oven	Oven Flame	Burner Flame	Total Event Energy Use	Energy Rate	
								BTU	BTU/h	kJ/h
1R	Oven Cleaning	Gas	Standard	NA[e]	434	481	--	55667	13917	14683
2	Stovetop Stir Fry	Gas	Standard	79.6	--	--	85[b]	5594	7991	8431
3A	Bacon	Gas	Standard	148	--	--	108[b]	2133	5817	6138
3B	Bacon	Gas	Standard	156	--	--	105[b]	1949	5848	6170
4	Tortillas	Gas	Standard	172[d]	--	--	97[b]	4704	6272	6617
5	French Fries	Gas	Standard	182[d]	--	--	729	8740	7712	8137
6A	Broil Fish	Gas	Standard	NM[e]	112	18	--	3673	9182	9687
6B	Broil Fish	Gas	Standard	NM[e]	112	25	--	3553	10658	11245
7	Bake Lasagna	Gas	Standard	47.4	190	225	--	10181	4848	5115
8	Oven Cleaning	Electric	Standard	NA	450	466	--	28756	7189	7585
9	Stovetop Stir Fry	Electric	Standard	105	--	--	289	2956	8445	8910
10A	Bacon	Electric	Standard	73.7	--	--	272	684	1784	1883
10B	Bacon	Electric	Standard	72.8	--	--	298	700	1501	1584
11	Tortillas	Electric	Standard	232.9[d]	--	--	No data[f]	5489	7659	8081
12	French Fries	Electric	Standard	171.4[d]	--	--	446	4392	10540	11120
13A	Broil Fish	Electric	Standard	NM[e]	189	83	--	3662	12206	12878
13B	Broil Fish	Electric	Standard	NM[e]	187	110	--	1889	6295	6642
14	Lasagna	Electric	Standard	107.9	178	182	--	6629	3287	3468
15A	Bacon	Microwave	Standard	NA	--	--	--	3753	5118	5400
15B	Bacon	Microwave	Standard	NA	--	--	--	3156	5118	5400
16	Lasagna	Microwave	Standard	NA	--	--	--	2986	5118	5400
17A	Stovetop Stir Fry	Gas	Worst Case	124	--	--	398	3489	8052	2360
17B	Stovetop Stir Fry	Gas	Worst Case	119	--	--	284	3394	8145	2387
18A	Bacon	Gas	Worst Case	184.1	--	--	268	2642	6096	1787
18B	Bacon	Gas	Worst Case	143.6	--	--	337	2613	5058	1482
19A	Broil Fish	Gas	Worst Case	NM[e]	168	24	--	4393	10544	3090
19B	Broil Fish	Gas	Worst Case	NM[e]	188	34	--	4365	10476	3070
20	Full Meal	Gas	Standard	192[d]	207	258	351	33309	14275	4184
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	88.3	--	--	418	2490	7862	2304
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	100	--	--	439	2808	8423	2468
22	French Fries	Gas	Test 5 Replicate	186.9[d]	--	--	277	11181	7623	2234
23	Bake Lasagna	Gas	Test 7 Replicate	112.3	198	243	--	10796	5353	1569
24	Fry Beef	Gas	Cast Iron Pan	95.3	--	--	No data[f]	1561	4460	1307
24RA	Fry Beef	Gas	Cast Iron Pan	93.7	--	--	270	1727	4934	1446

Test No.	Type	Range	Conditions	Temperature (°C)[a]				Cooking		
				Food	Oven	Oven Flame	Burner Flame	Total Event Energy Use	Energy Rate	
								BTU	BTU/h	kJ/h
24RB	Fry Beef	Gas	Cast Iron Pan	93.0	--	--	304	1293	3693	1082
25	Pork Roast	Gas	Aluminum Pan	77.3	--	--	No data[f]	10199	3400	996
26	Fry Beef	Gas	Exhaust Ventilation	94.7	--	--	264	1935	5529	1620
27	Pork Roast	Gas	Exhaust Ventilation	81.8	153	180	--	11001	3647	1069
28	Fry Beef	Gas	Range Hood Shields	81.7	--	--	237	1420	4056	1189
29	Pork Roast	Gas	Range Hood Shields	74.0	146	176	--	11039	3680	1078
30A	Stovetop Stir Fry	Gas	Vegetable Oil	104	--	--	513	2363	7875	2308
30B	Stovetop Stir Fry	Gas	Vegetable Oil	95.3	--	--	295	2207	7790	2283
31A	Fry Beef	Gas	Pan Lid	NM[g]	--	--	300	1289	3683	1079
31B	Fry Beef	Gas	Pan Lid	NM[g]	--	--	253	1165	3885	1138
32A	Popcorn	Microwave	Standard	NM[e]	--	--	--	341	5118	5400
32B	Popcorn	Microwave	Standard	NM[e]	--	--	--	341	5118	5400
33	Burner Baseline	Gas		NA	--	--	260	7787	7787	2282
34	Oven Baseline	Gas		NA	187	210	--	9567	4783	1402
N for Tests 1 through 32				37	14	14	26	46	46	46
Minimum				17	112	18	0	341	1501	996
Maximum				178	450	481	729	55667	14275	14683

[a] Peak temperature of the food during the test; average temperature for burner or oven during the test
[b] Thermocouple probe location for this test was inconsistent with later tests yielding variable flame temperatures, but other parameters indicate similar cooking temperatures
[c] Not applicable
[d] Temperature of cooking oil
[e] Not measured due to difficulty of inserting thermocouple into the uncooked food at the start of the test
[f] No data due to problem with the data acquisition system
[g] Not measured because of pan lid

3.2 $PM_{2.5}$ and PM_{10} Integrated Mass Measurements

$PM_{2.5}$ and PM_{10} mass was collected on Teflon® filters using size selective impactors to achieve the desired size cut-point. Mass was determined gravimetrically. Samples were collected in the kitchen, living room, master bedroom, and outdoors. Indoor samples were collected during the duration of the total exposure period of the test, as described in Section 2.0. Outdoor air samples were collected during the duration of testing on each day. If more than one test was conducted on a day, the integrated samples were collected over the total duration of all tests on that day. This protocol was followed to increase the amount of mass on the filters to improve the accuracy and precision of the gravimetric analysis. Results of the mass measurements are presented in Tables 3-4 and 3-5. Concentrations of $PM_{2.5}$ ranged from approximately 1 to 14 $\mu g/m^3$ outdoors. Indoor concentrations during the 31 tests with PM mass measurements ranged from 9 to 2660 $\mu g/m^3$ in the kitchen, 4.5 to 3880 $\mu g/m^3$ in the LR, and 2.9 to 2820 $\mu g/m^3$ in the MBR. The highest concentrations were during oven cleaning. PM_{10} concentrations outdoors ranged from none detectable to 19.3 $\mu g/m^3$. The indoor concentrations ranged from below the detection limit (3 $\mu g/m^3$) to 3660 $\mu g/m^3$ in the three rooms where samples were collected. The results of the PM mass measurements are discussed in Section 4.0.

3.3 Particle Concentrations and Size Distributions Measured with the ELPI

Measurements were performed continuously with the ELPI during cooking tests. One-minute averages were recorded for the data in 12 channels with size cutpoints of 0.04 to 8.38 μm geometric particle diameter. The average concentrations were calculated for the cooking period only and during the total exposure period. The results plus summary statistics for the 32 cooking tests are presented for the particle concentrations (Tables 3-6 and 3-7), dN/dlog(Dp) mode (Tables 3-8 and 3-9), and the estimated mass concentrations using the ELPI algorithm and a particle specific gravity of 1.0 g/ml (Tables 3-10 and 3-11). Results of background measurements before and after the tests are presented in Table 3-12. The background measurements were recorded for a minimum of ten minutes prior to the start of each test to measure the background PM levels in the kitchen. At the end of each day of testing, measurements were also made outdoors with the ELPI.

A strong correlation was not found between the PM mass concentrations measured with the ELPI and the mass measurements should only be used for comparison with gravimetric measurements. By comparing gravimetric outdoor data from Table 3-4 and ELPI background data from Table 3-12, it was found that concentration data was similar but not directly correlated. Therefore, the ELPI measurements should only be used as a comparison with gravimetric methods. PM_{10} measurements with the ELPI are reported in Table 3-12, but it can be seen that the measurements are not useful for documenting background concentrations. Due to the low particle counts in the channels for the three largest size fractions of particles, results for the large size fraction do not appear to be reasonable in most cases when compared to the results for the gravimetric samples.

Table 3-4. $PM_{2.5}$ Mass Concentrations ($\mu g/m^3$) during Cooking Tests

Test No.	Type	Range	Condition	K	LR	MBR	OUT
1R	Oven Cleaning	Gas	Standard	2032	3879	2818	3.8
2	Stovetop Stir Fry	Gas	Standard	241	191	185	7.0
3	Bacon	Gas	Standard	482	142	286	7.0
4	Tortillas	Gas	Standard	566	260	77.4	4.2
5	French Fries	Gas	Standard	195	71.9	83.3	4.2
6	Broil Fish	Gas	Standard	698	NA	673	7.0
7	Bake Lasagna	Gas	Standard	1090	139	48.7	4.9
8	Oven Cleaning	Electric	Standard	1020	577	106	13.6
9	Stovetop Stir Fry	Electric	Standard	214	1124	364	5.6
10	Bacon	Electric	Standard	207	276	235	5.7
11	Tortillas	Electric	Standard	1269	1175	1173	5.7
12	French Fries	Electric	Standard	374	94.7	90.2	5.7
13	Broil Fish	Electric	Standard	415	505	504	5.6
14	Lasagna	Electric	Standard	112	23.8	13.1	5.6
15	Bacon	Microwave	Standard	ELPI Only		--	--
16	Lasagna	Microwave	Standard	ELPI Only		--	--
17	Stovetop Stir Fry	Gas	Worst Case	1289	850	798	8.1
18	Bacon	Gas	Worst Case	484	711	771	8.8
19	Broil Fish	Gas	Worst Case	225	734	727	8.8
20	Full Meal	Gas	Standard	666	739	772	5.2
21	Stovetop Stir Fry	Gas	Test 2 Replicate	185	323	301	8.8
22	French Fries	Gas	Test 5 Replicate	162	91.9	70.5	4.1
23	Bake Lasagna	Gas	Test 7 Replicate	362	44.6	45.9	4.0
24	Fry Beef	Gas	Cast Iron Pan	51.9	8.6	8.8	3.6
24R	Fry Beef	Gas	Cast Iron Pan	153	7.73	8.64	1.5[a]
25	Pork Roast	Gas	Aluminum Pan	46.4	11.4	11.6	3.6
26	Fry Beef	Gas	Exhaust Ventilation	258	9.8	7.7	6.3
27	Pork Roast	Gas	Exhaust Ventilation	8.96	54.3	8.24	6.3
28	Fry Beef	Gas	Range Hood Shields	29.9	5.7	3.8	3.0
29	Pork Roast	Gas	Range Hood Shields	222	4.5	1.5[a]	3.0
30	Stovetop Stir Fry	Gas	Vegetable Oil	392	294	303	8.1
31	Fry Beef	Gas	Pan Lid	355	5.8	6.4	4.0
32	Popcorn	Microwave	Standard	ELPI Only		--	--
			N	30	29	29	29
			Minimum	9.0	4.5	1.5	1.5
			Maximum	2032	3879	2818	13.6

[a] – Below detectable limits. Value taken at ½ MDL.

Table 3-5. PM_{10} Mass Concentrations ($\mu g/m^3$) during Cooking Tests

Test No.	Type	Range	Conditions	K	LR	MBR	OUT
1R	Oven Cleaning	Gas	Standard	3661	2667	2159	10.4
2	Stovetop Stir Fry	Gas	Standard	269	469	385	9.7
3	Bacon	Gas	Standard	261	180	162	9.7
4	Tortillas	Gas	Standard	242	130	112	13.5
5	French Fries	Gas	Standard	342	147	114	13.5
6	Broil Fish	Gas	Standard	451	711	816	NA
7	Bake Lasagna	Gas	Standard	185	253	413	6.7
8	Oven Cleaning	Electric	Standard	395	634	957	9.30
9	Stovetop Stir Fry	Electric	Standard	1171	580	962	17.7
10	Bacon	Electric	Standard	289	304	294	8.0
11	Tortillas	Electric	Standard	1315	1213	1182	8.0
12	French Fries	Electric	Standard	207	131	118	8.0
13	Broil Fish	Electric	Standard	723	509	509	17.7
14	Lasagna	Electric	Standard	352	19.9	13.9	10.5
15	Bacon	Microwave	Standard	ELPI Only		--	--
16	Lasagna	Microwave	Standard	ELPI Only		--	--
17	Stovetop Stir Fry	Gas	Worst Case	1436	1361	1356	7.6
18	Bacon	Gas	Worst Case	753	792	834	14.4
19	Broil Fish	Gas	Worst Case	729	743	778	14.4
20	Full Meal	Gas	Standard	817	20.3	799	13.2
21	Stovetop Stir Fry	Gas	Test 2 Replicate	774	642	554	14.4
22	French Fries	Gas	Test 5 Replicate	183	114	103	5.9
23	Bake Lasagna	Gas	Test 7 Replicate	99.1	54.6	52.5	6.5
24	Fry Beef	Gas	Cast Iron Pan	98.2	23.6	18.9	6.2
24R	Fry Beef	Gas	Cast Iron Pan	189	24.2	22.7	1.5[a]
25	Pork Roast	Gas	Aluminum Pan	60.5	20.3	17.7	6.2
26	Fry Beef	Gas	Exhaust Ventilation	277	17.7	45.5	19.3
27	Pork Roast	Gas	Exhaust Ventilation	69.5	20.5	14.3	19.3
28	Fry Beef	Gas	Range Hood Shields	136	20.4	14.6	7.3
29	Pork Roast	Gas	Range Hood Shields	38.7	1.5[a]	6.4	7.3
30	Stovetop Stir Fry	Gas	Vegetable Oil	913	587	606	7.6
31	Fry Beef	Gas	Pan Lid	135	22.7	17.1	6.50
32	Popcorn	Microwave	Standard	ELPI Only		--	--
			N	30	30	30	28
			Minimum	38.7	0.4	6.4	1.5
			Maximum	3661	2667	2159	19.3

[a] – Below detectable limits. Value taken at ½ MDL.

Table 3-6. ELPI Average Particle Concentrations in 12 Size Fractions during the Cooking Period

			Concentration (Particles/cm^3) in Size Fraction													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
1	Gas	Oven Cleaning	227,014	90,766	45,390	33,091	35,469	19,045	7,900	2,100	157	73	47	45	460,933	461,098
1R	Gas	Oven Cleaning	280,903	171,750	116,159	94,022	73,510	44,320	1,921	124	40	25	21	26	782,750	782,822
2	Gas	Stovetop Stir Fry	83,240	36,312	15,621	6,697	1,044	202	54	25	12	7	5	5	143,205	143,222
3	Gas	Bacon	61,361	37,401	24,554	14,065	1,591	190	29	10	4	1	1	2	139,205	139,209
3A	Gas	Bacon	57,365	25,669	14,008	6,186	561	97	19	8	4	2	1	2	103,917	103,922
3B	Gas	Bacon	57,478	42,031	29,058	17,334	2,104	247	38	12	4	1	1	2	148,308	148,313
4	Gas	Tortillas	143,682	47,460	10,278	1,848	195	72	19	12	8	3	2	2	203,574	203,581
5	Gas	French Fries	125,329	38,240	12,358	3,548	273	83	23	12	9	3	2	2	179,875	179,882
6	Gas	Broil Fish	87,260	56,137	39,931	32,348	19,494	7,359	754	66	14	6	4	6	243,364	243,381
6A	Gas	Broil Fish	82,172	49,462	19,305	5,561	865	129	16	8	4	3	2	3	157,523	157,531
6B	Gas	Broil Fish	90,114	57,559	39,358	33,643	23,157	9,936	1,338	124	27	13	10	12	255,257	255,293
7	Gas	Bake Lasagna	219,036	89,693	40,291	24,344	4,128	818	127	27	7	3	2	3	378,472	378,480
8	Electric	Oven Cleaning	151,442	73,683	45,749	44,183	16,940	6,125	800	105	10	2	10	1	339,036	339,049
9	Electric	Stovetop Stir Fry	81,015	45,301	17,063	8,156	2,088	932	274	103	37	17	8	5	154,971	155,000
10	Electric	Bacon	20,562	13,792	11,641	12,147	3,168	451	30	8	0	3	0	1	61,799	61,804
10A	Electric	Bacon	11,925	5,865	3,929	3,210	596	71	11	3	0	2	0	1	25,610	25,614
10B	Electric	Bacon	26,368	18,892	14,799	14,660	3,604	519	40	11	1	4	1	1	78,894	78,899
11	Electric	Tortillas	136,828	125,806	90,918	48,176	13,700	3,716	566	119	26	12	6	7	419,854	419,879
12	Electric	French Fries	66,141	30,406	7,305	2,153	306	76	18	8	2	3	1	2	106,416	106,422
13	Electric	Broil Fish	70,217	39,672	27,294	25,406	7,238	1,988	169	19	4	1	1	1	172,007	172,010
13A	Electric	Broil Fish	23,185	10,800	5,246	3,397	806	233	27	5	2	1	1	1	43,702	43,704
13B	Electric	Broil Fish	66,827	36,244	23,784	23,234	6,785	1,810	145	16	4	1	1	1	158,848	158,851
14	Electric	Lasagna	7,715	3,556	1,585	692	101	9	0	0	1	0	1	1	13,659	13,661
15	Microwave	Lasagna	2,561	850	762	465	170	60	5	2	1	0	0	0	4,876	4,876
16	Microwave	Bacon	2,299	1,123	797	640	263	121	27	10	3	1	1	0	5,283	5,285
16A	Microwave	Bacon	2,235	989	753	598	251	109	22	7	2	2	1	0	4,967	4,969
16B	Microwave	Bacon	2,115	1,173	831	696	288	141	34	13	4	2	1	0	5,296	5,298
17	Gas	Stovetop Stir Fry	126,334	44,158	29,020	24,276	8,102	2,796	0	0	0	0	0	0	234,686	234,686
17A	Gas	Stovetop Stir Fry	100,731	32,731	17,825	11,049	3,585	1,397	0	0	0	0	0	0	167,319	167,319
17B	Gas	Stovetop Stir Fry	134,944	48,289	31,148	30,030	10,092	3,408	0	0	0	0	0	0	257,911	257,911
18	Gas	Bacon	75,732	59,894	47,714	52,855	16,203	4,089	296	61	13	4	2	3	256,855	256,864
18A	Gas	Bacon	101,005	63,976	38,823	26,955	5,552	975	99	33	11	5	4	4	237,429	237,443
18B	Gas	Bacon	91,291	58,998	44,217	53,728	17,796	4,565	319	67	14	5	3	4	270,995	271,007
19	Gas	Broil Fish	205,502	155,142	114,378	77,253	7,803	1,013	99	41	0	0	0	0	561,232	561,232

Concentration (Particles/cm^3) in Size Fraction															
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
19A	Gas	Broil Fish	317,050	217,412	109,773	37,096	2,815	497	122	67	0	0	0	0	684,833	684,833
19B	Gas	Broil Fish	248,370	250,981	184,203	101,825	10,370	1,364	125	59	0	0	0	0	797,297	797,297
20	Gas	Full Meal	460,280	168,719	84,717	65,281	21,608	4,240	517	110	27	14	10	14	805,499	805,536
21	Gas	Stovetop Stir Fry	96,357	35,925	19,854	14,191	2,381	434	96	48	20	9	5	4	169,307	169,324
21A	Gas	Stovetop Stir Fry	103,859	34,203	14,591	9,222	1,546	305	68	36	17	9	6	5	163,847	163,867
21B	Gas	Stovetop Stir Fry	146,088	52,646	29,306	21,930	4,286	800	168	79	32	16	9	7	255,334	255,366
22	Gas	French Fries	124,804	66,432	25,839	7,280	531	131	26	14	7	3	2	2	225,065	225,073
22A	Gas	French Fries	99,122	46,337	11,000	2,371	283	80	16	10	5	2	2	2	159,225	159,232
22B	Gas	French Fries	162,854	88,602	49,758	17,435	1,009	226	43	23	10	4	2	3	319,960	319,969
23	Gas	Bake Lasagna	108,482	49,030	14,956	3,062	153	38	9	6	0	0	0	0	175,735	175,735
24	Gas	Fry Beef	9,377	2,009	659	226	59	22	4	2	2	0	0	0	12,359	12,361
24R	Gas	Fry Beef	24,998	10,623	2,388	577	99	26	7	3	2	1	1	1	38,723	38,725
24RA	Gas	Fry Beef	41,458	12,285	2,406	531	93	26	8	4	2	1	1	1	56,814	56,817
24RB	Gas	Fry Beef	10,975	7,363	1,703	446	84	22	6	2	2	1	0	0	20,603	20,604
25	Gas	Pork Roast	20,757	12,883	5,237	2,399	318	31	2	1	2	0	0	0	41,628	41,628
26	Gas	Fry Beef	6,912	970	359	164	61	17	5	2	0	0	0	0	8,490	8,490
27	Gas	Pork Roast	6,552	2,534	891	375	0	0	0	0	0	0	0	0	10,352	10,352
28	Gas	Fry Beef	0	746	348	142	64	16	2	1	0	0	0	2	1,319	1,321
29	Gas	Pork Roast	1,739	271	97	60	24	5	1	0	1	0	0	0	2,198	2,199
30	Gas	Stovetop Stir Fry	94,119	32,867	20,025	10,291	2,937	1,046	255	59	20	9	5	3	161,618	161,635
30A	Gas	Stovetop Stir Fry	55,191	16,141	7,058	2,849	813	341	100	27	12	6	5	3	82,533	82,547
30B	Gas	Stovetop Stir Fry	91,171	29,215	18,962	10,849	3,091	1,063	240	56	19	7	5	3	154,666	154,680
31	Gas	Fry Beef	0	536	155	89	32	6	11	0	3	0	1	6	832	839
31A	Gas	Fry Beef	0	508	176	92	30	6	9	0	2	0	0	3	822	825
31B	Gas	Fry Beef	0	575	147	92	34	6	12	0	4	0	1	8	870	879
32	Microwave	Popcorn	7,366	2,582	1,300	811	191	50	7	2	1	0	0	0	12,310	12,311
33	Gas	Range Baseline	27,883	12,847	2,422	651	153	47	12	5	2	2	1	1	44,022	44,026
34	Gas	Oven Baseline	47,611	24,904	7,174	2,306	464	80	5	0	0	0	0	0	82,544	82,544
N			48	48	48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	271	97	60	0	0	0	0	0	0	0	0	822	825
Maximum			460,280	250,981	184,203	101,825	73,510	44,320	1,921	124	40	25	21	26	805,499	805,536

Table 3-7. Average Particle Concentrations in 12 Size Fractions during the Total Exposure Period of Cooking Events

			Concentration (Particles/cm^3) in Size Fraction													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
1	Gas	Oven Cleaning	169,009	68,156	34,313	25,266	31,146	18,675	6,519	1,783	126	56	35	34	354,993	355,119
1R	Gas	Oven Cleaning	229,191	141,593	98,010	80,803	62,748	38,967	1,872	97	31	19	16	20	653,311	653,367
2	Gas	Stovetop Stir Fry	69,580	34,140	19,792	9,807	1,504	278	71	31	13	6	3	4	135,217	135,230
3	Gas	Bacon	54,250	36,875	25,754	16,178	2,039	230	34	10	4	1	1	2	135,373	135,376
3A	Gas	Bacon	62,448	36,422	23,563	13,331	1,474	177	27	9	4	1	1	2	137,456	137,460
3B	Gas	Bacon	46,289	37,413	27,978	19,027	2,601	282	41	11	4	1	0	2	133,648	133,651
4	Gas	Tortillas	109,938	53,960	19,598	4,588	237	85	18	11	7	2	1	1	188,442	188,446
5	Gas	French Fries	101,538	33,164	14,413	5,544	366	105	26	13	8	2	2	1	155,178	155,182
6	Gas	Broil Fish	91,059	55,516	48,509	47,698	28,707	11,840	1,365	105	21	9	6	9	284,818	284,843
6A	Gas	Broil Fish	86,951	56,052	40,183	32,094	18,662	6,766	620	53	11	5	3	5	241,391	241,404
6B	Gas	Broil Fish	95,525	55,213	57,004	63,426	38,799	16,928	2,111	157	31	14	10	13	329,195	329,232
7	Gas	Bake Lasagna	169,667	72,118	35,355	22,670	3,802	727	107	21	6	2	1	2	304,472	304,478
8	Electric	Oven Cleaning	124,142	62,247	39,152	39,288	15,705	5,479	689	87	8	1	10	0	286,796	286,808
9	Electric	Stovetop Stir Fry	66,622	32,037	16,338	10,016	2,976	1,340	397	144	44	17	6	3	129,914	129,939
10	Electric	Bacon	21,681	19,129	17,320	21,733	7,058	1,316	76	13	1	4	0	1	88,328	88,333
10A	Electric	Bacon	18,607	12,061	10,571	11,294	3,020	428	27	7	0	3	0	1	56,014	56,018
10B	Electric	Bacon	24,277	25,043	22,961	30,449	10,427	2,057	118	19	2	4	0	1	115,354	115,359
11	Electric	Tortillas	70,689	85,950	86,298	66,471	28,195	5,346	682	124	23	9	5	5	343,778	343,798
12	Electric	French Fries	79,847	41,988	18,266	6,071	612	157	36	15	2	5	1	1	146,994	147,001
13	Electric	Broil Fish	79,560	46,734	33,489	32,121	9,333	2,832	429	49	6	2	1	1	204,554	204,558
13A	Electric	Broil Fish	70,989	40,394	27,990	25,830	7,325	2,022	174	19	4	2	1	1	174,748	174,752
13B	Electric	Broil Fish	88,688	53,463	39,295	38,733	11,440	3,682	696	81	8	2	0	1	236,086	236,090
14	Electric	Lasagna	8,772	4,212	1,911	863	126	6	0	0	0	0	1	1	15,890	15,892
15	Microwave	Lasagna	2,232	791	678	420	156	58	5	2	1	0	0	0	4,342	4,342
16	Microwave	Bacon	2,378	1,229	847	663	268	127	30	11	3	1	0	0	5,556	5,558
16A	Microwave	Bacon	2,360	1,107	787	622	255	115	25	9	2	1	1	0	5,281	5,284
16B	Microwave	Bacon	2,399	1,364	913	708	282	141	35	13	4	1	0	0	5,861	5,863
17	Gas	Stovetop Stir Fry	116,545	42,779	28,851	27,286	9,578	3,121	0	0	0	0	0	0	228,160	228,160
17A	Gas	Stovetop Stir Fry	124,218	43,097	28,476	22,681	7,548	2,627	0	0	0	0	0	0	228,646	228,646
17B	Gas	Stovetop Stir Fry	111,280	42,620	29,156	30,585	11,029	3,475	0	0	0	0	0	0	228,146	228,146
18	Gas	Bacon	65,626	52,039	43,777	54,568	18,717	4,618	322	67	14	4	2	3	239,747	239,756
18A	Gas	Bacon	70,509	60,410	49,063	52,605	15,644	3,920	287	59	13	4	2	3	252,510	252,519
18B	Gas	Bacon	61,324	44,498	39,014	56,431	21,553	5,260	353	75	15	4	2	2	228,523	228,532
19	Gas	Broil Fish	166,267	124,286	104,311	111,548	18,776	2,032	157	50	0	0	0	0	527,427	527,427

Concentration (Particles/cm^3) in Size Fraction															
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
19A	Gas	Broil Fish	194,131	128,309	94,801	70,441	7,085	916	92	36	0	0	0	0	495,812	495,812
19B	Gas	Broil Fish	140,611	121,052	113,773	150,893	29,921	3,097	219	64	0	0	0	0	559,630	559,630
20	Gas	Full Meal	184,066	70,895	40,228	37,416	15,266	5,702	927	105	10	5	4	5	354,615	354,629
21	Gas	Stovetop Stir Fry	97,480	37,167	23,549	18,655	3,647	638	130	59	22	10	5	3	181,346	181,363
21A	Gas	Stovetop Stir Fry	83,702	31,678	17,435	12,200	1,888	340	78	40	17	8	4	3	147,377	147,392
21B	Gas	Stovetop Stir Fry	109,861	42,092	28,976	24,368	5,201	902	175	76	27	11	5	3	211,678	211,698
22	Gas	French Fries	99,049	50,020	24,758	9,333	615	142	26	13	6	2	1	1	183,963	183,967
22A	Gas	French Fries	115,484	61,063	20,155	4,885	418	109	22	12	6	3	2	2	202,154	202,161
22B	Gas	French Fries	87,198	42,137	27,820	12,380	749	164	30	14	6	1	1	1	170,498	170,500
23	Gas	Bake Lasagna	96,610	42,043	15,604	3,991	169	36	7	4	0	0	0	0	158,463	158,463
24	Gas	Fry Beef	10,862	2,171	563	197	59	22	4	2	2	0	0	0	13,881	13,882
24R	Gas	Fry Beef	19,269	8,956	2,044	498	88	23	6	3	2	1	0	0	30,890	30,891
24RA	Gas	Fry Beef	28,778	11,504	2,573	612	103	27	8	4	2	1	1	1	43,612	43,614
24RB	Gas	Fry Beef	11,021	6,745	1,586	399	74	20	5	2	2	0	0	0	19,853	19,854
25	Gas	Pork Roast	16,186	10,437	4,305	1,954	257	25	1	1	2	0	0	0	33,166	33,167
26	Gas	Fry Beef	11,324	1,439	393	165	65	19	6	2	0	0	0	0	13,413	13,413
27	Gas	Pork Roast	5,157	1,981	728	329	0	0	0	0	0	0	0	0	8,195	8,195
28	Gas	Fry Beef	4	632	285	118	60	14	2	0	1	0	0	2	1,116	1,118
29	Gas	Pork Roast	1,499	285	115	69	26	5	1	0	1	0	0	0	2,002	2,003
30	Gas	Stovetop Stir Fry	96,241	32,529	20,883	11,768	3,448	1,178	146	33	12	5	3	2	166,237	166,246
30A	Gas	Stovetop Stir Fry	94,992	33,763	20,291	10,171	2,904	1,043	259	59	21	9	5	3	163,502	163,520
30B	Gas	Stovetop Stir Fry	97,514	31,521	21,422	13,164	3,924	1,296	47	11	4	1	1	1	168,902	168,905
31	Gas	Fry Beef	0	528	147	86	32	6	12	0	4	0	1	7	814	822
31A	Gas	Fry Beef	0	528	157	89	31	6	11	0	3	0	1	5	825	831
31B	Gas	Fry Beef	0	529	137	83	33	5	12	0	5	0	1	9	804	814
32	Microwave	Popcorn	7,926	2,648	1,308	808	197	54	8	2	1	0	0	0	12,952	12,953
33	Gas	Range Baseline	23,512	21,234	4,661	876	156	46	10	4	2	2	1	1	50,501	50,505
34	Gas	Oven Baseline	34,831	19,366	6,054	2,038	430	70	4	0	0	0	0	0	62,793	62,793
N			48	48	48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	285	115	69	0	0	0	0	0	0	0	0	804	814
Maximum			229,191	141,593	113,773	150,893	62,748	38,967	2,111	157	44	19	16	20	653,311	653,367

Table 3-8. Average Particle Concentrations [dN/dlog (Dp)] in 12 Size Fractions during the Cooking Period

Particle Concentrations [dN/dlog (Dp)] in Size Fractions													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**
1	Gas	Oven Cleaning	754,123	373,466	219,596	176,874	189,588	90,609	41,132	9,977	858	349	208	249
1R	Gas	Oven Cleaning	933,140	706,681	561,976	502,560	392,921	210,860	10,002	590	221	119	92	145
2	Gas	Stovetop Stir Fry	276,517	149,407	75,572	35,795	5,579	960	280	118	67	34	20	27
3	Gas	Bacon	203,837	153,890	118,792	75,180	8,504	905	151	47	20	6	4	10
3A	Gas	Bacon	190,562	105,616	67,772	33,066	2,999	461	99	39	21	9	6	10
3B	Gas	Bacon	190,939	172,942	140,585	92,655	11,249	1,173	196	57	25	6	5	13
4	Gas	Tortillas	477,302	195,279	49,723	9,878	1,044	341	98	56	44	16	10	9
5	Gas	French Fries	416,334	157,340	59,788	18,964	1,461	397	117	59	47	15	11	9
6	Gas	Broil Fish	289,871	230,981	193,187	172,901	104,200	35,014	3,926	316	77	30	19	34
6A	Gas	Broil Fish	272,969	203,515	93,396	29,726	4,624	614	84	40	24	14	11	17
6B	Gas	Broil Fish	299,354	236,829	190,414	179,828	123,777	47,273	6,968	590	148	64	44	69
7	Gas	Bake Lasagna	727,623	369,051	194,929	130,123	22,067	3,890	660	128	39	15	8	16
8	Electric	Oven Cleaning	503,080	303,173	221,332	236,164	90,546	29,141	4,167	497	54	9	46	3
9	Electric	Stovetop Stir Fry	269,126	186,396	82,553	43,595	11,161	4,436	1,428	491	200	81	35	25
10	Electric	Bacon	68,304	56,749	56,320	64,925	16,933	2,147	157	37	2	16	2	5
10A	Electric	Bacon	39,615	24,131	19,007	17,159	3,185	337	56	16	1	12	2	4
10B	Electric	Bacon	87,591	77,735	71,595	78,359	19,264	2,468	207	52	8	17	3	7
11	Electric	Tortillas	454,534	517,640	439,858	257,506	73,231	17,677	2,944	564	140	57	28	36
12	Electric	French Fries	219,714	125,109	35,339	11,507	1,635	363	96	40	13	14	6	9
13	Electric	Broil Fish	233,255	163,235	132,048	135,796	38,687	9,459	880	89	23	7	3	6
13A	Electric	Broil Fish	77,018	44,437	25,379	18,157	4,311	1,111	140	25	12	4	3	5
13B	Electric	Broil Fish	149,129	115,068	124,190	36,265	8,610	753	74	22	5	3	6	0
14	Electric	Lasagna	25,628	14,631	7,667	3,700	540	44	0	0	3	0	5	7
15	Microwave	Lasagna	8,509	3,496	3,688	2,485	909	284	28	8	5	2	1	1
16	Microwave	Bacon	7,636	4,621	3,858	3,419	1,407	578	140	46	15	7	2	1
16A	Microwave	Bacon	7,426	4,068	3,645	3,196	1,342	517	115	35	11	8	3	1
16B	Microwave	Bacon	7,026	4,828	4,021	3,721	1,540	671	177	61	22	8	3	1
17	Gas	Stovetop Stir Fry	419,674	181,692	140,397	129,758	43,307	13,304	0	0	0	0	0	0
17A	Gas	Stovetop Stir Fry	334,622	134,674	86,239	59,060	19,164	6,644	0	0	0	0	0	0
17B	Gas	Stovetop Stir Fry	448,274	198,688	150,692	160,515	53,944	16,213	0	0	0	0	0	0
18	Gas	Bacon	251,575	246,438	230,838	282,514	86,606	19,453	1,539	289	72	21	10	16
18A	Gas	Bacon	335,530	263,235	187,825	144,080	29,677	4,639	516	157	60	26	17	23
18B	Gas	Bacon	303,264	242,751	213,922	287,183	95,121	21,717	1,659	318	79	25	13	20
19	Gas	Broil Fish	682,661	638,345	553,358	412,927	41,710	4,822	517	195	0	0	0	0

Particle Concentrations [dN/dlog (Dp)] in Size Fractions														
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**
19A	Gas	Broil Fish	1,053,219	894,559	531,080	198,282	15,046	2,366	635	321	0	0	0	0
19B	Gas	Broil Fish	825,066	1,032,681	891,172	544,265	55,429	6,490	651	281	0	0	0	0
20	Gas	Full Meal	1,529,018	694,207	409,861	348,935	115,499	20,171	2,690	522	147	65	46	75
21	Gas	Stovetop Stir Fry	320,091	147,818	96,054	75,853	12,724	2,066	502	228	107	45	22	19
21A	Gas	Stovetop Stir Fry	345,012	140,732	70,592	49,290	8,265	1,450	355	172	91	45	27	25
21B	Gas	Stovetop Stir Fry	485,294	216,618	141,780	117,219	22,908	3,807	873	375	173	76	41	38
22	Gas	French Fries	414,592	273,342	125,009	38,912	2,838	625	134	69	38	14	8	13
22A	Gas	French Fries	329,277	190,657	53,217	12,675	1,515	381	85	45	30	12	8	11
22B	Gas	French Fries	540,990	364,562	240,730	93,191	5,391	1,075	224	111	52	18	9	15
23	Gas	Bake Lasagna	360,371	201,736	72,357	16,367	816	180	46	26	0	0	0	0
24	Gas	Fry Beef	31,151	8,264	3,189	1,210	315	102	22	9	9	2	1	2
24R	Gas	Fry Beef	83,040	43,708	11,552	3,083	531	125	38	16	12	4	3	3
24RA	Gas	Fry Beef	137,719	50,549	11,641	2,837	497	126	43	21	13	6	4	5
24RB	Gas	Fry Beef	36,457	30,294	8,240	2,384	451	104	31	11	10	3	2	2
25	Gas	Pork Roast	68,954	53,006	25,334	12,822	1,697	146	10	5	9	1	0	1
26	Gas	Fry Beef	22,963	3,992	1,738	879	324	79	27	8	0	0	0	0
27	Gas	Pork Roast	21,765	10,428	4,310	2,004	0	0	0	0	0	0	0	0
28	Gas	Fry Beef	0	3,070	1,685	759	340	74	11	3	3	0	1	8
29	Gas	Pork Roast	5,777	1,115	471	322	127	22	7	1	4	0	0	2
30	Gas	Stovetop Stir Fry	312,655	135,232	96,881	55,005	15,698	4,978	1,329	278	111	41	23	15
30A	Gas	Stovetop Stir Fry	183,342	66,415	34,146	15,229	4,344	1,623	520	131	65	31	21	17
30B	Gas	Stovetop Stir Fry	302,865	120,207	91,738	57,987	16,520	5,060	1,252	264	103	34	21	15
31	Gas	Fry Beef	0	2,204	751	477	170	29	58	0	17	0	3	32
31A	Gas	Fry Beef	0	2,090	850	489	160	27	46	0	10	0	1	17
31B	Gas	Fry Beef	0	2,366	709	494	180	28	65	0	22	0	4	45
32	Microwave	Popcorn	16,618	7,964	5,476	4,102	907	190	28	7	5	1	1	0
33	Gas	Range Baseline	92,627	52,861	11,718	3,479	816	225	62	22	11	9	6	6
34	Gas	Oven Baseline	158,159	102,471	34,706	12,326	2,480	380	26	0	0	0	0	0
N			48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	1,115	471	322	0	0	0	0	0	0	0	0
Maximum			1,529,018	1,032,681	891,172	544,265	392,921	210,860	10,002	590	221	119	92	145

Table 3-9. Average Particle Concentrations [dN/dlog (Dp)] in 12 Size Fractions during the Total Exposure Period of Cooking Events

Particle Concentrations [dN/dlog (Dp)] in Size Fractions														
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**
1	Gas	Oven Cleaning	561,437	280,431	166,007	135,051	166,477	88,849	33,940	8,472	690	270	157	186
1R	Gas	Oven Cleaning	761,355	582,595	474,172	431,901	335,394	185,393	9,745	460	172	93	72	113
2	Gas	Stovetop Stir Fry	231,140	140,471	95,755	52,419	8,040	1,322	369	148	74	29	15	21
3	Gas	Bacon	180,214	151,727	124,595	86,471	10,897	1,095	178	49	20	4	3	10
3A	Gas	Bacon	207,448	149,862	113,999	71,257	7,878	844	141	44	19	5	3	9
3B	Gas	Bacon	153,770	153,940	135,357	101,701	13,905	1,344	214	54	21	3	2	10
4	Gas	Tortillas	365,207	222,023	94,813	24,525	1,267	405	94	51	37	9	5	6
5	Gas	French Fries	337,301	136,457	69,728	29,636	1,959	501	136	62	44	10	7	5
6	Gas	Broil Fish	302,490	228,424	234,685	254,950	153,440	56,330	7,105	499	116	45	29	49
6A	Gas	Broil Fish	288,844	230,629	194,405	171,545	99,751	32,191	3,226	253	61	22	14	27
6B	Gas	Broil Fish	317,327	227,178	275,784	339,021	207,387	80,541	10,990	745	171	69	44	71
7	Gas	Bake Lasagna	563,621	296,735	171,047	121,174	20,320	3,460	557	101	30	11	5	11
8	Electric	Oven Cleaning	412,390	256,120	189,415	209,999	83,945	26,065	3,588	412	45	7	46	2
9	Electric	Stovetop Stir Fry	221,312	131,820	79,045	53,538	15,906	6,375	2,065	684	241	79	25	15
10	Electric	Bacon	72,022	78,710	83,794	116,164	37,724	6,262	398	64	6	17	2	6
10A	Electric	Bacon	61,810	49,624	51,142	60,369	16,141	2,037	140	31	0	16	1	4
10B	Electric	Bacon	80,648	103,040	111,086	162,755	55,735	9,786	613	91	10	18	2	7
11	Electric	Tortillas	234,823	353,648	417,509	355,297	150,707	25,435	3,550	588	125	45	24	30
12	Electric	French Fries	265,244	172,762	88,370	32,449	3,273	748	188	72	11	22	4	8
13	Electric	Broil Fish	264,294	192,289	162,017	171,692	49,888	13,475	2,233	235	34	8	3	7
13A	Electric	Broil Fish	235,821	166,206	135,417	138,063	39,152	9,621	904	92	24	7	3	7
13B	Electric	Broil Fish	219,980	190,109	207,032	61,148	17,516	3,625	385	44	8	2	8	0
14	Electric	Lasagna	29,141	17,331	9,245	4,611	675	27	0	0	2	0	3	4
15	Microwave	Lasagna	7,414	3,253	3,281	2,244	831	274	28	8	5	1	0	0
16	Microwave	Bacon	7,899	5,058	4,097	3,542	1,433	606	154	51	17	7	2	1
16A	Microwave	Bacon	7,839	4,555	3,807	3,323	1,364	548	128	42	13	7	2	1
16B	Microwave	Bacon	7,969	5,614	4,419	3,785	1,510	670	183	62	22	7	2	1
17	Gas	Stovetop Stir Fry	387,155	176,017	139,580	145,847	51,196	14,848	0	0	0	0	0	0
17A	Gas	Stovetop Stir Fry	412,642	177,326	137,765	121,235	40,343	12,497	0	0	0	0	0	0
17B	Gas	Stovetop Stir Fry	369,666	175,365	141,056	163,482	58,954	16,533	0	0	0	0	0	0
18	Gas	Bacon	218,003	214,117	211,793	291,672	100,046	21,971	1,675	319	75	20	8	14
18A	Gas	Bacon	234,226	248,561	237,368	281,179	83,620	18,650	1,496	279	69	20	9	15
18B	Gas	Bacon	203,714	183,091	188,748	301,633	115,204	25,026	1,840	355	81	20	8	13
19	Gas	Broil Fish	552,326	511,384	504,658	596,236	100,360	9,666	819	239	0	0	0	0
19A	Gas	Broil Fish	644,890	527,938	458,648	376,517	37,873	4,358	480	171	0	0	0	0
19B	Gas	Broil Fish	467,100	498,078	550,432	806,541	159,930	14,733	1,143	306	0	0	0	0
20	Gas	Full Meal	611,453	291,705	194,623	199,994	81,597	27,129	4,824	499	56	23	16	27

Particle Concentrations [dN/dlog (Dp)] in Size Fractions														
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**
21	Gas	Stovetop Stir Fry	323,821	152,925	113,932	99,714	19,491	3,035	674	281	122	46	20	17
21A	Gas	Stovetop Stir Fry	278,053	130,342	84,350	65,210	10,092	1,616	406	190	90	37	17	15
21B	Gas	Stovetop Stir Fry	364,952	173,190	140,186	130,249	27,797	4,289	912	362	150	54	22	19
22	Gas	French Fries	329,034	205,811	119,780	49,886	3,286	675	137	64	32	9	5	8
22A	Gas	French Fries	383,630	251,249	97,509	26,113	2,233	519	112	58	35	13	8	13
22B	Gas	French Fries	289,666	173,376	134,591	66,174	4,005	781	154	67	30	6	2	5
23	Gas	Bake Lasagna	320,930	172,990	75,494	21,332	901	169	36	20	0	0	0	0
24	Gas	Fry Beef	36,081	8,933	2,722	1,053	317	104	21	9	10	2	1	1
24R	Gas	Fry Beef	64,010	36,851	9,891	2,662	469	111	34	13	11	3	2	2
24RA	Gas	Fry Beef	95,599	47,334	12,450	3,272	553	130	40	18	12	4	3	4
24RB	Gas	Fry Beef	36,609	27,753	7,672	2,132	396	94	28	10	10	2	1	1
25	Gas	Pork Roast	53,767	42,944	20,825	10,442	1,373	119	7	3	10	0	0	1
26	Gas	Fry Beef	37,618	5,921	1,902	884	349	89	30	9	0	0	0	0
27	Gas	Pork Roast	17,130	8,149	3,524	1,758	0	0	0	0	0	0	0	0
28	Gas	Fry Beef	14	2,599	1,381	631	319	68	9	1	4	0	1	11
29	Gas	Pork Roast	4,981	1,172	556	371	141	23	7	1	5	0	0	2
30	Gas	Stovetop Stir Fry	319,705	133,843	101,029	62,901	18,430	5,604	758	159	63	24	13	8
30A	Gas	Stovetop Stir Fry	315,556	138,920	98,169	54,364	15,521	4,964	1,348	282	113	43	24	15
30B	Gas	Stovetop Stir Fry	323,935	129,695	103,639	70,365	20,972	6,164	245	52	20	7	4	3
31	Gas	Fry Beef	0	2,172	711	459	172	27	60	0	20	0	4	39
31A	Gas	Fry Beef	0	2,171	761	473	168	30	56	0	15	0	3	30
31B	Gas	Fry Beef	0	2,175	663	445	176	24	64	0	25	0	4	49
32	Microwave	Popcorn	26,330	10,894	6,330	4,318	1,053	255	42	10	6	1	1	0
33	Gas	Range Baseline	78,106	87,369	22,547	4,684	835	218	54	19	9	8	5	5
34	Gas	Oven Baseline	115,706	79,682	29,289	10,893	2,298	333	22	0	0	0	0	0
39	Electric	Oven Dirtying	180,287	90,063	75,054	66,874	17,357	3,921	387	89	24	6	0	2
N			48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	1,172	556	371	0	0	0	0	0	0	0	0
Maximum			761,355	582,595	550,432	806,541	335,394	185,393	10,990	745	241	93	72	113

Table 3-10. Average Estimated Particle Mass Concentrations in 12 Size Fractions during the Cooking Period

			μg/m³													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
1	**Gas**	**Oven Cleaning**	**9**	**24**	**56**	**160**	**623**	**1,319**	**2,195**	**2,345**	**683**	**1,223**	**3,547**	**13,862**	**7,413**	**26,046**
1R	Gas	Oven Cleaning	11	45	144	453	1,291	3,069	534	139	176	417	1,568	8,061	5,862	15,907
2	Gas	Stovetop Stir Fry	3	10	19	32	18	14	15	28	53	118	349	1,482	193	2,142
3	Gas	Bacon	2	10	30	68	28	13	8	11	16	20	62	548	187	816
3A	Gas	Bacon	2	7	17	30	10	7	5	9	17	32	111	536	104	783
3B	Gas	Bacon	2	11	36	84	37	17	10	13	20	23	83	746	230	1,082
4	Gas	Tortillas	6	12	13	9	3	5	5	13	35	57	172	490	102	821
5	Gas	French Fries	5	10	15	17	5	6	6	14	37	54	183	498	116	850
6	Gas	Broil Fish	3	15	49	156	342	510	210	74	61	105	328	1,921	1,421	3,775
6A	Gas	Broil Fish	3	13	24	27	15	9	5	9	19	48	183	933	124	1,288
6B	Gas	Broil Fish	4	15	49	162	407	688	372	139	118	223	752	3,842	1,953	6,771
7	Gas	Bake Lasagna	9	23	50	117	73	57	35	30	31	54	137	902	425	1,517
8	Electric	Oven Cleaning	6	19	57	213	297	424	222	117	43	30	778	163	1,399	2,370
9	Electric	Stovetop Stir Fry	3	12	21	39	37	65	76	115	159	283	599	1,417	528	2,826
10	Electric	Bacon	1	4	14	59	56	31	8	9	2	57	26	254	183	521
10A	Electric	Bacon	0	2	5	15	10	5	3	4	1	41	28	216	45	330
10B	Electric	Bacon	1	5	18	71	63	36	11	12	6	60	56	365	224	706
11	Electric	Tortillas	5	33	113	232	241	257	157	133	112	201	483	2,029	1,282	3,996
12	Electric	French Fries	3	8	9	10	5	5	5	9	11	49	102	508	66	724
13	Electric	Broil Fish	3	10	34	123	127	138	47	21	19	24	53	362	521	959
13A	Electric	Broil Fish	1	3	6	16	14	16	7	6	10	14	53	265	80	412
13B	Electric	Broil Fish	3	9	29	112	119	125	40	17	17	17	43	311	473	844
14	Electric	Lasagna	0	1	2	3	2	1	0	0	2	0	85	369	11	465
15	Microwave	Lasagna	0	0	1	2	3	4	1	2	4	6	9	29	18	61
16	Microwave	Bacon	0	0	1	3	5	8	7	11	12	25	41	42	48	156
16A	Microwave	Bacon	0	0	1	3	4	8	6	8	9	27	52	68	39	186
16B	Microwave	Bacon	0	0	1	3	5	10	9	14	18	29	44	44	61	178
17	Gas	Stovetop Stir Fry	5	12	36	117	142	194	0	0	0	0	0	0	506	506
17A	Gas	Stovetop Stir Fry	4	9	22	53	63	97	0	0	0	0	0	0	248	248
17B	Gas	Stovetop Stir Fry	5	13	39	145	177	236	0	0	0	0	0	0	615	615
18	Gas	Bacon	3	16	59	255	285	283	82	68	57	75	174	918	1,107	2,275
18A	Gas	Bacon	4	17	48	130	98	68	28	37	48	91	292	1,309	476	2,168
18B	Gas	Bacon	4	15	55	259	313	316	89	75	63	86	224	1,100	1,188	2,598
19	Gas	Broil Fish	8	41	142	373	137	70	28	46	0	0	0	0	844	844
19A	Gas	Broil Fish	13	57	136	179	49	34	34	75	0	0	0	0	577	577

			μg/m³												
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
19B	Gas	Broil Fish	10	66	228	491	182	94	35	66	0	0	0	0	1,172	1,172
20	Gas	Full Meal	18	44	105	315	379	294	144	123	117	228	776	4,208	1,539	6,751
21	Gas	Stovetop Stir Fry	4	9	25	68	42	30	27	54	85	158	376	1,086	344	1,963
21A	Gas	Stovetop Stir Fry	4	9	18	44	27	21	19	41	73	157	455	1,391	256	2,259
21B	Gas	Stovetop Stir Fry	6	14	36	106	75	55	47	88	138	265	695	2,129	565	3,654
22	Gas	French Fries	5	17	32	35	9	9	7	16	30	50	144	734	161	1,090
22A	Gas	French Fries	4	12	14	11	5	6	5	11	24	41	132	640	90	904
22B	Gas	French Fries	7	23	62	84	18	16	12	26	42	62	152	829	288	1,332
23	Gas	Bake Lasagna	4	13	19	15	3	3	2	6	0	0	0	9	64	74
24	Gas	Fry Beef	0	1	1	1	1	1	1	2	7	8	22	84	16	130
24R	Gas	Fry Beef	1	3	3	3	2	2	2	4	9	14	43	195	28	280
24RA	Gas	Fry Beef	2	3	3	3	2	2	2	5	10	20	62	272	31	385
24RB	Gas	Fry Beef	0	2	2	2	1	2	2	3	8	9	29	124	22	184
25	Gas	Pork Roast	1	3	6	12	6	2	1	1	7	2	5	41	39	87
26	Gas	Fry Beef	0	0	0	1	1	1	1	2	0	0	0	0	7	7
27	Gas	Pork Roast	0	1	1	2	0	0	0	0	0	0	0	0	4	4
28	Gas	Fry Beef	0	0	0	1	1	1	1	1	2	0	16	473	7	496
29	Gas	Pork Roast	0	0	0	0	0	0	0	0	4	1	4	116	5	126
30	Gas	Stovetop Stir Fry	4	9	25	50	52	72	71	65	88	145	396	826	435	1,802
30A	Gas	Stovetop Stir Fry	2	4	9	14	14	24	28	31	51	109	356	930	177	1,572
30B	Gas	Stovetop Stir Fry	4	8	23	52	54	74	67	62	82	119	357	824	426	1,727
31	Gas	Fry Beef	0	0	0	0	1	0	3	0	13	0	49	1,805	18	1,872
31A	Gas	Fry Beef	0	0	0	0	1	0	2	0	8	0	24	924	12	960
31B	Gas	Fry Beef	0	0	0	0	1	0	3	0	18	0	71	2,515	23	2,608
32	Microwave	Popcorn	0	1	2	4	3	3	2	2	5	5	12	17	23	58
33	Gas	Range Baseline	1	3	3	3	3	3	3	5	9	31	99	321	34	485
34	Gas	Oven Baseline	2	7	9	11	8	6	1	0	0	0	0	0	43	43
N			48	48	48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	0	0	0	0	0	0	0	0	0	0	0	4	4
Maximum			18	66	228	491	1,291	3,069	534	139	176	417	1,568	8,061	5,862	15,907

Table 3-11. Average Estimated Particle Mass Concentrations in 12 Size Fractions during the Total Exposure Period

			$\mu g/m^3$													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
1	Gas	Oven Cleaning	7	18	42	122	547	1,293	1,811	1,991	549	947	2,670	10,387	6,381	20,384
1R	Gas	Oven Cleaning	9	37	121	390	1,102	2,699	520	108	137	325	1,223	6,287	5,123	12,958
2	Gas	Stovetop Stir Fry	3	9	24	47	26	19	20	35	59	102	253	1,183	242	1,781
3	Gas	Bacon	2	10	32	78	36	16	9	12	16	14	45	537	210	807
3A	Gas	Bacon	2	10	29	64	26	12	8	10	15	19	58	503	177	757
3B	Gas	Bacon	2	10	35	92	46	20	11	13	17	10	33	573	244	860
4	Gas	Tortillas	4	14	24	22	4	6	5	12	30	32	90	320	122	563
5	Gas	French Fries	4	9	18	27	6	7	7	14	35	35	115	257	128	534
6	Gas	Broil Fish	4	15	60	230	504	820	379	117	92	159	487	2,722	2,221	5,588
6A	Gas	Broil Fish	3	15	50	155	328	469	172	59	48	79	233	1,491	1,299	3,102
6B	Gas	Broil Fish	4	14	71	306	681	1,172	587	175	136	240	742	3,962	3,146	8,090
7	Gas	Bake Lasagna	7	19	44	109	67	50	30	24	24	38	92	617	373	1,120
8	Electric	Oven Cleaning	5	16	48	189	276	379	192	97	36	24	791	128	1,239	2,181
9	Electric	Stovetop Stir Fry	3	8	20	48	52	93	110	161	192	278	429	830	687	2,225
10	Electric	Bacon	1	5	21	105	124	91	21	15	5	60	26	310	388	785
10A	Electric	Bacon	1	3	13	54	53	30	7	7	0	57	16	217	169	459
10B	Electric	Bacon	1	7	28	147	183	142	33	21	8	64	35	389	571	1,058
11	Electric	Tortillas	3	23	107	321	495	370	189	138	100	159	405	1,679	1,745	3,989
12	Electric	French Fries	3	11	23	29	11	11	10	17	9	76	75	440	123	715
13	Electric	Broil Fish	3	12	41	155	164	196	119	55	27	27	45	403	773	1,248
13A	Electric	Broil Fish	3	11	35	125	129	140	48	22	19	26	55	373	530	983
13B	Electric	Broil Fish	4	14	49	187	201	255	193	90	35	28	36	436	1,028	1,529
14	Electric	Lasagna	0	1	2	4	2	0	0	0	1	0	51	221	12	284
15	Microwave	Lasagna	0	0	1	2	3	4	2	2	4	5	7	21	17	50
16	Microwave	Bacon	0	0	1	3	5	9	8	12	14	24	36	38	52	150
16A	Microwave	Bacon	0	0	1	3	4	8	7	10	10	24	40	42	44	149
16B	Microwave	Bacon	0	0	1	3	5	10	10	15	17	25	32	34	61	152
17	Gas	Stovetop Stir Fry	5	11	36	132	168	216	0	0	0	0	0	0	568	568
17A	Gas	Stovetop Stir Fry	5	11	35	109	133	182	0	0	0	0	0	0	475	475
17B	Gas	Stovetop Stir Fry	4	11	36	148	194	241	0	0	0	0	0	0	634	634
18	Gas	Bacon	3	14	54	263	329	320	89	75	60	71	143	785	1,206	2,206
18A	Gas	Bacon	3	16	61	254	275	271	80	66	55	71	158	857	1,080	2,166

			μg/m³													
Test	**Range**	**Food**	**0.04**	**0.08**	**0.13**	**0.21**	**0.32**	**0.51**	**0.81**	**1.29**	**2.02**	**3.18**	**5.24**	**8.38**	**$PM_{2.5}$**	**PM_{10}**
18B	Gas	Bacon	2	12	48	272	378	364	98	83	65	71	130	722	1,324	2,247
19	Gas	Broil Fish	7	33	129	538	330	141	44	56	0	0	0	0	1,277	1,277
19A	Gas	Broil Fish	8	34	117	340	124	63	26	40	0	0	0	0	752	752
19B	Gas	Broil Fish	6	32	141	728	525	214	61	72	0	0	0	0	1,779	1,779
20	Gas	Full Meal	7	19	50	180	268	395	257	117	45	79	265	1,505	1,339	3,188
21	Gas	Stovetop Stir Fry	4	10	29	90	64	44	36	66	97	161	341	943	440	1,885
21A	Gas	Stovetop Stir Fry	3	8	22	59	33	24	22	45	72	130	295	819	287	1,531
21B	Gas	Stovetop Stir Fry	4	11	36	118	91	62	49	85	119	189	383	1,055	576	2,203
22	Gas	French Fries	4	13	31	45	11	10	7	15	26	32	81	459	161	734
22A	Gas	French Fries	5	16	25	24	7	8	6	14	28	47	141	710	131	1,030
22B	Gas	French Fries	3	11	34	60	13	11	8	16	24	22	39	282	181	525
23	Gas	Bake Lasagna	4	11	19	19	3	2	2	5	0	0	0	6	65	72
24	Gas	Fry Beef	0	1	1	1	1	2	1	2	8	7	15	59	17	98
24R	Gas	Fry Beef	1	2	3	2	2	2	2	3	9	11	28	128	25	193
24RA	Gas	Fry Beef	1	3	3	3	2	2	2	4	10	16	47	214	30	306
24RB	Gas	Fry Beef	0	2	2	2	1	1	1	2	8	8	12	54	21	94
25	Gas	Pork Roast	1	3	5	9	5	2	0	1	8	1	4	29	34	67
26	Gas	Fry Beef	0	0	0	1	1	1	2	2	0	0	0	0	8	8
27	Gas	Pork Roast	0	1	1	2	0	0	0	0	0	0	0	0	3	3
28	Gas	Fry Beef	0	0	0	1	1	1	1	0	3	0	14	635	7	656
29	Gas	Pork Roast	0	0	0	0	0	0	0	0	4	1	3	114	6	123
30	Gas	Stovetop Stir Fry	4	9	26	57	61	82	40	37	50	82	226	471	365	1,144
30A	Gas	Stovetop Stir Fry	4	9	25	49	51	72	72	66	90	151	407	830	438	1,826
30B	Gas	Stovetop Stir Fry	4	8	27	63	69	90	13	12	16	23	70	161	302	556
31	Gas	Fry Beef	0	0	0	0	1	0	3	0	16	0	60	2,198	21	2,279
31A	Gas	Fry Beef	0	0	0	0	1	0	3	0	12	0	44	1,648	17	1,709
31B	Gas	Fry Beef	0	0	0	0	1	0	3	0	20	0	75	2,741	25	2,841
32	Microwave	Popcorn	0	1	2	4	3	4	2	2	5	4	9	13	23	50
33	Gas	Range Baseline	1	6	6	4	3	3	3	5	7	26	83	282	37	429
34	Gas	Oven Baseline	1	5	7	10	8	5	1	0	0	0	0	0	37	37
N			48	48	48	48	48	48	48	48	48	48	48	48	48	48
Minimum			0	0	0	0	0	0	0	0	0	0	0	0	3	3
Maximum			9	37	141	728	1,102	2,699	587	175	192	325	1,223	6,287	5,123	12,958

Table 3-12. ELPI Estimated PM Mass Concentrations in Background Samples Prior to Cooking Tests and Outdoors at the End of the Tests

Test No.	Type	Range	Conditions	Kitchen Pre-test				Outdoor Post Test			
				Particles/cm^3		Mass (μg/m^3)		Particles/cm^3		Mass (μg/m^3)	
				$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
1R	Oven Cleaning	Gas	Standard	4001	4003	10	153	9201	9201	37	37
2	Stovetop Stir Fry	Gas	Standard	2683	2684	7	439	6509	6510	16	400
3	Bacon	Gas	Standard	2376	2376	5	111	2644	2645	8	459
4	Tortillas	Gas	Standard	2202	2202	13	22	3797	3797	19	19
5	French Fries	Gas	Standard	3423	3424	16	24	2876	2876	17	17
6	Broil Fish	Gas	Standard	2028	2028	6	13	2638	2638	26	26
7	Bake Lasagna	Gas	Standard	876	876	7	54	7400	7400	21	24
8	Oven Cleaning	Electric	Standard	1641	1642	4	108	1232	1244	12	890
9	Stovetop Stir Fry	Electric	Standard	1405	1406	13	30	982	982	15	19
10	Bacon	Electric	Standard	1215	1216	2	89	15992	15992	29	50
11	Tortillas	Electric	Standard	3994	3999	147	618	15992	15992	29	50
12	French Fries	Electric	Standard	4844	4845	7	118	15992	15992	29	50
13	Broil Fish	Electric	Standard	954	954	10	12	590	591	13	15
14	Lasagna	Electric	Standard	3965	3967	6	379	4923	4923	5	5
15	Bacon	Microwave	Standard	4563	4565	16	113	3757	3757	20	30
16	Lasagna	Microwave	Standard	5064	5064	15	60	3076	3076	22	28
17	Stovetop Stir Fry	Gas	Worst Case	1039	1039	3	3	7786	7786	8	8
18	Bacon	Gas	Worst Case	1394	1394	8	8	319	319	9	9
19	Broil Fish	Gas	Worst Case	4616	4616	9	9	8377	8377	21	21
20	Full Meal	Gas	Standard	3756	3756	7	18	356	356	4	4
21	Stovetop Stir Fry	Gas	Test 2 Replicate	1645	1645	9	13	2755	2755	15	16
22	French Fries	Gas	Test 5 Replicate	462	462	6	6	1849	1849	9	9
23	Bake Lasagna	Gas	Test 7 Replicate	575	576	3	151	11698	11698	12	12
24	Fry Beef	Gas	Cast Iron Pan	1615	1615	7	7	2374	2374	15	15
24R	Fry Beef	Gas	Cast Iron Pan	2479	2480	7	33	1879	1879	12	12
25	Pork Roast	Gas	Aluminum Pan	2290	2290	10	14	1668	1668	11	11
26	Fry Beef	Gas	Exhaust Hood On	1588	1588	4	4	1137	1137	3	3

Test No.	Type	Range	Conditions	Kitchen Pre-test				Outdoor Post Test			
				Particles/cm^3		Mass (μg/m^3)		Particles/cm^3		Mass (μg/m^3)	
				$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}
27	Pork Roast	Gas	Exhaust Hood On	1449	1449	1	1	9406	9406	6	6
28	Fry Beef	Gas	Range Shields	1480	1481	7	352	16629	16629	26	26
29	Pork Roast	Gas	Range Shields	808	808	3	54	16629	16629	26	26
30	Stovetop Stir Fry	Gas	Vegetable Oil	857	858	7	28	325	325	1	1
31	Fry Beef	Gas	Pan Lid	481	483	7	499	90	101	25	3068
32	Popcorn	Microwave	Standard	8512	8512	17	36	9435	9435	11	11
33	Burner Baseline	Gas		5909	5910	12	83	5324	5325	15	51
34	Oven Baseline	Gas		3855	3855	13	13	14802	14802	22	22
N				35	35	35	35	35	35	35	35
Minimum				461.9	461.9	0.8	0.8	89.7	100.5	1.1	1.1
Maximum				8512	8512	147	618	16629	16629	37	3068

3.4 Particle Element Concentrations

A subset of the filters used to collect PM_{10} mass was selected for elemental analysis by XRF. Samples were analyzed from the oven cleaning tests with the gas and electric ranges, the full meal cooking test, and in tests during which ground beef or a pork roast were cooked using different pan materials. The results are summarized in Table 3-13. Summary statistics are presented in Table 3-14 for samples collected indoors and 3-15 for samples collected outdoors. The number and percent measurable represent samples with concentrations above the method uncertainty level, which was a function of the MDL and analytical uncertainty, as described in Section 2. Because of the small number of samples, and large number of samples with non-detectable concentrations, the summary statistics were calculated for all samples with detectable concentrations and with the non-detectable samples excluded. As shown in Table 3-14, only silicon and calcium were measurable in all nine indoor samples. A number of the heavy metals were detected in the indoor samples, but at concentrations below the MDL. Chromium was detected in 4 of the 9 indoor samples. In the outdoor samples, the number of elements that were measurable was higher. These samples were generally collected for longer time periods. The results are discussed in Section 4.0.

Table 3-13. Concentrations ($\eta g/m^3$) of Selected Elements Measured in PM_{10} Samples[a]

Test No.	**1**	**1**	**1R**	**1R**	**8**	**8**	**25**
Cooking Type	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Pork Roast
Pan Material	NA[b]	NA	NA	NA	NA	NA	Aluminum
Range Type	Gas	Gas	Gas	Gas	Electric	Electric	Gas
Location	K	OUT	K	OUT	K	OUT	K
Sodium	569.0	218.9	*225.2*	156.1	365.5	471.7	*250.1*
Magnesium	0.0[c]	40.9	*121.5*	*18.0*	0.0[c]	82.8	0.0[c]
Aluminum	392.9	38.2	0.0[c]	34.8	97.6	*4.2*	124.2
Silicon	845.5	131.0	8532.3	137.4	644.0	31.0	465.2
Phosphorous	177.7	*2.3*	7937.3	7.0	43.5	*6.0*	*18.0*
Sulfur	1613.8	187.6	2198.8	162.4	266.5	116.8	231.9
Chlorine	1715.4	267.6	6458.1	178.3	790.3	1096.0	*49.3*
Potassium	1086.6	60.4	3832.5	70.1	409.9	59.3	*4.3*
Calcium	216.6	58.6	345.4	37.3	94.7	45.8	221.5
Titanium	*19.7*	*3.4*	0.0[c]	*5.5*	*29.0*	*6.8*	0.0[c]
Vanadium	0.0[c]	*3.5*	0.0[c]	*2.4*	0.0[c]	*2.3*	0.0[c]
Chromium	80.8	*1.3*	1222.8	*1.7*	134.2	*1.0*	*15.5*
Manganese	0.0[c]	*0.6*	0.0[c]	*2.1*	0.0[c]	0.0[c]	0.0[c]
Iron	221.1	67.6	109.9	98.4	62.3	28.0	102.3
Cobalt	0.0[c]	0.0[c]	0.0[c]	*0.3*	0.0[c]	*0.7*	*4.1*
Nickel	*0.1*	*0.8*	37.7	*0.6*	27.7	*0.2*	*5.1*
Copper	100.1	*2.5*	273.7	4.8	42.9	4.6	92.3
Zinc	59.2	6.6	60.2	7.5	43.6	7.5	36.3

Test No.	1	1	1R	1R	8	8	25
Cooking Type	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Oven Cleaning	Pork Roast
Pan Material	NA[b]	NA	NA	NA	NA	NA	Aluminum
Range Type	Gas	Gas	Gas	Gas	Electric	Electric	Gas
Location	K	OUT	K	OUT	K	OUT	K
Gallium	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Arsenic	*5.3*	*1.6*	0.0[c]	*0.2*	0.0[c]	*0.2*	*2.2*
Selenium	0.0[c]	*0.8*	0.0[c]	*1.0*	0.0[c]	*0.5*	*4.6*
Bromine	62.4	2.8	3433.6	*1.1*	*7.3*	2.5	*2.8*
Rubidium	0.0[c]	*0.3*	0.0[c]	0.0[c]	*3.6*	0.0[c]	0.0[c]
Strontium	0.0[c]	*0.7*	0.0[c]	*0.2*	*1.2*	*1.1*	*4.6*
Yttrium	0.0[c]	*0.2*	0.0[c]	*0.5*	*6.7*	*0.6*	*9.8*
Zirconium	*3.3*	*0.7*	0.0[c]	*1.4*	*8.3*	*1.1*	*8.6*
Molybdenum	0.0[c]	*1.2*	0.0[c]	*2.2*	*12.2*	*2.6*	*17.4*
Palladium	0.0[c]	*8.1*	0.0[c]	*3.3*	0.0[c]	0.0[c]	0.0[c]
Silver	0.0[c]	*7.4*	*89.9*	*1.9*	0.0[c]	0.0[c]	*17.3*
Cadmium	0.0[c]	*2.1*	0.0[c]	*3.2*	*52.8*	*6.5*	*38.1*
Indium	0.0[c]	0.0[c]	0.0[c]	*1.2*	0.0[c]	0.0[c]	0.0[c]
Tin	0.0[c]	0.0[c]	*10.0*	*3.6*	0.0[c]	0.0[c]	0.0[c]
Antimony	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	*4.5*	0.0[c]
Barium	0.0[c]	0.0[c]	0.0[c]	0.0[c]	*113.4*	*9.2*	*251.3*
Lanthanum	0.0[c]	0.0[c]	*127.4*	0.0[c]	*278.4*	0.0[c]	*540.3*
Gold	0.0[c]	*1.1*	0.0[c]	0.0[c]	42.0	0.0[c]	*26.1*
Mercury	0.0[c]	*0.5*	0.0[c]	*1.6*	25.6	*1.6*	*18.6*
Thallium	*3.2*	*0.9*	0.0[c]	*0.4*	0.0[c]	*1.4*	*6.2*
Lead	0.0[c]	*1.4*	0.0[c]	4.2	*22.7*	*3.6*	*2.8*
Uranium	0.0[c]	*0.2*	0.0[c]	*1.4*	*3.7*	*1.6*	*14.2*

[a] Concentrations in italics are below the uncertainty level, as defined in Section 2.0
[b] Not applicable; no pan used
[c] Correction for background data resulted in zero or negative values.

Table 3-13 (continued). Concentrations (ηg/m^3) of Selected Elements Measured in PM_{10} Samples[a]

Test No.	24	24	24R	24R	31	31	20	20	20
Cooking Type	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Full Meal	Full Meal	Full Meal
Pan Material	Cast Iron	Cast Iron	Cast Iron	Cast Iron	Teflon® w/lid	Teflon® w/lid	Multiple types	Multiple types	Multiple types
Range Type	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas
Location	K	OUT	K	OUT	K	OUT	K	K	OUT
Sodium	*631.2*	252.9	*310.8*	*47.3*	582.8	353.8	*309.1*	*154.6*	1077.3
Magnesium	*453.1*	28.7	*104.7*	0.0[b]	0.0[b]	63.1	*94.8*	*19.7*	141.8
Aluminum	539.5	25.6	*127.3*	37.3	255.3	17.3	216.0	*77.8*	37.5
Silicon	855.4	102.6	1125.8	106.0	460.8	72.6	3901.6	3458.4	180.1
Phosphorous	166.2	*4.1*	152.6	16.4	65.1	*3.8*	263.6	239.9	*7.8*
Sulfur	*77.6*	167.5	322.2	140.9	117.3	100.9	1521.8	1286.3	234.6
Chlorine	*188.7*	386.3	*58.6*	*1.4*	208.8	707.8	804.0	720.5	2667.6
Potassium	0.0[b]	35.8	158.6	29.4	134.1	58.0	130.1	146.7	111.7
Calcium	339.8	42.5	595.3	37.7	409.1	46.4	446.7	398.9	133.6
Titanium	*11.3*	*7.6*	*55.5*	*3.3*	*13.8*	*6.9*	0.0[b]	*4.2*	*4.8*
Vanadium	0.0[b]	*5.3*	*30.0*	*3.4*	*22.6*	*3.9*	0.0[b]	*20.4*	*1.6*
Chromium	*20.3*	*1.3*	*6.1*	0.0[b]	0.0[b]	0.0[b]	39.4	*21.9*	*0.1*
Manganese	0.0[b]	*0.6*	0.0[b]	0.0[b]	0.0[b]	*0.2*	0.0[b]	0.0[b]	0.0[b]
Iron	*60.5*	65.7	128.6	52.2	60.2	61.7	105.1	83.6	92.9
Cobalt	*7.4*	*2.1*	0.0[b]	0.0[b]	*0.6*	*0.6*	*2.9*	0.0[b]	0.0[b]
Nickel	0.0[b]	0.0[b]	*0.5*	0.0[b]	0.0[b]	*0.5*	*1.5*	0.0[b]	0.0[b]
Copper	*65.1*	3.7	99.5	8.9	108.2	4.0	91.5	64.8	*2.1*
Zinc	*66.3*	5.1	69.8	15.7	58.0	6.6	30.4	*21.5*	6.8
Gallium	*7.4*	*1.4*	*19.3*	*3.9*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	*1.3*
Arsenic	*4.2*	*1.0*	0.0[b]	*0.2*	0.0[b]	*0.2*	0.0[b]	0.0[b]	*2.0*
Selenium	0.0[b]	*0.1*	0.0[b]	*0.6*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Bromine	*17.7*	1.5	*13.2*	*0.9*	*5.5*	1.9	183.2	157.6	4.8
Rubidium	0.0[b]	*0.0*	0.0[b]	0.0[b]	0.0[b]	*0.1*	0.0[b]	0.0[b]	0.0[b]
Strontium	*6.8*	*0.6*	*6.7*	*0.8*	*0.1*	*0.1*	*0.9*	0.0[b]	*1.6*
Yttrium	*1.9*	*0.4*	*3.4*	0.0[b]	0.0[b]	*0.1*	0.0[b]	*0.1*	*1.5*
Zirconium	*22.5*	*0.2*	*24.7*	*1.8*	*20.0*	*0.8*	26.3	*11.3*	0.0[b]
Molybdenum	*5.2*	*1.6*	*38.5*	*3.8*	*27.3*	*1.8*	*7.5*	*15.5*	*3.4*
Palladium	0.0[b]	*7.5*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	*12.7*	0.0[b]	0.0[b]
Silver	0.0[b]	*1.1*	0.0[b]	0.0[b]	0.0[b]	*2.7*	0.0[b]	0.0[b]	0.0[b]
Cadmium	*77.6*	*6.6*	*44.1*	0.0[b]	*120.5*	*8.7*	0.0[b]	*43.3*	0.0[b]
Indium	*139.5*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	*9.4*	0.0[b]
Tin	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Antimony	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]

Test No.	24	24	24R	24R	31	31	20	20	20
Cooking Type	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Fry Beef	Full Meal	Full Meal	Full Meal
Pan Material	Cast Iron	Cast Iron	Cast Iron	Cast Iron	Teflon® w/lid	Teflon® w/lid	Multiple types	Multiple types	Multiple types
Range Type	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas	Gas
Location	K	OUT	K	OUT	K	OUT	K	K	OUT
Barium	*610.3*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	*262.5*	0.0[b]	0.0[b]
Lanthanum	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	*28.8*	0.0[b]	*86.9*	*27.7*
Gold	0.0[b]	0.0[b]	*13.5*	*0.6*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Mercury	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Thallium	*33.2*	0.0[b]	0.0[b]	0.0[b]	*4.1*	0.0[b]	0.0[b]	*8.0*	*1.0*
Lead	0.0[b]	*0.1*	*36.9*	*1.2*	*7.4*	*1.0*	0.0[b]	0.0[b]	*0.8*
Uranium	*32.9*	0.0[b]	*16.1*	0.0[b]	0.0[b]	*1.0*	0.0[b]	*9.0*	*2.1*

[a] Concentrations in italics are below the uncertainty level, as defined in Section 2.0
[b] Correction for background data resulted in zero or negative values.

Table 3-14. Summary Statistics for Element Measurements Indoors[a]

Element	Number Measurable	Percent Measurable	Minimum	Maximum	Average	Std. Dev.	Median
			ηg/m^3	ηg/m^3	ηg/m^3	ηg/m^3	ηg/m^3
Sodium	3	33	154.6	631.2	377.6	173.8	310.8
Magnesium	0	0	19.7	453.1	158.8	169.1	104.7
Aluminum	6	67	77.8	539.5	228.8	162.8	171.6
Silicon	9	100	460.8	8532	2254	2688	855.4
Phosphorous	8	89	18.0	7937	1007	2600	166.2
Sulfur	8	89	77.6	2198	848.5	804.6	322.2
Chlorine	6	67	49.3	6458	1221	2034	720.5
Potassium	7	78	4.3	3832	737.9	1296	152.7
Calcium	9	100	94.7	595.3	340.9	147.6	345.4
Titanium	0	0	4.2	55.5	22.3	18.3	16.7
Vanadium	0	0	20.4	30.0	24.3	5.1	22.6
Chromium	4	44	6.1	1222	192.6	418.4	30.6
Manganese	0	0	0.0	0.0	0.0	0.0	0.0
Iron	8	89	60.2	221.1	103.7	50.4	102.3
Cobalt	0	0	0.6	7.4	3.7	2.9	3.5
Nickel	2	22	0.1	37.7	12.1	16.3	3.3
Copper	8	89	42.9	273.7	104.2	67.0	92.3
Zinc	7	78	21.5	69.8	49.5	17.1	58.0
Gallium	0	0	7.4	19.3	13.3	8.4	13.3
Arsenic	0	0	2.2	5.3	3.9	1.6	4.2
Selenium	0	0	4.6	4.6	4.6	0.0	4.6
Bromine	4	44	2.8	3433	431	1127	17.7
Rubidium	0	0	3.6	3.6	3.6	0.0	3.6
Strontium	0	0	0.1	6.8	3.4	3.0	2.9
Yttrium	0	0	0.1	9.8	4.4	3.9	3.4
Zirconium	1	11	3.3	26.3	15.6	8.8	15.7
Molybdenum	0	0	5.2	38.5	17.7	11.7	15.5
Palladium	0	0	12.7	12.7	12.7	0.0	12.7
Silver	0	0	17.3	89.9	53.6	51.3	53.6
Cadmium	0	0	38.1	120.5	62.7	31.6	48.5
Indium	0	0	9.4	139.5	74.4	92.0	74.4
Tin	0	0	10.0	10.0	10.0	0.0	10.0
Antimony	0	0	0.0	0.0	0.0	0.0	0.0
Barium	0	0	113.4	610.3	309.4	211.8	256.9
Lanthanum	0	0	86.9	540.3	258.2	205.3	202.9
Gold	1	11	13.5	42.0	27.2	14.3	26.1
Mercury	1	11	18.6	25.6	22.1	4.9	22.1
Thallium	0	0	3.2	33.2	10.9	12.6	6.2
Lead	0	0	2.8	36.9	17.5	15.5	15.0
Uranium	0	0	3.7	32.9	15.2	11.0	14.2

[a] Number and percent measurable: samples with concentrations above the level of uncertainty, as defined in Section 2.0; summary statistics calculated for all detectable concentrations and non-detectable samples excluded

Table 3-15. Summary Statistics for Element Measurements Outdoors[a]

Element	Number Measurable	Percent Measurable	Minimum	Maximum	Average	Std. Dev.	Median
			ηg/m^3	ηg/m^3	ηg/m^3	ηg/m^3	ηg/m^3
Sodium	7	78	47.3	1077	368.3	340.9	252.9
Magnesium	7	78	18.0	141.8	62.6	45.4	52.0
Aluminum	6	67	4.2	38.2	27.8	13.0	34.8
Silicon	7	78	31.0	180.1	108.7	48.0	106.0
Phosphorous	5	56	2.3	16.4	6.8	4.7	6.0
Sulfur	7	78	100.9	234.6	158.7	44.9	162.4
Chlorine	7	78	1.4	2667	757.9	917.4	386.3
Potassium	7	78	29.4	111.7	60.7	26.8	59.3
Calcium	7	78	37.3	133.6	57.4	34.3	45.8
Titanium	2	22	3.3	7.6	5.5	1.7	5.5
Vanadium	2	22	1.6	5.3	3.2	1.2	3.4
Chromium	2	22	0.1	1.7	1.1	0.6	1.3
Manganese	2	22	0.2	2.1	0.9	0.8	0.6
Iron	7	78	28.0	98.4	66.6	23.9	65.7
Cobalt	2	22	0.3	2.1	0.9	0.8	0.7
Nickel	2	22	0.2	0.8	0.5	0.2	0.6
Copper	6	67	2.1	8.9	4.4	2.2	4.0
Zinc	7	78	5.1	15.7	8.0	3.5	6.8
Gallium	2	22	1.3	3.9	2.2	1.5	1.4
Arsenic	2	22	0.2	2.0	0.8	0.8	0.2
Selenium	2	22	0.1	1.0	0.6	0.3	0.6
Bromine	6	67	0.9	4.8	2.2	1.3	1.9
Rubidium	2	22	0.0	0.3	0.1	0.1	0.1
Strontium	3	33	0.1	1.6	0.7	0.5	0.7
Yttrium	2	22	0.1	1.5	0.6	0.5	0.5
Zirconium	2	22	0.2	1.8	1.0	0.6	0.9
Molybdenum	2	22	1.2	3.8	2.4	1.0	2.2
Palladium	2	22	3.3	8.1	6.3	2.6	7.5
Silver	2	22	1.1	7.4	3.3	2.9	2.3
Cadmium	2	22	2.1	8.7	5.4	2.7	6.5
Indium	2	22	1.2	1.2	1.2	0	1.2
Tin	2	22	3.6	3.6	3.6	0	3.6
Antimony	2	22	4.5	4.5	4.5	0	4.5
Barium	2	22	9.2	9.2	9.2	0	9.2
Lanthanum	2	22	27.7	28.8	28.2	0.8	28.2
Gold	2	22	0.6	1.1	0.9	0.4	0.9
Mercury	2	22	0.5	1.6	1.2	0.6	1.6
Thallium	2	22	0.4	1.4	0.9	0.4	1.0
Lead	2	22	0.1	4.2	1.8	1.5	1.2
Uranium	2	22	0.2	2.1	1.3	0.7	1.4

[a] Number and percent measurable: samples with concentrations above the level of uncertainty, as defined in Section 2.0; summary statistics calculated for all detectable concentrations and non-detectable samples excluded

3.5 PAH Measurement Results

Samples were collected during selected tests for measurements of total PAHs (combined gas-phase and PM_{10} particulate phase). PAH samples were collected in Test No. 30 (stir-fry with vegetable oil) for comparison to emissions during stir-fry cooking with peanut oil, which had higher PAH concentrations in the bulk formulation (Table 3-2). Samples were also collected during the full meal cooking test and a limited number of other tests, as shown in Table 3-16. The table includes results for PAHs that were targeted for analysis in the study and a number of other semi-volatile compounds that were analyzed targeted for quantitation by DRI at the time of the main study. As shown in the table, the concentrations of the PAHs and other SVOCs were generally low. The summary statistics for the 13 samples collected in the main study are presented in Table 3-17. The results are discussed in Section 4.

3.6 Aldehyde Measurement Results

Although aldehydes were not originally targeted for measurement in the Study Design, a limited number of samples were collected to determine the magnitude of emissions during selected cooking events. The results of the measurements are presented in Table 3-18 and discussed in Section 4.

3.7 CO, NO, and NO_2 Concentrations During Cooking Tests

CO, NO, and NO_2 were measured continuously during the cooking tests with a system that collected samples sequentially from the kitchen, living room, master bedroom, and outdoors. The data were processed to obtain average concentrations during the cooking period and for the total exposure period. For each pollutant, two tables of summary data are presented. The first table presents the average and maximum concentrations during the cooking period, that is, from the time the oven or burner was turned on until it was turned off. The second table for each pollutant presents the average and maximum concentrations for the total exposure period, which included both the cooking period plus the one-hour post-cooking exposure period. For tests that had multiple cooking events, for example for broiling fish, the data are summarized for the separate cooking events. Results of the measurements and summary statistics for all 32 cooking tests are presented in Tables 3-19 through 3-24. The results are discussed in Section 4.

Table 3-16. PAH Concentrations (ηg/m^3) Measured during Cooking Tests[a]

Test No.	21	18,19,21	17	17- Dup	30	17,30
Cooking Method	Stir Fry		Stir Fry	Stir Fry	Stir Fry	
Range	Gas		Gas	Gas	Gas	
Test Type	Standard		Worst Case		Standard	
Cooking Oil	Peanut Oil		Peanut Oil	Peanut Oil	Veg. Oil	
Sampling Location	K	OUT	K	K	K	OUT
Acenaphthylene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Acenaphthene	0.0[b]	0.0[b]	0.0[b]	9.0	0.0[b]	0.0[b]
Phenanthrene [c,m]	53.3	6.2	21.6	0.0[b]	33.6	0.0[b]
Anthracene [c,m]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]

Test No.	21	18,19,21	17	17- Dup	30	17,30
Cooking Method	Stir Fry		Stir Fry	Stir Fry	Stir Fry	
Range	Gas		Gas	Gas	Gas	
Test Type	Standard		Worst Case		Standard	
Cooking Oil	Peanut Oil		Peanut Oil	Peanut Oil	Veg. Oil	
Sampling Location	K	OUT	K	K	K	OUT
Fluoranthene [m,r]	19.8	0.0[b]	0.0[b]	0.0[b]	*0.7*[a]	0.0[b]
Pyrene [c,m]	16.3	0.0[b]	19.1	9.0	17.4	0.0[b]
Benz(a)anthracene [c,m]	0.0[b]	*0.7*	0.0[b]	0.0[b]	*17.6*	0.0[b]
Chrysene [c]	0.0[b]	*0.2*	0.0[b]	*5.7*	0.0[b]	0.0[b]
Benzo(b+j+k)phenanthrene	*6.6*	*2.5*	0.0[b]	*7.4*	0.0[b]	4.8
BeP [c,m]	*3.5*	*0.2*	*9.6*	*0.8*	*4.3*	3.5
BaP [c,m]	*2.6*	*0.4*	*3.7*	0.0[b]	*2.7*	2.1
Indeno[1,2,3-cd]pyrene [c]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Benzo(g,h,i)perylene	0.0[b]	*0.1*	0.0[b]	0.0[b]	*0.5*	0.0[b]
Coronene	0.0[b]	*0.7*	*6.2*	*1.2*	0.0[b]	0.0[b]
Naphthalene	600.6	0.0[b]	631.4	0.0[b]	646.1	0.0[b]
Fluorene	40.5	*8.1*	*23.3*	*21.8*	33.4	5.1
2-Methylnaphthalene	33.0	8.5	27.4	22.2	43.9	0.0[b]
1-Methylnaphthalene	41.0	7.8	53.6	20.9	50.7	0.0[b]
Biphenyl	36.6	3.1	28.3	37.8	34.0	0.0[b]
1+2-Ethylnaphthalene	0.0[b]	10.3	28.7	23.4	0.0[b]	6.9
2,6+2,7-Dimethylnaphthalene	*22.5*	*5.0*	*18.7*	*27.1*	*49.4*	0.0[b]
1,3+1,6+1,7-Dimethylnaphthalene	*57.3*	*6.9*	*56.5*	*68.2*	*55.9*	0.0[b]
1,4+1,5+2,3-Dimethylnaphthalene	*17.2*	*3.2*	*20.0*	*14.8*	*23.0*	0.0[b]
1,2-Dimethylnaphthalene	0.0[b]	*1.3*	*0.8*	0.0[b]	0.0[b]	0.0[b]
2-Methylbiphenyl	736.7	0.0[b]	602.7	0.0[b]	588.6	0.0[b]
3-Methylbiphenyl	103.5	0.0[b]	298.5	220.9	0.0[b]	0.0[b]
4-Methylbiphenyl	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
a-Trimethylnaphthalene	10.1	75.6	19.5	63.6	0.0[b]	9.9
c-Trimethylnaphthalene	15.9	3.9	10.0	17.2	23.0	2.7
2-Ethyl-1-methylnaphthalene	*2.6*	0.0[b]	0.0[b]	0.0[b]	*0.7*	0.0[b]
e-Trimethylnaphthalene	22.0	4.5	9.6	18.1	27.9	3.5
f-Trimethylnaphthalene	11.9	1.8	5.0	8.6	17.6	0.0[b]
2,3,5+I-Trimethylnaphtalene	14.1	8.1	13.3	25.5	16.5	0.4
2,4,5-Trimethylnaphthalene	0.0[b]	*0.8*	0.0[b]	0.0[b]	0.0[b]	0.0[b]
j-Trimethylnaphthalene	5.3	1.8	22.4	28.3	9.5	1.1
1,4,5-Trimethylnaphthalene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
1,2,8-Trimethylnaphthalene	*4.4*	*1.5*	*16.6*	*9.0*	0.0[b]	1.2
a-Methylfluorene	28.6	0.6	27.0	5.7	24.6	0.9

Test No.	**21**	**18,19,21**	**17**	**17- Dup**	**30**	**17,30**
Cooking Method	Stir Fry		Stir Fry	Stir Fry	Stir Fry	
Range	Gas		Gas	Gas	Gas	
Test Type	Standard		Worst Case		Standard	
Cooking Oil	Peanut Oil		Peanut Oil	Peanut Oil	Veg. Oil	
Sampling Location	K	OUT	K	K	K	OUT
1-Methylfluorene	0.0[b]	0.0[b]	3.3	14.4	0.0[b]	0.0[b]
b-Methylfluorene	*4.0*	*0.4*	*6.2*	*2.5*	*3.4*	1.6
9-Fluorenone	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Xanthone	0.0[b]	6.0	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Acenaphthenequinone	0.0[b]	0.0[b]	0.0[b]	9.9	0.0[b]	0.0[b]
Perinaphthenone	*8.4*	*0.8*	*4.2*	0.0[b]	21.4	14.0
a-Methylphenanthrene	6.2	0.9	5.8	0.0[b]	7.0	0.0[b]
2-Methylphenanthrene	15.4	0.0[b]	0.0[b]	0.0[b]	6.3	0.0[b]
b-Methylphenanthrene	*2.2*	0.0[b]	0.0[b]	0.0[b]	*2.9*	0.0[b]
c-Methylphenanthrene	22.9	0.0[b]	2.9	0.0[b]	5.2	0.0[b]
1-Methylphenanthrene	65.2	0.0[b]	4.2	0.0[b]	0.0[b]	0.0[b]
Anthraquinone	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
3,6-Dimethylphenanthre	15.0	1.2	0.0[b]	0.0[b]	0.0[b]	0.0[b]
a-Dimethylphenanthrene	11.9	2.5	5.0	0.0[b]	0.0[b]	0.0[b]
b-Dimethylphenanthrene	14.1	0.0[b]	0.8	0.0[b]	0.0[b]	0.0[b]
c-Dimethylphenanthrene	31.7	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
1,7-Dimethylphenanthre	13.7	0.0[b]	0.4	0.0[b]	0.0[b]	0.0[b]
d-Dimethylphenanthrene	4.0	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
e-Dimethylphenanthrene	11.0	0.0[b]	0.0[b]	0.0[b]	6.5	0.0[b]
9-Methylanthracene	0.0[b]	*11.4*	0.0[b]	0.0[b]	0.0[b]	0.0[b]
9-Anthraldehyde	*20.7*	0.0[b]	*4.6*	0.0[b]	0.0[b]	0.0[b]
Retene	13.7	1.9	30.3	0.0[b]	3.8	0.0[b]
Benzonaphthothiophene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
1-MeFl+C-MePy/Fl	56.4	0.0[b]	4.6	0.0[b]	0.0[b]	0.0[b]
a-MePy/MeFl	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
b-MePy/MeFl	*7.5*	0.0[b]	*10.8*	0.0[b]	*11.7*	0.0[b]
c-MePy/MeFl	*4.8*	0.0[b]	0.0[b]	*5.7*	*0.9*	1.4
d-MePy/MeFl	8.8	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
4-Methylpyrene	*1.3*	0.0[b]	0.0[b]	*11.1*	*0.7*	0.5
1-Methylpyrene	*4.0*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Benzo(c)phenanthrene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
7-Methylbenz(a)anthracene	*1.3*	0.0[b]	*2.5*	*1.2*	39.2	0.0[b]
Benz(a)anthracene-7,12-dione	*4.4*	10.8	*0.4*	0.0[b]	4.5	2.8
5+6-Methylchrysene	0.0[b]	*1.8*	0.0[b]	0.0[b]	*3.4*	0.0[b]

Test No.	21	18,19,21	17	17- Dup	30	17,30
Cooking Method	Stir Fry		Stir Fry	Stir Fry	Stir Fry	
Range	Gas		Gas	Gas	Gas	
Test Type	Standard		Worst Case		Standard	
Cooking Oil	Peanut Oil		Peanut Oil	Peanut Oil	Veg. Oil	
Sampling Location	K	OUT	K	K	K	OUT
7-Methylbenzo(a)pyrene	0.0[b]	*35.1*	0.0[b]	0.0[b]	*1187.4*	0.0[b]
Perylene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Dibenz(ah+ac)anthracene	*5.7*	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]
Benzo(b)chrysene	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]	0.0[b]

[a] Concentrations in italics are below the uncertainty level, as defined in Section 2.0
[b] Correction with background data resulted in zero or negative value.
[c] Designated as a carcinogen or probable carcinogen
[m] Designated as a mutagen
[t] Designated as a teratogen

Designations from: U.S. Environmental Protection Agency (USEPA), 1989a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume I, Part A. Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December.

Table 3-16 (continued) PAH Concentrations (ηg/m^3) Measured during Cooking Tests[a]

Test No.	18	19	20	20-Dup	20	22	22
Cooking Method	Bacon	Fish	Full Meal	Full Meal		Fr. Fries	
Range	Gas	Gas	Gas	Gas		Gas	
Test Type	Worst Case	Worst Case	Standard	Standard		Standard	
Cooking Oil		Olive				Veg.	
Sampling Location	K	K	K	K	OUT	K	OUT
Acenaphthylene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Acenaphthene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*3.1*
Phenanthrene [c,m]	16.1	18.5	12.9	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Anthracene [c,m]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Fluoranthene [m,t]	0.0[a]	0.0[a]	*1.7*	0.0[a]	0.0[a]	0.0[a]	*2.7*
Pyrene [c,m]	7.7	16.7	15.4	0.4	4.9	6.0	*2.4*
Benz(a)anthracene [c,m]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Chrysene [c]	*10.5*	*0.8*	11.5	0.0[a]	0.0[a]	0.0[a]	*0.9*
Benzo(b+j+k)phenanthrene	*7.3*	*0.6*	*2.5*	0.0[a]	*1.8*	0.0[a]	*1.3*
BeP [c,m]	0.0[a]	*8.3*	*8.1*	*2.9*	*2.4*	0.0[a]	0.0[a]
BaP [c,m]	0.0[a]	*20.6*	0.0[a]	*1.1*	*3.7*	0.0[a]	0.0[a]
Indeno[1,2,3-cd]pyrene [c]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Benzo(g,h,i)perylene	0.0[a]	*9.2*	0.0[a]	*1.4*	0.0[a]	0.0[a]	0.0[a]
Coronene	0.0[a]	0.0[a]	*2.5*	0.0[a]	*2.8*	0.0[a]	*0.7*
Naphthalene	365.5	553.6	284.9	0.0[a]	0.0[a]	44.9	154.6
Fluorene	*28.6*	*28.3*	34.2	*12.6*	*7.0*	*13.4*	*0.2*
2-Methylnaphthalene	89.5	53.1	167.6	18.3	10.1	40.2	0.0[a]
1-Methylnaphthalene	94.3	58.7	174.3	33.4	15.6	55.5	0.0[a]
Biphenyl	35.9	51.4	69.6	15.8	0.0[a]	27.3	0.0[a]
1+2-Ethylnaphthalene	0.0[a]	38.1	40.4	0.0[a]	14.7	44.4	*9.3*
2,6+2,7-Dimethylnaphthalene	*23.0*	*19.4*	*49.7*	*24.8*	*2.8*	*27.7*	0.0[a]
1,3+1,6+1,7-Dimethylnaphthalene	*58.4*	*41.0*	92.1	*47.8*	*15.0*	*68.4*	0.0[a]
1,4+1,5+2,3-Dimethylnaphthalene	*15.7*	*15.0*	*37.9*	*15.1*	*4.6*	*16.6*	0.0[a]
1,2-Dimethylnaphthalene	*4.4*	*3.3*	*15.7*	*24.4*	*0.6*	0.0[a]	*4.9*
2-Methylbiphenyl	42.7	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	258.0
3-Methylbiphenyl	0.0[a]	46.6	0.0[a]	0.0[a]	0.0[a]	24.0	103.2
4-Methylbiphenyl	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
a-Trimethylnaphthalene	121.7	50.2	11.5	78.3	*1.5*	48.1	1.6
c-Trimethylnaphthalene	14.5	15.0	30.3	21.5	11.9	15.3	0.0[a]
2-Ethyl-1-methylnaphthalene	0.0[a]	*1.2*	*4.2*	0.0[a]	*0.9*	0.0[a]	0.0[a]
e-Trimethylnaphthalene	22.6	17.7	25.0	14.7	8.9	*14.8*	*2.2*
f-Trimethylnaphthalene	13.3	8.1	16.0	5.4	5.5	5.5	0.0[a]

Test No.	18	19	20	20-Dup	20	22	22
Cooking Method	Bacon	Fish	Full Meal	Full Meal		Fr. Fries	
Range	Gas	Gas	Gas	Gas		Gas	
Test Type	Worst Case	Worst Case	Standard	Standard		Standard	
Cooking Oil		Olive				Veg.	
Sampling Location	K	K	K	K	OUT	K	OUT
2,3,5+I-Trimethylnaphtalene	20.1	13.9	30.9	13.6	6.1	24.5	11.6
2,4,5-Trimethylnaphthalene	0.0[a]	0.0[a]	*0.3*	0.0[a]	0.0[a]	0.0[a]	0.0[a]
j-Trimethylnaphthalene	2.4	13.1	32.0	0.0[a]	11.0	*2.8*	0.0[a]
1,4,5-Trimethylnaphthalene	21.4	0.0[a]	*1.4*	0.0[a]	0.0[a]	*0.9*	*4.9*
1,2,8-Trimethylnaphthalene	*18.5*	*11.7*	*4.5*	*0.4*	0.0[a]	*24.0*	0.0[a]
a-Methylfluorene	17.7	19.6	27.5	10.4	1.5	21.7	0.0[a]
1-Methylfluorene	0.0[a]	10.2	0.0[a]	0.0[a]	0.0[a]	12.0	0.0[a]
b-Methylfluorene	*6.0*	0.0[a]	*3.4*	*2.2*	0.0[a]	0.0[a]	*2.0*
9-Fluorenone	0.0[a]	32.9	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Xanthone	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Acenaphthenequinone	0.0[a]	2.5	0.0[a]	0.0[a]	0.0[a]	22.2	0.0[a]
Perinaphthenone	*4.0*	*1.7*	0.0[a]	19.8	*3.1*	*0.5*	*6.5*
a-Methylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	2.2
2-Methylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.9
b-Methylphenanthrene	*0.8*	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*0.9*	0.0[a]
c-Methylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	17.1
1-Methylphenanthrene	4.0	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Anthraquinone	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
3,6-Dimethylphenanthre	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
a-Dimethylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	3.3
b-Dimethylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	2.9
c-Dimethylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	10.0
1,7-Dimethylphenanthre	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	13.1
d-Dimethylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	3.3
e-Dimethylphenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	10.5
9-Methylanthracene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*118.1*
9-Anthraldehyde	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Retene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	12.5
Benzonaphthothiophene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
1-MeFl+C-MePy/Fl	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	4.9
a-MePy/MeFl	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
b-MePy/MeFl	0.0[a]	*4.6*	*2.2*	*8.3*	*2.4*	*9.2*	*0.2*
c-MePy/MeFl	0.0[a]	*0.8*	*0.6*	0.0[a]	0.0[a]	0.0[a]	0.0[a]
d-MePy/MeFl	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
4-Methylpyrene	0.0[a]	*7.5*	*4.2*	*1.1*	*3.7*	*6.9*	*3.3*
1-Methylpyrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*0.9*	0.0[a]	0.0[a]
Benzo(c)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*49.2*

Test No.	18	19	20	20-Dup	20	22	22
Cooking Method	Bacon	Fish	Full Meal	Full Meal		Fr. Fries	
Range	Gas	Gas	Gas	Gas		Gas	
Test Type	Worst Case	Worst Case	Standard	Standard		Standard	
Cooking Oil		Olive				Veg.	
Sampling Location	K	K	K	K	OUT	K	OUT
7-Methylbenz(a)anthracene	*1.2*	*1.2*	114.5	20.5	*0.9*	*25.0*	*5.3*
Benz(a)anthracene-7,12-dione	*11.3*	*0.4*	*1.1*	*5.7*	*4.9*	*3.2*	*6.5*
5+6-Methylchrysene	0.0[a]	*3.1*	49.7	*20.5*	0.0[a]	*15.3*	*0.7*
7-Methylbenzo(a)pyrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]
Perylene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	*0.2*
Dibenz(ah+ac)anthracene	0.0[a]	0.0[a]	0.0[a]	*0.4*	*3.1*	0.0[a]	0.0[a]
Benzo(b)chrysene	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]	0.0[a]

[a] Correction with background data resulted in zero or negative value.
[c] Designated as a carcinogen or probable carcinogen
[m] Designated as a mutagen
[t] Designated as a teratogen

Designations from: U.S. Environmental Protection Agency (USEPA), 1989a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume I, Part A. Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December.

Table 3-17 Summary Statistics for Indoor and Outdoor PAH Measurements

Compound	N	Measurable	Minimum	Maximum
		%	ηg/m^3	ηg/m^3
Acenaphthylene	0	0%	--	--
Acenaphthene	2	15%	0	9.0
Phenanthrene [c,m]	7	54%	0	53.3
Anthracene [c,m]	0	0%	--	--
Fluoranthene [m,t]	4	31%	0	19.8
Pyrene [c,m]	11	85%	0	19.1
Benz(a)anthracene [c,m]	2	15%	0	17.6
Chrysene [c]	6	46%	0	11.5
Benzo(b+j+k)phenanthrene	9	69%	0	7.4
BeP [c,m]	10	77%	0	9.6
BaP [c,m]	8	62%	0	20.6
Indeno[123-cd]pyrene [c]	0	0%	--	--
Benzo(ghi)perylene	4	31%	0	9.2
Coronene	6	46%	0	6.2
Naphthalene	8	62%	0	646.1
Fluorene	13	100%	0	40.5
2-Methylnaphthalene	11	85%	0	167.6
1-Methylnaphthalene	11	85%	0	174.3
Biphenyl	10	77%	0	69.6
1+2-Ethylnaphthalene	9	69%	0	44.4
2,6+2,7-Dimethylnaphthalene	11	85%	0	49.7
1,3+1,6+1,7-Dimethylnaphthalene	11	85%	0	92.1
1,4+1,5+2,3-Dimethylnaphthalene	11	85%	0	37.9
1,2-Dimethylnaphthalene	8	62%	0	24.4
2-Methylbiphenyl	5	38%	0	736.7
3-Methylbiphenyl	6	46%	0	298.5
4-Methylbiphenyl	0	0%	--	--
a-Trimethylnaphthalene	12	92%	0	121.7
c-Trimethylnaphthalene	12	92%	0	30.3
2-Ethyl-1-methylnaphthalene	5	38%	0	4.2
e-Trimethylnaphthalene	13	100%	0	27.9
f-Trimethylnaphthalene	11	85%	0	17.6
2,3,5+I-Trimethylnaphtalene	13	100%	0	30.9
2,4,5-Trimethylnaphthalene	2	15%	0	0.8
j-Trimethylnaphthalene	11	85%	0	32.0
1,4,5-Trimethylnaphthalene	4	31%	0	21.4
1,2,8-Trimethylnaphthalene	10	77%	0	24.0

Compound	N	Measurable	Minimum	Maximum
		%	ηg/m^3	ηg/m^3
a-Methylfluorene	12	92%	0	28.6
1-Methylfluorene	4	31%	0	14.4
b-Methylfluorene	10	77%	0	6.2
9-Fluorenone	1	8%	--	--
Xanthone	1	8%	--	--
Acenaphthenequinone	3	23%	0	22.2
Perinaphthenone	11	85%	0	21.4
a-Methylphenanthrene	5	38%	0	7.0
2-Methylphenanthrene	3	23%	0	15.4
b-Methylphenanthrene	4	31%	0	2.9
c-Methylphenanthrene	4	31%	0	22.9
1-Methylphenanthrene	3	23%	0	65.2
Anthraquinone	0	0%	--	--
3,6-Dimethylphenanthre	2	15%	0	15.0
a-Dimethylphenanthrene	4	31%	0	11.9
b-Dimethylphenanthrene	3	23%	0	14.1
c-Dimethylphenanthrene	2	15%	0	31.7
1,7-Dimethylphenanthre	3	23%	0	13.7
d-Dimethylphenanthrene	2	15%	0	4.0
e-Dimethylphenanthrene	3	23%	0	11.0
9-Methylanthracene	2	15%	0	118.1
9-Anthraldehyde	2	15%	0	20.7
Retene	5	38%	0	30.3
Benzonaphthothiophene	0	0%	--	--
1-MeFl+C-MePy/Fl	3	23%	0	56.4
a-MePy/MeFl	0	0%	--	--
b-MePy/MeFl	9	69%	0	11.7
c-MePy/MeFl	6	46%	0	5.7
d-MePy/MeFl	1	8%	0	8.8
4-Methylpyrene	10	77%	0	11.1
1-Methylpyrene	2	15%	0	4.0
Benzo(c)phenanthrene	1	8%	0	49.2
7-Methylbenz(a)anthracene	11	85%	0	114.5
Benz(a)anthracene-7,12-dione	12	92%	0	11.3
5+6-Methylchrysene	7	54%	0	49.7
7-Methylbenzo(a)pyrene	2	15%	0	1187.4
Perylene	1	8%	0	0.2
Dibenz(ah+ac)anthracene	3	23%	0	5.7

Compound	N	Measurable	Minimum	Maximum
		%	ηg/m^3	ηg/m^3
Benzo(b)chrysene	0	0%	--	--

[c] Designated as a carcinogen or probable carcinogen
[m] Designated as a mutagen
[t] Designated as a teratogen

Designations from: U.S. Environmental Protection Agency (USEPA), 1989a. Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Volume I, Part A. Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December.

Table 3-18. Aldehyde Measurement Results

Test No.	Type	Range	Conditions		µg/m³	
					K	OUT
1	Oven Cleaning	Gas	Standard	Formaldehyde	417.3	2.7
				Acetaldehyde	433.7	0.25[a]
				Propanal	144.3	0.25[a]
				Butanal	72.4	0.25[a]
				Benzaldehyde	16.1	0.25[a]
				Pentanal	145.7	0.25[a]
				Hexanal	131.3	0.25[a]
6	Broil Fish	Gas	Standard	Formaldehyde	129.3	1.5
				Acetaldehyde	92.3	0.25[a]
				Propanal	28.5	0.25[a]
				Butanal	11.1	0.25[a]
				Benzaldehyde	8.6	0.25[a]
				Pentanal	20.2	0.25[a]
				Hexanal	26.5	0.25[a]
8	Oven Cleaning	Electric	Standard	Formaldehyde	224.5	0.8
				Acetaldehyde	330.8	0.25[a]
				Propanal	86.6	0.25[a]
				Butanal	40.2	0.25[a]
				Benzaldehyde	13.0	0.25[a]
				Pentanal	81.7	0.25[a]
				Hexanal	76.9	0.25[a]
13	Broil Fish	Electric	Standard	Formaldehyde	129.4	0.4
				Acetaldehyde	109.2	0.7
				Propanal	34.3	0.25[a]
				Butanal	14.6	0.25[a]
				Benzaldehyde	3.8	0.25[a]
				Pentanal	24.5	0.25[a]
				Hexanal	34.4	0.25[a]
25	Pork Roast	Gas	Aluminum Pan	Formaldehyde	49.1	1.0
				Acetaldehyde	13.2	16.6
				Propanal	3.0	0.25[a]
				Butanal	1.6	0.25[a]
				Benzaldehyde	0.0	0.25[a]
				Pentanal	4.3	0.25[a]
				Hexanal	13.7	0.25[a]

Test No.	Type	Range	Conditions		µg/m³	
					K	OUT
27	Pork Roast	Gas	Exhaust Ventilation	Formaldehyde	36.5	1.1
				Acetaldehyde	14.2	1.0
				Propanal	1.9	0.25[a]
				Butanal	1.1	0.25[a]
				Benzaldehyde	0.0	0.25[a]
				Pentanal	3.0	0.25[a]
				Hexanal	10.2	0.25[a]

Summary Statistics		Indoor	Indoor	Indoor
		N	Minimum	Maximum
	Formaldehyde	6	36.5	417.3
	Acetaldehyde	6	13.2	433.7
	Propanal	6	1.9	144.3
	Butanal	6	1.1	72.4
	Benzaldehyde	4	0.0	16.1
	Pentanal	6	3.0	145.7
	Hexanal	6	10.2	131.3
		Outdoor	Outdoor	Outdoor
		N	Minimum	Maximum
	Formaldehyde	6	0.4	2.7
	Acetaldehyde	6	0.25[a]	16.6
	Propanal	6	0.25[a]	0.25[a]
	Butanal	6	0.25[a]	0.25[a]
	Benzaldehyde	6	0.25[a]	0.25[a]
	Pentanal	6	0.25[a]	0.25[a]
	Hexanal	6	0.25[a]	0.25[a]

[a] – Below detection limits. Value taken at ½ MDL.

Table 3-19. Average CO Concentrations (ppm) Measured at Four Locations during the Cooking Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	14.8	19.9	14.9	19.9	14.8	20.0	0.6	0.9
2	Stovetop Stir Fry	Gas	Standard	1.2	1.5	1.4	2.2	0.9	1.4	0.4	0.5
3A	Bacon	Gas	Standard	0.4	0.5	0.4	0.5	0.5	0.8	0.4	0.4
3B	Bacon	Gas	Standard	1.0	1.0	1.0	1.0	0.9	1.2	0.3	0.3
4	Tortillas	Gas	Standard	0.8	1.2	0.9	1.1	0.8	1.1	0.3	0.3
5	French Fries	Gas	Standard	2.5	4.6	2.5	4.7	2.4	4.4	0.3	0.4
6A	Broil Fish	Gas	Standard	3.2	4.0	4.0	4.4	2.6	4.0	0.3	0.4
6B	Broil Fish	Gas	Standard	10.1	11.4	8.9	9.6	8.6	9.4	0.3	0.4
7	Bake Lasagne	Gas	Standard	2.5	3.6	2.6	3.3	2.4	3.4	0.3	0.6
8	Oven Cleaning	Electric	Standard	7.8	12.0	7.9	12.1	7.5	11.5	0.6	1.1
9	Stovetop Stir Fry	Electric	Standard	0.7	0.7	0.9	0.9	0.7	0.8	0.5	0.6
10A	Bacon	Electric	Standard	0.5	0.7	0.4	0.5	0.4	0.5	0.4	0.4
10B	Bacon	Electric	Standard	0.5	0.5	0.5	0.6	0.5	0.6	0.4	0.5
11	Tortillas	Electric	Standard	1.1	1.4	1.2	1.4	1.1	1.5	0.5	0.8
12	French Fries	Electric	Standard	1.0	1.2	1.1	1.2	0.8	0.9	0.6	0.7
13A	Broil Fish	Electric	Standard	0.6	0.7	0.8	0.8	0.8	0.9	0.7	0.8
13B	Broil Fish	Electric	Standard	2.6	2.6	2.9	3.6	2.6	3.2	0.6	0.6
14	Lasagne	Electric	Standard	0.6	1.1	0.6	1.3	0.7	1.2	0.4	1.1
15A	Bacon	Microwave	Standard	0.6	0.7	0.6	0.7	0.7	0.8	0.8	1.1
15B	Bacon	Microwave	Standard	0.9	0.9	0.9	0.9	0.8	1.0	0.8	0.9
16	Lasagne	Microwave	Standard	0.7	0.8	0.7	0.8	0.7	0.7	0.5	0.5
17A	Stovetop Stir Fry	Gas	Worst Case	1.1	1.8	0.8	1.6	0.7	1.4	0.2	0.3
17B	Stovetop Stir Fry	Gas	Worst Case	2.5	3.0	2.7	3.5	2.4	3.0	0.1	0.1
18A	Bacon	Gas	Worst Case	1.0	1.3	1.3	1.6	0.9	1.4	0.5	0.6
18B	Bacon	Gas	Worst Case	1.7	2.1	1.8	2.2	1.8	2.3	0.4	0.4
19A	Broil Fish	Gas	Worst Case	3.3	4.8	3.8	5.4	2.4	3.6	0.5	0.6
19B	Broil Fish	Gas	Worst Case	3.7	4.7	4.6	6.8	3.5	4.3	0.8	0.9
20	Full Meal	Gas	Standard	4.6	8.8	4.6	9.5	4.4	9.1	0.4	0.6

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	1.1	1.8	1.1	1.6	0.6	0.9	0.4	0.5
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	2.6	3.3	2.8	3.2	2.2	2.4	0.4	0.4
22	French Fries	Gas	Test 5 Replicate	4.3	7.5	4.1	7.0	3.1	5.9	0.4	0.5
23	Bake Lasagne	Gas	Test 7 Replicate	2.0	2.9	1.8	2.9	1.7	2.7	0.3	0.6
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	0.9	1.0	0.9	1.0	1.0	1.0	0.5	0.6
24RB	Fry Beef	Gas	Cast Iron Pan	1.0	1.1	1.1	1.1	1.0	1.1	0.5	0.5
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventillation	0.9	0.9	0.8	0.8	0.8	0.9	0.5	0.6
27	Pork Roast	Gas	Exhaust Ventillation	1.2	1.8	1.2	1.7	1.1	1.5	0.5	0.7
28	Fry Beef	Gas	Range Hood Shields	0.4	0.4	0.4	0.5	0.4	0.5	0.3	0.3
29	Pork Roast	Gas	Range Hood Shields	1.0	2.0	0.9	1.4	0.9	1.5	0.3	0.4
30A	Stovetop Stir Fry	Gas	Vegetable Oil	0.9	1.5	0.9	1.3	0.6	0.7	0.1	0.1
30B	Stovetop Stir Fry	Gas	Vegetable Oil	1.7	1.9	2.2	2.5	1.8	2.0	0.2	0.2
31A	Fry Beef	Gas	Pan Lid	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4
31B	Fry Beef	Gas	Pan Lid	0.4	0.4	0.6	0.7	0.5	0.6	0.3	0.3
32A	Popcorn	Microwave	Standard	0.8	0.9	0.9	0.9	0.8	0.8	1.1	1.1
32B	Popcorn	Microwave	Standard	0.9	0.9	1.0	1.0	0.9	0.9	0.8	0.8
33	Burner Baseline	Gas		3.2	5.1	3.5	5.3	2.8	4.6	1.2	1.4
34	Oven Baseline	Gas		2.0	3.0	2.0	3.3	2.1	3.2	0.5	0.6
N				44	44	44	44	44	44	44	44
Minimum				0.4	0.4	0.4	0.4	0.4	0.5	0.1	0.1
Maximum				14.8	19.9	14.9	19.9	14.8	20.0	1.1	1.1

[a] No sample – data acquisition system failed on this day of testing

Table 3-20. Average CO Concentrations (ppm) Measured at Four Locations during the Total Exposure Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	13.7	19.9	13.8	19.9	13.9	20.0	0.6	0.9
2	Stovetop Stir Fry	Gas	Standard	2.0	2.3	1.9	2.4	1.8	2.3	0.5	0.6
3A	Bacon	Gas	Standard	0.6	1.0	0.7	1.2	0.7	0.9	0.5	0.6
3B	Bacon	Gas	Standard	1.1	1.2	1.0	1.1	1.0	1.2	0.5	0.6
4	Tortillas	Gas	Standard	1.0	1.3	1.0	1.2	1.0	1.2	0.3	0.4
5	French Fries	Gas	Standard	3.5	5.1	3.4	4.9	3.6	5.0	0.3	0.4
6A	Broil Fish	Gas	Standard	6.9	9.3	7.0	8.9	6.9	9.4	0.3	0.4
6B	Broil Fish	Gas	Standard	11.7	13.2	11.5	13.3	11.6	13.5	0.3	0.4
7	Bake Lasagna	Gas	Standard	2.7	3.7	2.8	3.7	2.6	3.6	0.3	0.6
8	Oven Cleaning	Electric	Standard	7.2	12.0	7.2	12.1	6.9	11.5	0.5	1.1
9	Stovetop Stir Fry	Electric	Standard	0.6	0.7	0.6	0.9	0.5	0.8	0.4	0.6
10A	Bacon	Electric	Standard	0.4	0.7	0.4	0.5	0.4	0.5	0.3	0.4
10B	Bacon	Electric	Standard	0.5	0.5	0.5	0.7	0.4	0.6	0.4	0.7
11	Tortillas	Electric	Standard	1.1	1.4	1.1	1.4	1.1	1.5	0.3	0.8
12	French Fries	Electric	Standard	0.8	1.2	0.8	1.2	0.8	1.1	0.4	0.7
13A	Broil Fish	Electric	Standard	2.0	2.8	2.1	3.0	1.9	2.7	0.4	0.8
13B	Broil Fish	Electric	Standard	3.4	3.9	3.4	4.0	3.4	4.0	0.3	0.6
14	Lasagna	Electric	Standard	0.6	1.1	0.7	1.3	0.7	1.2	0.4	1.1
15A	Bacon	Microwave	Standard	0.6	0.7	0.6	0.7	0.7	0.8	0.8	1.1
15B	Bacon	Microwave	Standard	0.9	1.1	0.9	1.0	0.9	1.0	0.7	0.9
16	Lasagna	Microwave	Standard	0.7	0.8	0.7	0.8	0.7	0.8	0.5	0.7
17A	Stovetop Stir Fry	Gas	Worst Case	1.8	2.3	1.7	2.3	1.6	2.1	0.2	0.3
17B	Stovetop Stir Fry	Gas	Worst Case	3.0	3.7	3.0	3.8	3.0	3.7	0.2	0.5
18A	Bacon	Gas	Worst Case	1.5	1.9	1.6	1.8	1.4	1.7	0.5	0.6
18B	Bacon	Gas	Worst Case	1.9	2.3	1.9	2.2	1.9	2.3	0.4	0.5
19A	Broil Fish	Gas	Worst Case	4.0	8.0	3.8	7.1	3.9	6.4	0.6	0.7

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
19B	Broil Fish	Gas	Worst Case	5.7	9.4	5.7	10.6	5.7	9.0	0.8	1.0
20	Full Meal	Gas	Standard	4.7	9.4	4.7	9.5	4.8	9.1	0.3	0.6
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	1.8	2.2	1.9	2.3	1.6	2.1	0.4	0.5
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	2.9	3.4	3.2	3.7	3.0	3.4	0.4	0.6
22	French Fries	Gas	Test 5 Replicate	5.2	7.5	5.0	7.0	4.7	7.1	0.4	0.7
23	Bake Lasagna	Gas	Test 7 Replicate	2.2	2.9	2.1	3.0	1.9	2.9	0.4	0.8
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	1.0	1.1	1.0	1.1	1.0	1.1	0.5	0.6
24RB	Fry Beef	Gas	Cast Iron Pan	0.9	1.1	1.0	1.1	1.0	1.1	0.5	0.6
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	0.8	0.9	0.8	0.9	0.8	0.9	0.5	0.6
27	Pork Roast	Gas	Exhaust Ventilation	1.1	1.8	1.1	1.7	1.1	1.5	0.6	0.9
28	Fry Beef	Gas	Range Hood Shields	0.4	0.5	0.4	0.5	0.4	0.6	0.3	0.5
29	Pork Roast	Gas	Range Hood Shields	0.9	2.0	0.8	1.4	0.8	1.5	0.3	0.7
30A	Stovetop Stir Fry	Gas	Vegetable Oil	1.4	1.8	1.5	2.0	1.4	1.9	0.2	0.3
30B	Stovetop Stir Fry	Gas	Vegetable Oil	2.1	2.5	2.2	2.6	2.2	2.7	0.2	0.3
31A	Fry Beef	Gas	Pan Lid	0.5	0.6	0.5	0.6	0.5	0.6	0.3	0.4
31B	Fry Beef	Gas	Pan Lid	0.6	0.7	0.6	0.7	0.6	0.7	0.3	0.4
32A	Popcorn	Microwave	Standard	0.9	0.9	0.9	0.9	0.9	1.0	0.9	1.1
32B	Popcorn	Microwave	Standard	0.9	1.1	0.9	1.0	0.9	1.0	0.7	1.0
33	Range Baseline	Gas		4.2	5.8	4.5	5.9	4.0	5.9	1.1	1.4
34	Oven Baseline	Gas		2.2	3.4	2.4	3.4	2.2	3.3	0.6	0.9
N				44	44	44	44	44	44	44	44
Minimum				0.4	0.5	0.4	0.5	0.4	0.5	0.2	0.3
Maximum				13.7	19.9	13.8	19.9	13.9	20.0	0.9	1.1

No sample – data acquisition system failed on this day of testing

Table 3-21. Average NO Concentrations (ppb) Measured at Four Locations during the Cooking Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	692.1	999.4	716.4	999.4	699.2	999.4	24.9	33.0
2	Stovetop Stir Fry	Gas	Standard	45.9	82.2	76.1	138.4	32.2	78.1	7.8	11.9
3A	Bacon	Gas	Standard	9.6	12.9	12.0	22.8	8.3	14.5	2.2	3.6
3B	Bacon	Gas	Standard	111.3	128.6	119.8	156.0	89.3	127.7	4.5	8.3
4	Tortillas	Gas	Standard	109.4	206.2	136.6	238.3	108.2	219.9	12.4	20.7
5	French Fries	Gas	Standard	282.0	514.0	282.6	548.2	282.1	519.2	17.7	28.0
6A	Broil Fish	Gas	Standard	4.9	11.2	14.3	18.8	0.9	2.3	0.0	0.0
6B	Broil Fish	Gas	Standard	29.6	40.9	24.5	38.2	27.3	37.2	8.1	13.5
7	Bake Lasagna	Gas	Standard	190.8	314.1	199.4	327.2	176.5	294.5	9.6	18.2
8	Oven Cleaning	Electric	Standard	148.9	184.2	149.3	184.8	143.1	181.9	14.8	29.9
9	Stovetop Stir Fry	Electric	Standard	14.0	19.9	15.6	19.1	14.0	19.3	12.1	14.6
10A	Bacon	Electric	Standard	11.0	14.2	6.1	8.3	10.2	11.6	12.2	20.1
10B	Bacon	Electric	Standard	5.8	13.5	20.2	29.4	7.2	14.5	10.7	18.8
11	Tortillas	Electric	Standard	8.1	15.1	9.6	18.8	6.3	11.2	3.9	14.9
12	French Fries	Electric	Standard	5.0	14.9	1.7	5.0	2.1	4.0	3.5	8.3
13A	Broil Fish	Electric	Standard	8.1	12.9	12.7	23.4	3.1	6.3	0.0	0.0
13B	Broil Fish	Electric	Standard	0.0	0.0	5.0	9.9	2.3	4.6	8.8	8.8
14	Lasagna	Electric	Standard	NA	NA	NA	NA	NA	NA	NA	NA
15A	Bacon	Microwave	Standard	17.8	31.0	25.6	39.3	21.5	36.6	17.4	33.5
15B	Bacon	Microwave	Standard	58.4	76.9	49.1	68.4	47.0	65.8	13.8	17.8
16	Lasagna	Microwave	Standard	21.8	31.3	25.6	33.8	21.5	24.3	18.0	21.5
17A	Stovetop Stir Fry	Gas	Worst Case	120.1	191.4	97.7	170.0	87.0	173.9	33.9	42.1
17B	Stovetop Stir Fry	Gas	Worst Case	255.0	312.8	265.9	326.5	251.7	298.2	34.4	37.1
18A	Bacon	Gas	Worst Case	75.8	128.2	107.2	164.9	62.3	116.3	19.4	25.4
18B	Bacon	Gas	Worst Case	182.4	242.3	183.3	221.0	171.4	227.5	15.9	19.0
19A	Broil Fish	Gas	Worst Case	33.5	40.0	29.1	41.0	31.0	40.1	18.6	20.2

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
19B	Broil Fish	Gas	Worst Case	34.3	41.4	44.4	51.8	33.6	40.7	17.6	22.2
20	Full Meal	Gas	Standard	530.4	999.4	523.3	999.4	502.0	999.4	27.3	34.4
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	88.8	155.1	86.9	123.2	35.9	50.2	20.4	25.0
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	222.0	274.2	216.9	259.6	163.9	190.7	22.1	26.3
22	French Fries	Gas	Test 5 Replicate	354.6	629.3	332.7	621.3	273.5	541.4	10.1	18.8
23	Bake Lasagna	Gas	Test 7 Replicate	301.1	430.4	290.8	447.1	270.6	427.3	24.2	29.6
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	90.5	121.9	81.4	99.8	54.1	68.9	20.9	22.3
24RB	Fry Beef	Gas	Cast Iron Pan	126.2	154.1	120.7	131.5	115.3	137.9	18.0	21.5
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	49.3	84.0	46.4	72.3	36.1	61.6	11.9	13.0
27	Pork Roast	Gas	Exhaust Ventilation	80.1	137.0	79.6	113.9	75.7	116.1	28.7	41.4
28	Fry Beef	Gas	Range Hood Shields	19.8	22.7	18.4	24.0	14.4	14.7	17.3	30.0
29	Pork Roast	Gas	Range Hood Shields	68.6	115.3	66.4	157.3	62.5	107.6	19.3	28.6
30A	Stovetop Stir Fry	Gas	Vegetable Oil	72.7	129.7	83.2	116.6	44.7	52.5	28.8	35.0
30B	Stovetop Stir Fry	Gas	Vegetable Oil	157.3	176.2	184.5	216.3	160.7	183.6	18.4	22.2
31A	Fry Beef	Gas	Pan Lid	57.4	73.5	27.2	45.6	29.1	45.1	13.5	18.0
31B	Fry Beef	Gas	Pan Lid	93.4	97.8	73.8	80.6	78.6	92.0	27.9	33.1
32A	Popcorn	Microwave	Standard	26.0	32.3	26.4	26.4	20.9	20.9	35.5	38.8
32B	Popcorn	Microwave	Standard	27.2	28.9	29.9	29.9	35.2	36.9	16.3	16.3
33	Range Baseline	Gas		268.5	451.8	293.2	462.1	218.5	396.3	55.9	69.3
34	Oven Baseline	Gas		276.3	385.9	272.2	378.6	279.8	381.9	23.8	36.8
N				43	43	43	43	43	43	43	43
Minimum				0.0	0.0	1.7	5.0	0.9	2.3	0.0	0.0
Maximum				692.1	999.4	716.4	999.4	699.2	999.4	35.5	42.1

No sample – data acquisition system failed on this day of testing

Measurements for NO may be truncated to 1000 ppb due to scale limitations during monitoring.

Table 3-22. Average NO Concentrations (ppb) Measured at Four Locations during the Total Exposure Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	763.0	999.4	776.0	999.4	762.4	999.4	25.6	37.5
2	Stovetop Stir Fry	Gas	Standard	105.6	126.5	105.5	138.4	98.3	137.7	12.5	36.6
3A	Bacon	Gas	Standard	40.5	84.8	39.5	81.2	40.1	85.7	3.8	20.8
3B	Bacon	Gas	Standard	128.3	160.0	119.4	158.8	123.5	158.5	4.2	12.9
4	Tortillas	Gas	Standard	180.0	256.6	189.4	257.9	180.7	247.8	11.5	20.7
5	French Fries	Gas	Standard	411.0	580.7	393.0	581.1	413.9	579.4	19.6	28.0
6A	Broil Fish	Gas	Standard	11.7	29.7	12.7	27.4	7.1	15.3	0.0	0.0
6B	Broil Fish	Gas	Standard	39.4	50.4	38.6	48.7	40.6	53.0	8.9	14.0
7	Bake Lasagna	Gas	Standard	222.5	316.8	223.6	327.2	210.7	295.1	9.8	18.2
8	Oven Cleaning	Electric	Standard	148.6	184.2	148.9	184.8	144.3	181.9	16.4	29.9
9	Stovetop Stir Fry	Electric	Standard	16.8	28.7	15.6	19.7	18.0	28.4	14.2	20.8
10A	Bacon	Electric	Standard	5.7	14.2	3.9	8.9	4.5	11.6	7.1	20.1
10B	Bacon	Electric	Standard	14.4	28.2	18.9	29.4	14.0	24.4	12.8	22.8
11	Tortillas	Electric	Standard	6.4	15.1	8.5	19.0	6.5	14.5	2.4	14.9
12	French Fries	Electric	Standard	4.6	14.9	3.2	14.5	6.2	16.2	3.3	8.9
13A	Broil Fish	Electric	Standard	16.3	27.3	16.4	24.5	12.9	25.7	11.0	24.4
13B	Broil Fish	Electric	Standard	1.7	10.2	4.7	17.1	6.3	22.8	2.5	9.9
14	Lasagna	Electric	Standard	NA	NA	NA	NA	NA	NA	NA	NA
15A	Bacon	Microwave	Standard	17.8	31.0	25.6	39.3	21.5	36.6	17.4	33.5
15B	Bacon	Microwave	Standard	62.8	76.9	61.7	78.2	61.0	77.1	13.4	22.2
16	Lasagna	Microwave	Standard	19.1	31.3	22.0	33.8	21.0	24.3	14.9	21.5
17A	Stovetop Stir Fry	Gas	Worst Case	188.9	239.2	184.0	237.8	168.7	220.7	30.4	42.1
17B	Stovetop Stir Fry	Gas	Worst Case	284.7	342.2	285.9	349.9	289.7	349.1	32.7	44.4
18A	Bacon	Gas	Worst Case	134.0	183.5	141.0	169.1	130.4	176.6	16.4	25.4
18B	Bacon	Gas	Worst Case	219.2	267.4	216.7	252.7	214.5	258.8	17.6	25.3
19A	Broil Fish	Gas	Worst Case	28.5	40.0	28.3	41.0	27.6	40.1	18.5	22.4

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
19B	Broil Fish	Gas	Worst Case	31.5	41.4	35.6	51.8	33.1	40.7	19.1	28.4
20	Full Meal	Gas	Standard	639.5	999.4	627.6	999.4	642.7	999.4	32.9	43.7
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	138.6	173.9	145.6	186.6	124.0	157.1	20.8	25.0
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	256.0	306.6	258.1	295.4	246.0	295.8	22.4	30.4
22	French Fries	Gas	Test 5 Replicate	429.4	629.3	414.2	622.1	397.5	601.0	10.7	22.6
23	Bake Lasagna	Gas	Test 7 Replicate	324.6	430.4	319.1	447.1	301.8	427.3	26.4	42.5
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	107.7	132.2	108.9	129.9	97.9	123.0	20.3	23.2
24RB	Fry Beef	Gas	Cast Iron Pan	130.2	156.1	131.4	152.7	132.6	154.4	25.3	37.6
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	69.6	94.5	66.6	81.7	65.2	81.7	16.9	25.5
27	Pork Roast	Gas	Exhaust Ventilation	75.7	137.0	74.1	113.9	71.3	116.1	28.3	41.9
28	Fry Beef	Gas	Range Hood Shields	24.4	30.5	23.7	34.4	23.7	31.0	18.1	30.0
29	Pork Roast	Gas	Range Hood Shields	61.6	115.3	61.0	157.3	57.9	107.6	20.0	29.0
30A	Stovetop Stir Fry	Gas	Vegetable Oil	118.8	156.1	130.9	172.0	120.9	171.1	25.6	35.2
30B	Stovetop Stir Fry	Gas	Vegetable Oil	183.3	222.7	184.0	216.3	182.5	228.1	22.0	27.8
31A	Fry Beef	Gas	Pan Lid	68.4	79.7	58.5	78.3	61.0	74.2	17.1	26.1
31B	Fry Beef	Gas	Pan Lid	92.7	100.5	89.2	102.0	89.3	104.3	20.4	33.1
32A	Popcorn	Microwave	Standard	27.2	32.8	26.1	32.0	29.4	34.0	26.8	38.8
32B	Popcorn	Microwave	Standard	31.4	37.0	29.8	33.7	33.2	39.6	22.8	30.1
33	Range Baseline	Gas		355.2	504.0	374.7	516.5	330.2	509.9	44.6	69.3
34	Oven Baseline	Gas		300.6	391.4	297.2	388.9	306.3	397.8	23.8	36.8
			N	43	43	43	43	43	43	43	43
			Minimum	1.7	10.2	3.2	8.9	4.5	11.6	0.0	0.0
			Maximum	763.0	999.4	776.0	999.4	762.4	999.4	32.9	44.4

No sample – data acquisition system failed on this day of testing
Measurements for NO may be truncated to 1000 ppb due to scale limitations during monitoring.

Table 3-23. Average NO_2 Concentrations (ppb) Measured at Four Locations during the Cooking Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	402.7	564.6	427.3	617.6	446.6	673.7	25.8	46.7
2	Stovetop Stir Fry	Gas	Standard	40.0	41.1	55.8	72.2	30.9	47.0	19.2	22.6
3A	Bacon	Gas	Standard	13.2	17.0	15.1	21.6	15.2	20.9	21.8	29.7
3B	Bacon	Gas	Standard	53.4	61.2	55.8	63.4	50.2	60.0	17.2	17.6
4	Tortillas	Gas	Standard	30.8	54.3	39.7	58.0	28.3	54.8	4.7	9.4
5	French Fries	Gas	Standard	70.4	113.0	68.6	123.4	66.0	119.5	10.3	16.0
6A	Broil Fish	Gas	Standard	94.1	124.6	121.1	145.4	78.4	119.3	32.0	39.1
6B	Broil Fish	Gas	Standard	114.9	158.0	107.2	138.5	75.0	85.6	26.8	32.9
7	Bake Lasagna	Gas	Standard	91.2	113.1	94.4	131.3	84.6	102.9	23.8	32.3
8	Oven Cleaning	Electric	Standard	34.5	65.5	41.4	70.2	36.3	69.3	22.8	47.8
9	Stovetop Stir Fry	Electric	Standard	15.4	16.9	22.5	31.1	18.0	24.1	23.3	31.2
10A	Bacon	Electric	Standard	25.7	30.6	21.7	24.6	19.8	24.9	20.7	23.6
10B	Bacon	Electric	Standard	24.4	27.1	30.0	37.0	23.7	35.8	25.9	29.7
11	Tortillas	Electric	Standard	34.8	43.5	40.7	47.0	32.0	49.0	32.5	46.3
12	French Fries	Electric	Standard	33.7	35.7	28.2	30.5	30.5	38.5	30.6	36.6
13A	Broil Fish	Electric	Standard	25.4	27.8	32.1	33.8	20.2	32.1	19.1	23.9
13B	Broil Fish	Electric	Standard	27.2	27.2	37.6	50.2	31.8	42.6	19.1	19.1
14	Lasagna	Electric	Standard	27.6	37.5	34.1	44.0	32.9	39.6	36.0	48.1
15A	Bacon	Microwave	Standard	10.5	15.4	14.3	20.0	8.2	12.7	13.8	18.3
15B	Bacon	Microwave	Standard	21.4	27.6	17.8	26.7	19.9	21.7	22.2	25.9
16	Lasagna	Microwave	Standard	12.8	21.3	17.2	31.5	17.7	30.0	11.6	16.9
17A	Stovetop Stir Fry	Gas	Worst Case	47.0	70.3	36.8	60.1	31.3	52.4	7.7	10.6
17B	Stovetop Stir Fry	Gas	Worst Case	55.7	68.4	57.6	92.7	62.8	76.7	16.6	24.5
18A	Bacon	Gas	Worst Case	40.4	50.6	35.2	45.5	24.2	31.7	11.9	19.3
18B	Bacon	Gas	Worst Case	40.4	61.1	35.9	54.6	34.2	49.8	10.9	16.8
19A	Broil Fish	Gas	Worst Case	92.7	150.5	96.5	167.3	46.0	84.2	17.3	27.1

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
19B	Broil Fish	Gas	Worst Case	81.4	131.4	109.4	170.3	47.1	70.2	11.4	16.6
20	Full Meal	Gas	Standard	190.9	374.9	195.6	402.5	184.1	421.4	7.4	19.1
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	41.6	75.6	37.8	51.9	25.9	35.6	11.8	17.9
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	57.8	80.0	67.3	79.1	34.6	39.0	11.5	17.4
22	French Fries	Gas	Test 5 Replicate	120.4	167.6	112.6	158.3	84.3	131.3	19.4	32.1
23	Bake Lasagna	Gas	Test 7 Replicate	85.4	95.7	84.9	108.9	73.0	106.0	18.8	34.2
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	17.9	28.7	24.5	28.8	16.6	22.7	12.5	27.9
24RB	Fry Beef	Gas	Cast Iron Pan	23.7	34.3	20.2	22.0	27.2	28.7	3.5	6.9
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	27.2	43.4	24.3	35.0	23.7	30.0	22.3	23.6
27	Pork Roast	Gas	Exhaust Ventilation	17.5	40.3	15.7	33.2	15.2	30.2	11.9	43.4
28	Fry Beef	Gas	Range Hood Shields	1.6	2.7	10.2	14.8	2.2	4.5	0.9	2.7
29	Pork Roast	Gas	Range Hood Shields	18.3	61.2	14.5	45.0	15.5	31.9	9.7	29.1
30A	Stovetop Stir Fry	Gas	Vegetable Oil	25.0	33.0	54.0	68.9	29.4	41.2	9.9	13.6
30B	Stovetop Stir Fry	Gas	Vegetable Oil	28.1	38.9	43.2	50.1	36.8	41.1	22.1	32.4
31A	Fry Beef	Gas	Pan Lid	24.4	31.6	13.1	15.7	13.6	14.8	6.8	16.0
31B	Fry Beef	Gas	Pan Lid	29.0	40.3	24.4	26.4	27.6	30.2	8.7	12.4
32A	Popcorn	Microwave	Standard	19.3	20.3	7.4	7.4	5.1	5.1	25.8	39.1
32B	Popcorn	Microwave	Standard	12.4	14.2	0.0	0.0	12.7	25.1	0.0	0.0
33	Range Baseline	Gas		67.0	108.2	73.7	108.2	53.2	97.5	18.8	23.7
34	Oven Baseline	Gas		90.3	129.2	78.8	114.9	93.7	121.0	17.3	22.6
35	NO_X Background	Gas		62.4	68.1	48.5	71.4	67.2	86.9	24.7	35.5
36	NO_X Background	Gas		72.0	86.4	83.1	116.8	61.8	87.5	20.9	27.7
37	NO_X Verification	Gas		16.9	21.1	18.4	26.4	19.6	26.5	19.7	27.7
38	Oven Dirtying	Gas		113.3	190.7	122.2	177.5	94.9	178.2	22.6	33.1
38R	Oven Dirtying	Gas		108.2	146.2	113.1	161.7	64.4	94.6	23.3	30.1

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
39	Oven Dirtying	Electric		26.4	41.9	25.7	37.3	29.0	40.1	22.0	30.2
			N	44	44	44	44	44	44	44	44
			Minimum	1.6	2.7	0.0	0.0	2.2	4.5	0.0	0.0
			Maximum	402.7	564.6	427.3	617.6	446.6	673.7	36.0	48.1

[a] No sample – data acquisition system failed on this day of testing

Table 3-24. Average NO_2 Concentrations (ppb) Measured at Four Locations during the Total Exposure Period

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	377.8	564.6	400.0	617.6	425.1	673.7	24.0	46.7
2	Stovetop Stir Fry	Gas	Standard	45.1	77.6	46.8	72.2	42.1	67.9	15.9	28.9
3A	Bacon	Gas	Standard	32.2	58.3	30.9	57.6	30.8	56.8	25.2	39.4
3B	Bacon	Gas	Standard	49.7	64.7	50.8	63.4	47.9	72.2	21.2	30.9
4	Tortillas	Gas	Standard	33.2	54.3	37.8	60.2	29.8	56.7	4.7	15.4
5	French Fries	Gas	Standard	74.3	136.2	70.5	123.4	67.6	119.5	10.7	17.9
6A	Broil Fish	Gas	Standard	108.3	160.2	115.5	164.0	105.0	169.7	33.9	41.6
6B	Broil Fish	Gas	Standard	118.0	178.6	120.4	194.4	116.6	187.5	20.3	32.9
7	Bake Lasagna	Gas	Standard	82.9	113.1	86.0	131.3	78.4	102.9	23.4	32.3
8	Oven Cleaning	Electric	Standard	31.1	65.5	37.9	70.2	33.6	69.3	20.6	47.8
9	Stovetop Stir Fry	Electric	Standard	15.0	27.7	21.2	33.4	14.8	24.5	18.3	31.2
10A	Bacon	Electric	Standard	27.5	35.8	26.3	40.8	26.0	35.8	27.0	43.5
10B	Bacon	Electric	Standard	19.7	31.3	21.6	37.0	18.1	35.8	19.8	29.7
11	Tortillas	Electric	Standard	34.4	47.0	39.0	47.0	36.5	49.0	32.5	46.3
12	French Fries	Electric	Standard	28.1	43.5	27.6	39.0	30.5	38.5	28.7	37.3
13A	Broil Fish	Electric	Standard	23.0	37.4	22.7	33.8	19.4	37.7	18.8	35.7

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
13B	Broil Fish	Electric	Standard	33.3	42.6	37.0	57.6	35.6	50.0	28.8	45.8
14	Lasagna	Electric	Standard	34.4	52.3	36.4	50.6	35.8	53.4	35.5	48.1
15A	Bacon	Microwave	Standard	10.5	15.4	14.3	20.0	8.2	12.7	13.8	18.3
15B	Bacon	Microwave	Standard	18.9	27.6	15.1	26.7	18.7	27.4	21.3	29.3
16	Lasagna	Microwave	Standard	11.0	25.8	12.7	31.5	13.9	30.0	14.1	27.6
17A	Stovetop Stir Fry	Gas	Worst Case	50.1	74.5	49.9	76.3	45.4	63.3	10.6	22.7
17B	Stovetop Stir Fry	Gas	Worst Case	53.2	93.0	49.2	92.7	50.0	90.2	15.3	26.8
18A	Bacon	Gas	Worst Case	32.4	52.2	31.5	45.5	29.6	47.0	7.3	19.3
18B	Bacon	Gas	Worst Case	40.5	61.1	41.0	64.8	37.8	60.4	10.5	20.0
19A	Broil Fish	Gas	Worst Case	98.3	250.3	87.4	201.3	74.1	145.9	12.7	27.1
19B	Broil Fish	Gas	Worst Case	97.9	234.0	103.1	237.2	85.1	171.2	13.4	19.5
20	Full Meal	Gas	Standard	114.1	374.9	117.1	402.5	125.5	421.4	15.2	43.9
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	38.3	75.6	41.7	66.0	37.3	57.4	11.3	17.9
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	52.1	83.1	51.1	79.1	41.2	56.5	13.7	30.6
22	French Fries	Gas	Test 5 Replicate	100.0	167.6	97.1	158.3	84.7	146.8	17.4	32.1
23	Bake Lasagna	Gas	Test 7 Replicate	74.1	95.7	72.4	108.9	68.6	106.0	22.3	36.4
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	20.6	32.8	27.4	42.0	23.4	34.0	12.3	44.0
24RB	Fry Beef	Gas	Cast Iron Pan	23.8	41.1	40.3	73.3	38.3	71.6	9.3	30.0
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	21.9	43.4	22.3	41.7	23.2	40.4	14.8	24.3
27	Pork Roast	Gas	Exhaust Ventilation	17.1	40.3	13.8	33.2	14.9	30.2	11.9	43.4
28	Fry Beef	Gas	Range Hood Shields	7.0	19.1	12.4	26.1	12.2	28.5	3.0	13.4
29	Pork Roast	Gas	Range Hood Shields	15.7	61.2	12.4	45.0	14.2	31.9	9.6	29.1
30A	Stovetop Stir Fry	Gas	Vegetable Oil	32.2	49.4	43.6	71.4	37.6	64.0	9.8	34.3
30B	Stovetop Stir Fry	Gas	Vegetable Oil	35.6	59.3	39.4	52.1	40.0	67.0	10.3	32.4
31A	Fry Beef	Gas	Pan Lid	22.2	31.6	18.1	29.2	17.4	25.9	11.3	21.8

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
31B	Fry Beef	Gas	Pan Lid	23.2	40.3	17.6	27.0	24.6	33.0	14.2	32.4
32A	Popcorn	Microwave	Standard	12.2	24.8	9.8	25.8	8.3	31.2	14.4	28.8
32B	Popcorn	Microwave	Standard	7.3	12.4	12.4	31.2	15.7	25.8	8.2	16.6
33	Range Baseline	Gas		72.2	112.0	75.6	117.6	67.7	128.5	21.1	33.8
34	Oven Baseline	Gas		84.5	129.2	78.5	116.0	91.9	121.0	17.7	29.4
N				44	44	44	44	44	44	44	44
Minimum				7.0	12.4	9.8	20.0	8.2	12.7	3.0	13.4
Maximum				377.8	564.6	400.0	617.6	425.1	673.7	35.5	48.1

[a] No sample – data acquisition system failed on this day of testing

3.8 Air Exchange Rates and Environmental Monitoring Data

Air exchange rates were measured by the tracer gas decay method using SF_6. SF_6 was measured in the kitchen, living room, and master bedroom, and air exchange rates were calculated for each room. A whole house air exchange rate was calculated as the average of the measurements in the three rooms. The results are presented in Table 3-25. The whole house air exchange rate averaged 0.32 ± 0.19 air changes per hour (ACH) for all 42 measurement periods. The median was 0.27 ACH. The 42 measurement periods included four tests with the range hood on and one test during which a bedroom window was inadvertently left open. If these five periods are excluded, the average air exchange rate was 0.26 hr^{-1}. As shown in the Table, the air exchange rates in the three rooms were generally very similar even though there were no mixing fans operating during the tests.

Temperature and relative humidity were measured indoors and outdoors during the test period. Average temperature and relative humidity during each test are presented in Table 3-26. Humidity measurements sometimes reached 100% with the thin film capacitance sensors on rainy days.

3.9 Estimated Emission Rates

Emission rates were calculated for each test using a dynamic mass balance model, as described in Section 2.0. In addition to the rates, the source strengths were calculated normalized to the food weight and the power use for cooking. The results are summarized in Tables 3-27 through 3-37 and are discussed in Section 4.0.

Emission rates were calculated for $PM_{2.5}$ and PM_{10} using the gravimetric mass data. Emission rates were also calculated for $PM_{0.1}$, $PM_{0.5}$, $PM_{1.0}$, $PM_{2.5}$, and PM_{10} mass and particle concentrations using the data from the ELPI for the total exposure period. The data are calculated for the total particle or mass emissions for particles of less than the indicated size. The usefulness of this data is primarily for comparison of the relative differences between the size fractions. It cannot be compared to the emission rates calculated from the gravimetric data because the relationship between ELPI mass measurements and gravimetric could not be established.

Emission rates were also calculated for CO, NO, and NO_2. The data are presented for the average emissions over the duration of the test and for the peak emissions.

Emission rates were also estimated for the PAHs and elements even though the concentrations were low and there were only a limited number of samples. These values should be considered only as crude estimates because many of the values are based on concentrations that were below the method uncertainty level, and because they are based on only a single sample collected in the kitchen. The estimated emission rate was made using the kitchen concentration and volume. Because so many of the concentrations of the elements were below the uncertainty level, only the emission rates are presented; the emission rates have not been normalized to the amount of food cooked or energy used.

Table 3-25. Air Exchange Rates (hr^{-1}) during the Cooking Tests

Test No.	Type	Range	Conditions	LR	Kitchen	MBR	House
1	Oven Cleaning	Gas	Standard	0.24	0.28	0.30	0.27
1R	Oven Cleaning	Gas	Standard	0.29	0.29	0.29	0.29
2	Stovetop Stir Fry	Gas	Standard	0.28	0.27	0.28	0.28
3	Bacon	Gas	Standard	0.27	0.26	0.37	0.30
4	Tortillas	Gas	Standard	0.23	0.22	0.23	0.22
5	French Fries	Gas	Standard	0.25	0.24	0.25	0.25
6	Broil Fish	Gas	Standard	0.20	0.22	0.23	0.22
7	Bake Lasagna	Gas	Standard	0.24	0.24	0.25	0.24
8	Oven Cleaning	Electric	Standard	0.25	0.27	0.25	0.26
9	Stovetop Stir Fry	Electric	Standard	0.21	0.22	0.23	0.22
10	Bacon	Electric	Standard	0.23	0.27	0.29	0.26
11	Tortillas	Electric	Standard	0.29	0.30	0.30	0.29
12	French Fries	Electric	Standard	0.18	0.20	0.21	0.20
13	Broil Fish	Electric	Standard	0.32	0.29	0.29	0.30
14	Lasagna	Electric	Standard	0.22	0.22	0.24	0.23
15	Lasagna	Microwave	Standard	0.26	0.26	0.23	0.25
16	Bacon	Microwave	Standard	0.22	0.24	0.19	0.22
17	Stovetop Stir Fry	Gas	Worst Case	0.27	0.27	0.26	0.27
18	Bacon	Gas	Worst Case	0.24	0.24	0.23	0.24
19	Broil Fish	Gas	Worst Case & Open Window	0.99	0.94	1.02	0.98
20	Full Meal	Gas	Standard	0.26	0.26	0.25	0.26
21	Stovetop Stir Fry	Gas	Test 2 Replicate	0.24	0.25	0.22	0.24
22	French Fries	Gas	Test 5 Replicate	0.25	0.25	0.23	0.24
23	Bake Lasagna	Gas	Test 7 Replicate	0.28	0.29	0.28	0.28
24	Fry Beef	Gas	Cast Iron Pan	0.31	0.31	0.27	0.30
24R	Fry Beef	Gas	Cast Iron Pan	0.31	0.27	0.27	0.28
25	Pork Roast	Gas	Aluminum Pan	0.28	0.28	0.28	0.28
26	Fry Beef	Gas	Exhaust Ventilation	0.52	0.62	0.59	0.58
27	Pork Roast	Gas	Exhaust Ventilation	1.06	1.07	1.08	1.07
28	Fry Beef	Gas	Range Hood Shields	0.55	0.50	0.54	0.53
29	Pork Roast	Gas	Range Hood Shields	0.78	0.78	0.78	0.78
30	Stovetop Stir Fry	Gas	Vegetable Oil	0.30	0.30	0.29	0.30
31	Fry Beef	Gas	Pan Lid	0.24	0.24	0.24	0.24
32	Popcorn	Microwave	Standard	0.29	0.24	0.32	0.29
33	Range Baseline	Gas		0.27	0.26	0.32	0.28
34	Oven Baseline	Gas		0.23	0.26	0.28	0.26

Test No.	Type	Range	Conditions	LR	Kitchen	MBR	House
35	Instrument Evaluation	Gas		0.29	0.28	0.27	0.28
36	Instrument Evaluation	Gas		0.21	0.22	0.21	0.21
37	Instrument Evaluation	Gas		0.27	0.26	0.23	0.25
38	Oven Dirtying	Gas		0.27	0.27	0.26	0.26
38R	Oven Dirtying	Gas		0.31	0.32	0.32	0.32
39	Oven Dirtying	Electric		0.24	0.24	0.20	0.23
	Summary - all tests		N	42	42	42	42
			Minimum	0.18	0.20	0.19	0.20
			Maximum	1.06	1.07	1.08	1.07

Table 3-26. Average Temperature (°C) during Cooking Tests

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1R	Oven Cleaning	Gas	Standard	24.7	27.3	22.7	25.5	21.8	23.7	7.1	9.2
2	Stovetop Stir Fry	Gas	Standard	20.9	22.7	19.8	21.5	20.3	21.6	13.2	14.7
3A	Bacon	Gas	Standard	19.6	21.1	18.9	20.1	19.0	19.5	10.9	11.7
3B	Bacon	Gas	Standard	20.5	21.5	20.3	20.9	19.5	19.8	11.0	12.6
4	Tortillas	Gas	Standard	21.9	23.2	19.7	21.3	19.5	20.2	13.7	15.3
5	French Fries	Gas	Standard	23.4	24.5	21.3	22.5	19.9	20.8	13.1	15.7
6A	Broil Fish	Gas	Standard	21.2	23.0	20.5	21.6	18.2	18.8	15.1	17.0
6B	Broil Fish	Gas	Standard	23.0	23.5	22.5	23.2	19.9	21.1	18.0	18.8
7	Bake Lasagna	Gas	Standard	21.8	24.6	21.7	23.1	20.8	21.4	12.7	14.6
8	Oven Cleaning	Electric	Standard	22.5	25.4	21.9	24.7	21.8	24.4	10.9	13.2
9	Stovetop Stir Fry	Electric	Standard	22.9	23.3	23.2	23.5	22.8	23.1	12.1	13.4
10A	Bacon	Electric	Standard	20.5	21.1	20.5	20.9	20.5	20.8	9.2	10.7
10B	Bacon	Electric	Standard	21.4	22.5	21.3	21.6	20.8	21.1	8.4	10.3
11	Tortillas	Electric	Standard	21.3	22.9	21.1	21.7	20.3	20.5	9.7	11.5
12	French Fries	Electric	Standard	20.6	21.4	20.6	21.3	20.2	20.5	9.4	10.6
13A	Broil Fish	Electric	Standard	22.2	23.6	22.3	22.7	22.1	22.5	11.1	12.2
13B	Broil Fish	Electric	Standard	23.4	24.0	23.1	23.7	22.1	22.5	12.6	14.5
14	Lasagna	Electric	Standard	22.2	23.5	22.0	23.2	21.0	21.5	12.2	14.2
15A	Bacon	Microwave	Standard	19.2	19.9	19.9	20.6	19.1	19.5	11.1	11.9
15B	Bacon	Microwave	Standard	20.3	20.9	21.0	21.2	19.5	19.7	9.7	10.3
16	Lasagna	Microwave	Standard	21.5	22.0	22.0	22.3	20.6	21.1	13.8	14.9
17A	Stovetop Stir Fry	Gas	Worst Case	26.1	27.0	24.7	25.2	23.1	23.9	15.1	15.5
17B	Stovetop Stir Fry	Gas	Worst Case	27.2	28.3	25.4	25.7	23.8	24.2	12.8	15.0
18A	Bacon	Gas	Worst Case	21.9	23.0	21.6	22.6	20.7	21.0	11.5	14.2
18B	Bacon	Gas	Worst Case	23.4	24.3	23.0	23.4	21.4	21.9	12.5	14.7
19A	Broil Fish	Gas	Worst Case	22.1	22.6	20.8	21.2	19.9	20.2	6.5	7.3
19B	Broil Fish	Gas	Worst Case	22.3	23.0	20.8	21.3	19.8	20.2	5.6	6.0

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
20	Full Meal	Gas	Standard	27.1	29.7	24.8	26.6	23.3	24.6	13.6	15.9
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	23.4	24.5	22.1	22.6	21.9	22.4	12.2	13.2
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	24.7	25.2	22.7	23.0	21.7	22.0	9.9	11.0
22	French Fries	Gas	Test 5 Replicate	22.2	23.0	22.5	23.2	22.1	22.7	10.4	10.8
23	Bake Lasagna	Gas	Test 7 Replicate	24.3	25.2	21.8	22.7	20.7	21.0	7.2	11.0
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24RA	Fry Beef	Gas	Cast Iron Pan	22.9	23.6	21.7	23.0	22.3	22.5	11.9	12.9
24RB	Fry Beef	Gas	Cast Iron Pan	24.2	24.7	22.0	23.4	22.5	22.7	14.0	15.7
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	22.3	23.8	21.0	22.3	21.4	21.9	15.6	16.5
27	Pork Roast	Gas	Exhaust Ventilation	24.0	25.0	21.9	22.9	21.9	22.5	12.3	15.8
28	Fry Beef	Gas	Range Hood Shields	21.3	22.0	21.1	21.5	20.8	21.1	8.9	9.2
29	Pork Roast	Gas	Range Hood Shields	21.4	22.6	20.9	21.9	20.6	21.0	9.0	11.8
30A	Stovetop Stir Fry	Gas	Vegetable Oil	23.5	24.6	23.9	24.7	22.3	22.6	13.1	14.6
30B	Stovetop Stir Fry	Gas	Vegetable Oil	24.8	27.2	25.0	25.4	22.4	23.3	14.3	16.2
31A	Fry Beef	Gas	Pan Lid	20.0	21.4	19.3	20.1	18.7	19.0	12.0	15.0
31B	Fry Beef	Gas	Pan Lid	21.4	22.1	19.5	21.3	19.3	19.8	11.7	13.3
32A	Popcorn	Microwave	Standard	21.2	21.8	19.5	19.7	21.3	21.4	10.4	10.9
32B	Popcorn	Microwave	Standard	21.5	21.9	19.6	20.0	21.1	21.4	10.0	10.4
33	Range Baseline	Gas		20.3	20.7	19.7	20.1	18.9	19.4	4.2	6.7
34	Oven Baseline	Gas		23.3	23.9	22.6	23.3	21.3	22.0	5.3	6.5
N				45	45	45	45	45	45	45	45
Minimum				19.2	19.9	18.9	19.7	18.2	18.8	5.6	6.0
Maximum				27.2	29.7	25.4	26.6	23.8	24.6	18.0	18.8

[a] No sample due to problem with the data acquisition system on this day of testing

Table 3-27. Average Relative Humidity (%) during the Cooking Tests

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
1	Oven Cleaning	Gas	Standard	58.1	62.8	67.2	71.5	75.6	78.7	99.9	100.0
1R	Oven Cleaning	Gas	Standard	47.9	49.8	57.3	58.7	65.9	69.2	42.0	58.2
2	Stovetop Stir Fry	Gas	Standard	60.2	63.3	69.2	74.2	72.4	76.9	100.0	100.0
3	Bacon	Gas	Standard	59.7	60.9	67.0	69.9	71.5	72.6	100.0	100.0
3B	Bacon	Gas	Standard	59.1	60.3	67.3	69.6	73.7	75.1	100.0	100.0
4	Tortillas	Gas	Standard	56.4	57.3	65.6	67.5	72.1	74.3	83.3	86.0
5	French Fries	Gas	Standard	57.0	61.2	66.6	71.8	73.6	78.2	76.7	81.2
6	Broil Fish	Gas	Standard	54.8	57.9	62.0	63.8	67.9	68.7	89.6	100.0
6B	Broil Fish	Gas	Standard	52.6	54.2	61.1	63.0	69.2	71.3	75.0	82.9
7	Bake Lasagna	Gas	Standard	54.6	60.0	63.1	65.0	68.9	69.9	78.3	100.0
8	Oven Cleaning	Electric	Standard	51.4	56.6	55.3	60.1	64.9	66.6	70.4	90.4
9	Stovetop Stir Fry	Electric	Standard	52.1	53.1	62.2	63.2	65.3	66.3	51.5	60.8
10	Bacon	Electric	Standard	54.9	56.5	62.8	64.6	65.1	67.2	87.4	88.5
10B	Bacon	Electric	Standard	55.3	57.5	63.9	65.5	66.7	68.2	86.3	90.3
11	Tortillas	Electric	Standard	53.3	55.0	58.3	60.5	66.2	68.2	87.6	90.9
12	French Fries	Electric	Standard	57.5	62.4	67.0	74.2	69.2	73.7	88.0	89.7
13	Broil Fish	Electric	Standard	54.3	56.2	63.7	65.0	69.0	70.3	56.8	69.3
13B	Broil Fish	Electric	Standard	53.8	58.6	63.9	64.8	70.5	71.8	62.6	79.5
14	Lasagna	Electric	Standard	58.7	63.0	64.8	67.4	71.7	73.2	95.5	97.8
15	Bacon	Microwave	Standard	60.7	63.4	61.8	63.0	69.7	71.1	100.0	100.0
15B	Bacon	Microwave	Standard	61.6	62.8	66.3	67.3	74.2	75.3	100.0	100.0
16	Lasagna	Microwave	Standard	57.0	57.8	59.5	61.6	69.2	70.4	92.5	95.4
17	Stovetop Stir Fry	Gas	Worst Case	46.4	51.4	57.4	59.4	60.8	63.0	15.4	16.2
17B	Stovetop Stir Fry	Gas	Worst Case	48.2	52.6	60.7	65.2	66.3	68.2	15.7	16.4
18	Bacon	Gas	Worst Case	54.1	55.8	65.4	67.6	71.4	73.3	36.1	46.0
18B	Bacon	Gas	Worst Case	51.9	53.4	64.6	66.2	72.0	73.6	23.9	32.0
19	Broil Fish	Gas	Worst Case	48.1	50.1	56.3	59.5	62.9	64.5	49.3	57.4

Test No.	Type	Range	Conditions	K		LR		MBR		OUT	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
19B	Broil Fish	Gas	Worst Case	48.1	49.7	56.8	58.3	63.5	64.8	65.5	70.2
20	Full Meal	Gas	Standard	50.3	55.5	63.9	74.9	72.2	89.2	16.7	50.5
21	Stovetop Stir Fry	Gas	Test 2 Replicate	48.3	49.4	60.6	62.1	62.4	66.0	17.6	22.7
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	51.9	54.9	64.8	66.5	69.2	71.4	18.9	35.4
22	French Fries	Gas	Test 5 Replicate	56.2	61.4	66.4	71.8	69.7	73.2	64.9	74.2
23	Bake Lasagna	Gas	Test 7 Replicate	49.0	55.0	59.5	61.8	64.8	66.8	19.8	42.0
24	Fry Beef	Gas	Cast Iron Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
24R	Fry Beef	Gas	Cast Iron Pan	51.4	53.9	61.0	63.5	65.6	67.3	39.4	51.3
24RB	Fry Beef	Gas	Cast Iron Pan	48.2	50.6	60.5	63.0	65.3	66.1	17.9	28.1
25	Pork Roast	Gas	Aluminum Pan	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]	NS[a]
26	Fry Beef	Gas	Exhaust Ventilation	53.2	56.4	64.5	65.9	70.1	72.0	33.4	41.2
27	Pork Roast	Gas	Exhaust Ventilation	48.1	51.0	60.1	62.0	65.2	67.6	22.6	46.1
28	Fry Beef	Gas	Range Hood Shields	51.0	52.5	60.1	61.2	61.7	63.5	62.4	69.4
29	Pork Roast	Gas	Range Hood Shields	50.4	54.1	59.3	62.1	64.6	67.6	63.8	80.0
30	Stovetop Stir Fry	Gas	Vegetable Oil	48.0	51.3	59.7	62.3	65.3	67.1	18.5	29.9
30B	Stovetop Stir Fry	Gas	Vegetable Oil	46.4	49.4	58.4	61.0	65.6	67.4	16.1	19.8
31	Fry Beef	Gas	Pan Lid	51.3	54.7	60.9	62.9	65.3	66.1	15.7	16.4
31B	Fry Beef	Gas	Pan Lid	50.5	52.2	61.0	61.9	65.6	66.5	17.5	29.2
32	Popcorn	Microwave	Standard	52.6	58.0	59.9	60.8	62.1	64.3	59.5	64.6
32B	Popcorn	Microwave	Standard	53.2	53.7	61.2	61.9	64.8	65.7	58.4	62.3
33	Range Baseline	Gas		56.3	60.6	63.9	69.4	68.0	74.7	58.2	68.5
34	Oven Baseline	Gas		50.6	53.1	56.3	59.1	61.8	65.2	56.7	61.7
N				45	45	45	45	45	45	45	45
Minimum				46.4	49.4	55.3	58.3	60.8	63.0	15.4	16.2
Maximum				61.6	63.4	69.2	74.9	75.6	89.2	100.0	100.0

[a] No sample due to problem with the data acquisition system on this day of testing

Table 3-28. CO Emission Rates during the Cooking Tests

Test No.	Type	Range	Conditions	Emission Rate		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak[a]	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
1R	Oven Cleaning	Gas	Standard	1991.9	2900.9	No food	No food	No food	No food	143.1	208.5
2	Stovetop Stir Fry	Gas	Standard	1344.1	1557.5	463.5	537.1	1324.2	1534.5	168.2	194.9
3A	Bacon	Gas	Standard	160.2	323.7	118.6	239.8	323.6	653.9	27.5	55.6
3B	Bacon	Gas	Standard	543.6	529.3	377.5	367.6	1132.4	1102.8	92.9	90.5
4	Tortillas	Gas	Standard	328.5	400.4	133.9	163.2	178.5	217.6	52.4	63.8
5	French Fries	Gas	Standard	1103.7	1584.6	256.8	368.8	226.6	325.4	143.1	205.5
6A	Broil Fish	Gas	Standard	5093.2	6900.9	3880.6	5257.8	9701.4	13144.6	554.7	751.6
6B	Broil Fish	Gas	Standard	10405.4	11688.5	6734.9	7565.4	20204.6	22696.2	976.3	1096.7
7	Bake Lasagna	Gas	Standard	535.6	674.3	965.5	1215.4	459.7	578.8	110.5	139.1
8	Oven Cleaning	Electric	Standard	990.8	1619.9	No food	No food	No food	No food	137.8	225.3
9	Stovetop Stir Fry	Electric	Standard	122.5	91.7	40.4	30.3	115.6	86.5	14.5	10.9
10A	Bacon	Electric	Standard	69.3	183.1	61.0	161.3	159.2	420.8	38.8	102.6
10B	Bacon	Electric	Standard	25.7	0.0[c]	26.4	0.0[c]	56.5	0.0[c]	17.1	0.0[c]
11	Tortillas	Electric	Standard	395.9	326.9	149.0	123.0	207.8	171.6	51.7	42.7
12	French Fries	Electric	Standard	309.2	368.3	26.4	31.5	63.4	75.5	29.3	34.9
13A	Broil Fish	Electric	Standard	1702.9	2129.1	1216.3	1520.8	4054.5	5069.2	139.5	174.4
13B	Broil Fish	Electric	Standard	3196.7	3459.7	2155.1	2332.4	7183.6	7774.7	507.8	549.6
14	Lasagna	Electric	Standard	43.7	0.0[c]	75.3	0.0[c]	37.3	0.0[c]	13.3	0.0[c]
15A	Bacon	Microwave	Standard	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
15B	Bacon	Microwave	Standard	145.4	96.1	221.3	146.4	358.9	237.3	28.4	18.8
16	Lasagna	Microwave	Standard	40.0	11.3	87.4	24.6	34.5	9.7	7.8	2.2
17A	Stovetop Stir Fry	Gas	Worst Case	1227.7	1554.3	587.9	744.2	1356.6	1717.4	152.5	193.0
17B	Stovetop Stir Fry	Gas	Worst Case	2145.0	2519.7	993.1	1166.5	2383.4	2799.6	263.4	309.4
18A	Bacon	Gas	Worst Case	742.8	935.8	723.3	911.3	1669.1	2102.9	121.8	153.5
18B	Bacon	Gas	Worst Case	930.8	1124.9	1034.3	1249.9	2001.8	2419.2	184.0	222.4
19A	Broil Fish	Gas	Worst Case	3837.5	8000.4	4099.8	8547.4	9839.6	20513.7	364.0	758.8

Test No.	Type	Range	Conditions	Emission Rate		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak[a]	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
19B	Broil Fish	Gas	Worst Case	5471.4	9282.4	5428.0	9208.7	13027.1	22101.0	522.3	886.1
20	Full Meal	Gas	Standard	906.2	1815.3	160.9	322.2	68.9	138.1	63.5	127.2
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	1359.8	1665.8	486.6	596.1	1536.5	1882.3	173.0	211.9
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	2313.5	2639.5	842.8	961.6	2528.4	2884.7	274.7	313.4
22	French Fries	Gas	Test 5 Replicate	1367.0	1924.6	384.4	541.3	262.1	369.1	179.3	252.5
23	Bake Lasagna	Gas	Test 7 Replicate	414.3	488.5	714.2	842.1	354.1	417.6	77.4	91.3
24RA	Fry Beef	Gas	Cast Iron Pan	425.3	415.7	163.6	159.9	467.4	456.8	86.2	84.3
24RB	Fry Beef	Gas	Cast Iron Pan	406.3	475.3	156.3	182.8	446.5	522.4	110.0	128.7
25	Pork Roast	Gas	Aluminum Pan	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]
26	Fry Beef	Gas	Exhaust Ventilation	355.9	353.1	137.6	136.6	393.3	390.2	64.4	63.9
27	Pork Roast	Gas	Exhaust Ventilation	216.3	332.1	333.0	511.2	110.4	169.5	59.3	91.1
28	Fry Beef	Gas	Range Hood Shields	139.1	83.0	53.2	31.8	152.0	90.7	34.3	20.5
29	Pork Roast	Gas	Range Hood Shields	161.1	374.5	201.0	467.1	67.0	155.7	43.8	101.8
30A	Stovetop Stir Fry	Gas	Vegetable Oil	1308.5	1577.5	443.6	534.7	1478.6	1782.5	166.2	200.3
30B	Stovetop Stir Fry	Gas	Vegetable Oil	2148.8	2453.6	669.1	764.0	2361.4	2696.3	275.8	315.0
31A	Fry Beef	Gas	Pan Lid	182.2	153.0	70.1	58.8	200.2	168.1	49.5	41.5
31B	Fry Beef	Gas	Pan Lid	281.1	278.9	92.7	91.9	308.9	306.4	72.4	71.8
32A	Popcorn	Microwave	Standard	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
32B	Popcorn	Microwave	Standard	817.4	412.6	495.4	250.1	7430.5	3751.2	159.7	80.6
33	Burner Baseline	Gas		1194.0	1644.2	N/A	N/A	N/A	N/A	153.3	211.1
34	Oven Baseline	Gas		374.6	567.0	N/A	N/A	N/A	N/A	78.3	118.5
N (All gas range tests except oven cleaning)				42	40	40	38	40	38	42	40
Minimum				25.7	11.3	26.4	24.6	34.5	9.7	7.8	2.2
Maximum				10405.4	11688.5	6734.9	9208.7	20204.6	22696.2	976.3	1096.7

[a] Emission rate calculated using the maximum concentration measured during the cooking test
[b] No sample due to problem with the data acquisition system on this day of testing
[c] Correction with background data resulted in zero or negative value.
Note: Peak emission rates may be lower than the average emission rates due to the peak outdoor concentration being higher than peak indoor concentrations. This may have resulted in an underestimation of the peak emission rates.

Table 3-29. NO Emission Rates during Cooking Tests

Test No.	Type	Range	Conditions	Emission Rate[a]		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
1R	Oven Cleaning	Gas	Standard	120.4	146.3	No food	No food	No food	No food	8.7	10.5
2	Stovetop Stir Fry	Gas	Standard	90.3	80.7	31.2	27.8	89.0	79.5	11.3	10.1
3A	Bacon	Gas	Standard	34.0	55.0	25.2	40.7	68.6	111.1	5.8	9.5
3B	Bacon	Gas	Standard	124.3	137.3	86.3	95.3	258.9	286.0	21.3	23.5
4	Tortillas	Gas	Standard	83.5	108.6	34.0	44.3	45.4	59.0	13.3	17.3
5	French Fries	Gas	Standard	143.2	188.1	33.3	43.8	29.4	38.6	18.6	24.4
6A	Broil Fish	Gas	Standard	9.7	23.1	7.4	17.6	18.5	44.0	1.1	2.5
6B	Broil Fish	Gas	Standard	30.3	33.1	19.6	21.4	58.8	64.2	2.8	3.1
7	Bake Lasagna	Gas	Standard	49.6	64.8	89.4	116.8	42.6	55.6	10.2	13.4
8	Oven Cleaning	Electric	Standard	21.2	22.9	No food	No food	No food	No food	3.0	3.2
9	Stovetop Stir Fry	Electric	Standard	3.3	6.9	1.1	2.3	3.1	6.5	0.4	0.8
10A	Bacon	Electric	Standard	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
10B	Bacon	Electric	Standard	1.8	3.8	1.9	3.9	4.0	8.3	1.2	2.5
11	Tortillas	Electric	Standard	2.3	0.1	0.9	0.1	1.2	0.1	0.3	0.0
12	French Fries	Electric	Standard	1.3	4.4	0.1	0.4	0.3	0.9	0.1	0.4
13A	Broil Fish	Electric	Standard	6.7	3.0	4.8	2.1	16.0	7.1	0.6	0.2
13B	Broil Fish	Electric	Standard	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
14	Lasagna	Electric	Standard	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
15A	Bacon	Microwave	Standard	0.8	0.0[c]	1.1	0.0[c]	1.5	0.0[c]	0.2	0.0[c]
15B	Bacon	Microwave	Standard	29.5	29.9	44.9	45.5	72.8	73.8	5.8	5.8
16	Lasagna	Microwave	Standard	1.1	1.9	2.4	4.2	0.9	1.7	0.2	0.4
17A	Stovetop Stir Fry	Gas	Worst Case	128.9	147.8	61.7	70.8	142.4	163.3	16.0	18.4
17B	Stovetop Stir Fry	Gas	Worst Case	211.1	230.8	97.7	106.8	234.5	256.4	25.9	28.3
18A	Bacon	Gas	Worst Case	93.4	116.1	90.9	113.0	209.8	260.8	15.3	19.0
18B	Bacon	Gas	Worst Case	137.6	153.4	152.9	170.4	295.9	329.8	27.2	30.3
19A	Broil Fish	Gas	Worst Case	13.2	19.4	14.1	20.8	33.8	49.8	1.3	1.8
19B	Broil Fish	Gas	Worst Case	16.1	14.3	16.0	14.1	38.4	34.0	1.5	1.4
20	Full Meal	Gas	Standard	134.4	197.1	23.9	35.0	10.2	15.0	9.4	13.8
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	123.4	143.9	44.2	51.5	139.4	162.6	15.7	18.3

Test No.	Type	Range	Conditions	Emission Rate[a]		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	232.6	255.3	84.8	93.0	254.3	279.0	27.6	30.3
22	French Fries	Gas	Test 5 Replicate	127.1	171.6	35.7	48.3	24.4	32.9	16.7	22.5
23	Bake Lasagna	Gas	Test 7 Replicate	75.6	91.3	130.3	157.3	64.6	78.0	14.1	17.0
24RA	Fry Beef	Gas	Cast Iron Pan	85.5	97.9	32.9	37.7	93.9	107.6	17.3	19.9
24RB	Fry Beef	Gas	Cast Iron Pan	102.6	106.5	39.5	41.0	112.7	117.0	27.8	28.8
25	Pork Roast	Gas	Aluminum Pan	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]
26	Fry Beef	Gas	Exhaust Ventilation	62.5	74.8	24.2	28.9	69.1	82.6	11.3	13.5
27	Pork Roast	Gas	Exhaust Ventilation	19.5	35.2	30.1	54.2	10.0	18.0	5.4	9.7
28	Fry Beef	Gas	Range Hood Shields	8.2	0.4	3.1	0.2	8.9	0.5	2.0	0.1
29	Pork Roast	Gas	Range Hood Shields	13.6	25.6	17.0	31.9	5.7	10.6	3.7	6.9
30A	Stovetop Stir Fry	Gas	Vegetable Oil	106.3	126.3	36.0	42.8	120.1	142.7	13.5	16.0
30B	Stovetop Stir Fry	Gas	Vegetable Oil	191.5	214.2	59.6	66.7	210.4	235.4	24.6	27.5
31A	Fry Beef	Gas	Pan Lid	49.6	47.3	19.1	18.2	54.5	52.0	13.5	12.9
31B	Fry Beef	Gas	Pan Lid	79.6	68.1	26.2	22.4	87.5	74.8	20.5	17.5
32A	Popcorn	Microwave	Standard	9.4	0.0[c]	5.7	0.0[c]	85.6	0.0[c]	1.8	0.0[c]
32B	Popcorn	Microwave	Standard	44.3	28.2	26.8	17.1	402.4	256.5	8.6	5.5
33	Burner Baseline	Gas		126.9	164.2	N/A	N/A	N/A	N/A	16.3	21.1
34	Oven Baseline	Gas		68.1	81.0	N/A	N/A	N/A	N/A	14.2	16.9
N (All gas range tests except oven cleaning)				41	39	39	37	39	37	41	39
Minimum				0.8	0.1	0.1	0.1	0.3	0.1	0.1	0.0
Maximum				232.6	255.3	152.9	170.4	402.4	329.8	27.8	30.3

[a] Emission rate calculated using the maximum concentration measured during the cooking test
[b] No sample due to problem with the data acquisition system on this day of testing
[c] Correction with background data resulted in zero or negative value.

Note: Peak emission rates may be lower than the average emission rates due to the peak outdoor concentration being higher than peak indoor concentrations. This may have resulted in an underestimation of the peak emission rates.

Table 3-30. NO_2 Emission Rates during Cooking Tests

Test No.	Type	Range	Conditions	Emission Rate		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak[a]	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
1R	Oven Cleaning	Gas	Standard	137.4	190.5	No food	No food	No food	No food	9.9	13.7
2	Stovetop Stir Fry	Gas	Standard	60.0	95.1	20.7	32.8	59.1	93.7	7.5	11.9
3A	Bacon	Gas	Standard	36.7	63.1	27.2	46.8	74.2	127.5	6.3	10.9
3B	Bacon	Gas	Standard	67.3	80.1	46.7	55.6	140.2	166.9	11.5	13.7
4	Tortillas	Gas	Standard	25.7	37.9	10.5	15.5	13.9	20.6	4.1	6.0
5	French Fries	Gas	Standard	44.6	76.5	10.4	17.8	9.2	15.7	5.8	9.9
6A	Broil Fish	Gas	Standard	129.0	179.5	98.3	136.7	245.8	341.8	14.1	19.5
6B	Broil Fish	Gas	Standard	167.8	235.8	108.6	152.6	325.8	457.9	15.7	22.1
7	Bake Lasagna	Gas	Standard	35.0	44.3	63.1	79.9	30.1	38.1	7.2	9.1
8	Oven Cleaning	Electric	Standard	9.6	18.2	No food	No food	No food	No food	1.3	2.5
9	Stovetop Stir Fry	Electric	Standard	16.0	27.7	5.3	9.1	15.1	26.1	1.9	3.3
10A	Bacon	Electric	Standard	28.5	31.3	25.1	27.5	65.5	71.9	16.0	17.5
10B	Bacon	Electric	Standard	17.4	25.7	17.8	26.3	38.2	56.5	11.6	17.1
11	Tortillas	Electric	Standard	22.4	27.6	8.4	10.4	11.8	14.5	2.9	3.6
12	French Fries	Electric	Standard	27.8	41.1	2.4	3.5	5.7	8.4	2.6	3.9
13A	Broil Fish	Electric	Standard	30.5	43.4	21.8	31.0	72.6	103.4	2.5	3.6
13B	Broil Fish	Electric	Standard	43.4	47.2	29.2	31.8	97.5	106.1	6.9	7.5
14	Lasagna	Electric	Standard	12.3	17.7	21.2	30.4	10.5	15.1	3.7	5.4
15A	Bacon	Microwave	Standard	6.2	8.6	8.5	11.8	11.6	16.0	1.2	1.7
15B	Bacon	Microwave	Standard	13.3	18.0	20.2	27.4	32.7	44.4	2.6	3.5
16	Lasagna	Microwave	Standard	3.3	7.5	7.1	16.3	2.8	6.4	0.6	1.5
17A	Stovetop Stir Fry	Gas	Worst Case	58.3	78.7	27.9	37.7	64.4	86.9	7.2	9.8
17B	Stovetop Stir Fry	Gas	Worst Case	62.6	101.6	29.0	47.1	69.5	112.9	7.7	12.5
18A	Bacon	Gas	Worst Case	37.2	53.7	36.2	52.3	83.6	120.7	6.1	8.8
18B	Bacon	Gas	Worst Case	40.2	55.5	44.7	61.7	86.6	119.4	8.0	11.0
19A	Broil Fish	Gas	Worst Case	155.6	372.7	166.3	398.2	399.1	955.6	14.8	35.3
19B	Broil Fish	Gas	Worst Case	154.5	353.4	153.2	350.6	367.8	841.5	14.7	33.7

Test No.	Type	Range	Conditions	Emission Rate		Source Strength (per gram of food)		Food-specific Emission Factor		Power-specific Emission Factor	
				Average	Peak[a]	Average	Peak	Average	Peak	Average	Peak
				mg/hr	mg/hr	µg/g	µg/g	µg/g/hr	µg/g/hr	µg/BTU	µg/BTU
20	Full Meal	Gas	Standard	48.2	148.1	8.6	26.3	3.7	11.3	3.4	10.4
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	55.8	103.6	20.0	37.1	63.0	117.1	7.1	13.2
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	73.3	105.6	26.7	38.5	80.1	115.4	8.7	12.5
22	French Fries	Gas	Test 5 Replicate	51.8	80.5	14.6	22.6	9.9	15.4	6.8	10.6
23	Bake Lasagna	Gas	Test 7 Replicate	32.5	38.1	56.0	65.6	27.8	32.5	6.1	7.1
24RA	Fry Beef	Gas	Cast Iron Pan	25.6	29.4	9.9	11.3	28.2	32.3	5.2	6.0
24RB	Fry Beef	Gas	Cast Iron Pan	31.3	45.4	12.1	17.5	34.4	49.9	8.5	12.3
25	Pork Roast	Gas	Aluminum Pan	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]	NS[b]
26	Fry Beef	Gas	Exhaust Ventilation	26.9	51.9	10.4	20.1	29.7	57.3	4.9	9.4
27	Pork Roast	Gas	Exhaust Ventilation	6.9	9.3	10.6	14.3	3.5	4.7	1.9	2.6
28	Fry Beef	Gas	Range Hood Shields	9.6	20.9	3.7	8.0	10.5	22.9	2.4	5.2
29	Pork Roast	Gas	Range Hood Shields	6.2	24.1	7.8	30.1	2.6	10.0	1.7	6.6
30A	Stovetop Stir Fry	Gas	Vegetable Oil	49.5	62.4	16.8	21.2	55.9	70.5	6.3	7.9
30B	Stovetop Stir Fry	Gas	Vegetable Oil	57.6	82.4	17.9	25.6	63.3	90.5	7.4	10.6
31A	Fry Beef	Gas	Pan Lid	28.3	35.5	10.9	13.6	31.1	39.0	7.7	9.6
31B	Fry Beef	Gas	Pan Lid	32.8	49.8	10.8	16.4	36.0	54.7	8.4	12.8
32A	Popcorn	Microwave	Standard	57.4	107.4	34.8	65.1	521.4	976.4	11.2	21.0
32B	Popcorn	Microwave	Standard	34.8	50.4	21.1	30.6	316.6	458.3	6.8	9.9
33	Burner Baseline	Gas		45.5	65.3	N/A	N/A	N/A	N/A	5.8	8.4
34	Oven Baseline	Gas		37.4	53.0	N/A	N/A	N/A	N/A	7.8	11.1
N (All gas range tests except oven cleaning)				44	44	42	42	42	42	44	44
Minimum				3.3	7.5	2.4	3.5	2.6	4.7	0.6	1.5
Maximum				167.8	372.7	166.3	398.2	521.4	976.4	16.0	35.3

[a] Emission rate calculated using the maximum concentration measured during the cooking test
[b] No sample due to problem with the data acquisition system on this day of testing

Table 3-31. $PM_{2.5}$ Mass Emission Rates during Cooking Tests

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
1R	Oven Cleaning	Gas	Standard	359.5	No Food	No Food	25.8
2	Stovetop Stir Fry	Gas	Standard	201.5	69.5	198.6	25.2
3	Bacon	Gas	Standard	233.0	167.3	239.0	40.0
4	Tortillas	Gas	Standard	253.2	103.2	137.6	40.4
5	French Fries	Gas	Standard	65.9	15.3	13.5	8.5
6	Broil Fish	Gas	Standard	318.2	224.3	305.9	32.3
7	Bake Lasagna	Gas	Standard	251.2	452.8	215.6	51.8
8	Oven Cleaning	Electric	Standard	176.3	No Food	No Food	24.5
9	Stovetop Stir Fry	Electric	Standard	175.1	57.8	165.2	20.7
10	Bacon	Electric	Standard	86.7	82.8	97.4	53.2
11	Tortillas	Electric	Standard	617.8	232.4	324.3	80.7
12	French Fries	Electric	Standard	262.2	22.4	53.8	24.9
13	Broil Fish	Electric	Standard	228.5	164.2	273.7	24.7
14	Lasagna	Electric	Standard	25.5	44.0	21.8	7.8
15	Bacon	Microwave	Standard	N/A	N/A	N/A	N/A
16	Lasagna	Microwave	Standard	N/A	N/A	N/A	N/A
17	Stovetop Stir Fry	Gas	Worst Case	545.7	257.0	302.3	67.4
18	Bacon	Gas	Worst Case	184.1	192.2	202.3	33.3
19	Broil Fish	Gas	Worst Case	137.0	140.9	169.1	13.0
20	Full Meal	Gas	Standard	147.2	26.1	11.2	10.3
21	Stovetop Stir Fry	Gas	Test 2 Replicate	92.4	33.4	51.3	11.3
22	French Fries	Gas	Test 5 Replicate	46.2	13.0	8.9	6.1
23	Bake Lasagna	Gas	Test 7 Replicate	89.0	153.5	76.1	16.6
24	Fry Beef	Gas	Cast Iron Pan	43.4	16.6	47.5	9.7
24R	Fry Beef	Gas	Cast Iron Pan	74.9	28.8	41.2	17.4
25	Pork Roast	Gas	Aluminum Pan	8.9	13.9	4.6	2.6

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
26	Fry Beef	Gas	Exhaust Ventilation	256.9	99.4	283.9	46.5
27	Pork Roast	Gas	Exhaust Ventilation	1.5	2.3	0.8	0.4
28	Fry Beef	Gas	Range Hood Shields	26.8	10.3	29.3	6.6
29	Pork Roast	Gas	Range Hood Shields	66.5	82.9	27.6	18.1
30	Stovetop Stir Fry	Gas	Vegetable Oil	221.8	72.1	123.6	28.3
31	Fry Beef	Gas	Pan Lid	179.4	64.1	98.6	47.5
32	Popcorn	Microwave	Standard	N/A	N/A	N/A	N/A
N (without oven cleaning tests 1 and 8)				28	28	28	28
Minimum				1.5	2.3	0.8	0.4
Maximum				617.8	452.8	324.3	80.7

Table 3-32. PM_{10} Mass Emission Rates during Cooking Tests

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
1R	Oven Cleaning	Gas	Standard	1173.4	No Food	No Food	84.3
2	Stovetop Stir Fry	Gas	Standard	318.3	109.8	313.6	39.8
3	Bacon	Gas	Standard	183.9	132.0	188.6	31.5
4	Tortillas	Gas	Standard	158.9	64.8	86.4	25.3
5	French Fries	Gas	Standard	177.0	41.2	36.3	22.9
6	Broil Fish	Gas	Standard	302.3	213.2	290.7	30.7
7	Bake Lasagna	Gas	Standard	70.7	127.4	60.7	14.6
8	Oven Cleaning	Electric	Standard	124.5	No Food	No Food	17.3
9	Stovetop Stir Fry	Electric	Standard	1361.8	449.7	1284.7	161.3
10	Bacon	Electric	Standard	180.3	172.2	202.6	110.7
11	Tortillas	Electric	Standard	933.9	351.3	490.3	121.9
12	French Fries	Electric	Standard	206.5	17.6	42.4	19.6
13	Broil Fish	Electric	Standard	574.4	412.7	687.9	62.1
14	Lasagna	Electric	Standard	135.6	233.8	115.9	41.3
15	Bacon	Microwave	Standard	N/A	N/A	N/A	N/A
16	Lasagna	Microwave	Standard	N/A	N/A	N/A	N/A
17	Stovetop Stir Fry	Gas	Worst Case	902.9	425.2	500.2	111.5
18	Bacon	Gas	Worst Case	432.7	451.7	475.5	78.2
19	Broil Fish	Gas	Worst Case	623.5	641.4	769.7	59.3
20	Full Meal	Gas	Standard	303.9	53.9	23.1	21.3
21	Stovetop Stir Fry	Gas	Test 2 Replicate	571.7	206.4	317.6	70.1
22	French Fries	Gas	Test 5 Replicate	82.6	23.2	15.8	10.8
23	Bake Lasagna	Gas	Test 7 Replicate	39.4	68.0	33.7	7.4
24	Fry Beef	Gas	Cast Iron Pan	117.4	44.9	128.4	26.3
24R	Fry Beef	Gas	Cast Iron Pan	134.6	51.8	73.9	31.2
25	Pork Roast	Gas	Aluminum Pan	20.5	32.0	10.7	6.0

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
26	Fry Beef	Gas	Exhaust Ventilation	372.9	144.2	412.0	67.4
27	Pork Roast	Gas	Exhaust Ventilation	31.4	48.4	16.0	8.6
28	Fry Beef	Gas	Range Hood Shields	175.8	67.3	192.2	43.3
29	Pork Roast	Gas	Range Hood Shields	16.4	20.5	6.8	4.5
30	Stovetop Stir Fry	Gas	Vegetable Oil	747.9	243.0	416.6	95.5
31	Fry Beef	Gas	Pan Lid	98.7	35.3	54.3	26.1
32	Popcorn	Microwave	Standard	N/A	N/A	N/A	N/A
N (without oven cleaning tests 1 and 8)				28	28	28	28
Minimum				16.4	17.6	6.8	4.5
Maximum				1361.8	641.4	1284.7	161.3

Table 3-33. Particle Emission Rates Measured with the ELPI during Cooking Tests

Test No.	Type	Range	Conditions	Particles X million/hr in size fraction of less than				
				0.1 μm	0.5 μm	1.0 μm	2.5 μm	10μm
1R	Oven Cleaning	Gas	Standard	108	152	158	158	158
2	Stovetop Stir Fry	Gas	Standard	116	144	144	144	144
3A	Bacon	Gas	Standard	106	139	139	139	139
3B	Bacon	Gas	Standard	97	143	143	143	143
4	Tortillas	Gas	Standard	101	113	113	113	113
5	French Fries	Gas	Standard	65	72	72	72	72
6A	Broil Fish	Gas	Standard	140	209	214	214	214
6B	Broil Fish	Gas	Standard	171	309	325	325	325
7	Bake Lasagna	Gas	Standard	85	101	101	101	101
8	Oven Cleaning	Electric	Standard	53	71	72	72	72
9	Stovetop Stir Fry	Electric	Standard	108	133	134	134	135
10A	Bacon	Electric	Standard	32	52	52	52	52
10B	Bacon	Electric	Standard	44	87	88	88	88
11	Tortillas	Electric	Standard	104	196	198	198	199
12	French Fries	Electric	Standard	114	134	134	134	134
13A	Broil Fish	Electric	Standard	142	203	205	205	205
13B	Broil Fish	Electric	Standard	181	271	275	275	275
14	Lasagna	Electric	Standard	5	5	5	5	5
15A	Bacon	Microwave	Standard	2	3	3	3	3
15B	Bacon	Microwave	Standard	3	3	4	4	4
16	Lasagna	Microwave	Standard	1	1	1	1	1
17A	Stovetop Stir Fry	Gas	Worst Case	158	201	203	203	203
17B	Stovetop Stir Fry	Gas	Worst Case	150	203	205	205	205
18A	Bacon	Gas	Worst Case	122	206	209	209	209
18B	Bacon	Gas	Worst Case	86	157	161	161	161
19A	Broil Fish	Gas	Worst Case	419	604	605	605	605
19B	Broil Fish	Gas	Worst Case	340	647	650	650	650
20	Full Meal	Gas	Standard	87	108	110	110	110
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	138	168	169	169	169
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	174	228	229	229	229
22	French Fries	Gas	Test 5 Replicate	62	74	74	74	74
23	Bake Lasagna	Gas	Test 7 Replicate	51	57	57	57	57

Test No.	Type	Range	Conditions	Particles X million/hr in size fraction of less than				
				0.1 μm	0.5 μm	1.0 μm	2.5 μm	10μm
24	Fry Beef	Gas	Cast Iron Pan	14	15	15	15	15
24RA	Fry Beef	Gas	Cast Iron Pan	45	48	48	48	48
24RB	Fry Beef	Gas	Cast Iron Pan	20	21	21	21	21
25	Pork Roast	Gas	Aluminum Pan	8	10	10	10	10
26	Fry Beef	Gas	Exhaust Ventilation	16	16	16	16	16
27	Pork Roast	Gas	Exhaust Ventilation	3	4	4	4	4
28	Fry Beef	Gas	Range Hood Shields	0	1	1	1	1
29	Pork Roast	Gas	Range Hood Shields	1	1	1	1	1
30A	Stovetop Stir Fry	Gas	Vegetable Oil	165	200	201	201	201
30B	Stovetop Stir Fry	Gas	Vegetable Oil	174	215	217	217	217
31A	Fry Beef	Gas	Pan Lid	0	0	0	0	0
31B	Fry Beef	Gas	Pan Lid	0	0	0	0	0
32A	Popcorn	Microwave	Standard	43	52	52	52	52
32B	Popcorn	Microwave	Standard	56	65	65	65	65
33	Burner Baseline	Gas		23	26	26	26	26
34	Oven Baseline	Gas		20	22	22	22	22
N				48	48	48	48	48
Minimum				0.2	0.4	0.4	0.4	0.4
Maximum				418.6	646.7	649.9	649.9	650.0

Table 3-34. Estimated Mass Emission Rates Measured with the ELPI during Cooking Tests

Test No.	Type	Range	Conditions	µg/hr in size fraction of less than				
				0.1 µm	0.5 µm	1.0 µm	2.5 µm	10µm
1R	Oven Cleaning	Gas	Standard	13.5	258.4	757.7	805.3	4433.7
2	Stovetop Stir Fry	Gas	Standard	13.1	94.7	124.8	203.5	2592.4
3A	Bacon	Gas	Standard	12.9	108.2	122.0	139.7	1002.7
3B	Bacon	Gas	Standard	13.5	161.1	185.3	208.0	1191.9
4	Tortillas	Gas	Standard	11.4	34.9	38.8	56.1	450.3
5	French Fries	Gas	Standard	6.1	23.6	27.6	43.7	335.6
6A	Broil Fish	Gas	Standard	17.8	385.3	831.4	913.8	3387.8
6B	Broil Fish	Gas	Standard	20.8	867.9	2307.0	2591.4	10410.3
7	Bake Lasagna	Gas	Standard	9.0	57.6	74.3	85.4	489.2
8	Oven Cleaning	Electric	Standard	6.1	84.6	173.5	200.4	668.7
9	Stovetop Stir Fry	Electric	Standard	12.1	107.6	268.2	574.2	2920.8
10A	Bacon	Electric	Standard	4.0	93.5	119.4	122.0	532.2
10B	Bacon	Electric	Standard	6.7	231.3	340.1	358.4	959.2
11	Tortillas	Electric	Standard	16.8	439.2	696.3	820.0	2946.1
12	French Fries	Electric	Standard	13.3	57.7	70.7	87.4	861.9
13A	Broil Fish	Electric	Standard	17.1	283.9	455.9	492.7	1289.2
13B	Broil Fish	Electric	Standard	22.4	426.2	843.7	972.4	1849.0
14	Lasagna	Electric	Standard	0.5	2.3	2.0	1.2	151.3
15A	Bacon	Microwave	Standard	0.2	3.5	9.2	17.0	113.3
15B	Bacon	Microwave	Standard	0.3	4.6	13.5	28.8	121.0
16	Lasagna	Microwave	Standard	0.1	1.0	1.7	1.9	18.7
17A	Stovetop Stir Fry	Gas	Worst Case	15.4	202.6	321.3	317.5	317.5
17B	Stovetop Stir Fry	Gas	Worst Case	15.2	276.3	439.1	435.1	435.1
18A	Bacon	Gas	Worst Case	17.4	406.4	636.6	724.0	2139.1
18B	Bacon	Gas	Worst Case	11.5	406.5	668.9	763.1	1820.9
19A	Broil Fish	Gas	Worst Case	53.8	637.3	721.2	757.7	757.7
19B	Broil Fish	Gas	Worst Case	48.5	1413.5	1678.4	1751.2	1751.2
20	Full Meal	Gas	Standard	8.9	108.7	242.2	282.9	1259.8
21A	Stovetop Stir Fry	Gas	Test 2 Replicate	14.0	114.2	152.1	259.2	2337.0
21B	Stovetop Stir Fry	Gas	Test 2 Replicate	17.7	222.5	313.8	498.1	3105.1
22	French Fries	Gas	Test 5 Replicate	7.2	32.5	36.6	47.6	407.7
23	Bake Lasagna	Gas	Test 7 Replicate	5.5	16.2	16.7	16.7	20.1

Test No.	Type	Range	Conditions	µg/hr in size fraction of less than				
				0.1 µm	0.5 µm	1.0 µm	2.5 µm	10µm
24	Fry Beef	Gas	Cast Iron Pan	1.1	2.6	3.0	7.1	135.2
24RA	Fry Beef	Gas	Cast Iron Pan	4.6	10.8	12.4	20.0	449.8
24RB	Fry Beef	Gas	Cast Iron Pan	2.4	6.2	6.8	11.5	125.4
25	Pork Roast	Gas	Aluminum Pan	1.1	4.7	4.7	5.3	21.9
26	Fry Beef	Gas	Exhaust Ventilation	1.0	2.3	2.3	0.0[a]	0.0[a]
27	Pork Roast	Gas	Exhaust Ventilation	0.3	0.8	0.0[a]	0.0[a]	0.0[a]
28	Fry Beef	Gas	Range Hood Shields	0.2	1.0	0.0[a]	0.0[a]	1086.9
29	Pork Roast	Gas	Range Hood Shields	0.0	0.0	0.0[a]	0.0[a]	69.6
30A	Stovetop Stir Fry	Gas	Vegetable Oil	16.2	134.9	269.4	425.7	2909.0
30B	Stovetop Stir Fry	Gas	Vegetable Oil	16.4	173.6	271.2	296.1	772.4
31A	Fry Beef	Gas	Pan Lid	0.1	0.4	1.7	7.7	2583.7
31B	Fry Beef	Gas	Pan Lid	0.1	0.4	2.2	16.4	4859.7
32A	Popcorn	Microwave	Standard	4.3	33.7	46.4	57.5	253.6
32B	Popcorn	Microwave	Standard	4.3	33.7	46.4	57.5	253.6
33	Burner Baseline	Gas		3.4	8.0	9.5	12.2	313.0
34	Oven Baseline	Gas		2.3	8.1	9.0	7.7	7.7
N				48	48	45	44	46
Minimum				0.0	0.0	1.7	1.2	7.7
Maximum				53.8	1413.5	2307.0	2591.4	10410.3

[a] Data correction for background data resulted in zero or negative value.

Table 3-35. Aldehyde Emission Rates

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
1	Oven Cleaning	Gas	Formaldehyde	49.8	N/A	N/A	9.4
			Acetaldehyde	52.1	N/A	N/A	9.9
			Propanal	17.3	N/A	N/A	3.3
			Butanal	8.7	N/A	N/A	1.6
			Benzaldehyde	1.9	N/A	N/A	0.4
			Pentanal	17.5	N/A	N/A	3.3
			Hexanal	15.8	N/A	N/A	3.0
6	Broil Fish	Gas	Formaldehyde	48.0	33.9	46.2	4.9
			Acetaldehyde	34.7	24.5	33.4	3.5
			Propanal	10.7	7.5	10.3	1.1
			Butanal	4.2	2.9	4.0	0.4
			Benzaldehyde	3.2	2.3	3.1	0.3
			Pentanal	7.6	5.4	7.3	0.8
			Hexanal	10.0	7.0	9.6	1.0
8	Oven Cleaning	Electric	Formaldehyde	26.6	N/A	N/A	3.7
			Acetaldehyde	39.3	N/A	N/A	5.5
			Propanal	10.3	N/A	N/A	1.4
			Butanal	4.8	N/A	N/A	0.7
			Benzaldehyde	1.5	N/A	N/A	0.2
			Pentanal	9.7	N/A	N/A	1.4
			Hexanal	9.1	N/A	N/A	1.3
13	Broil Fish	Electric	Formaldehyde	59.5	42.7	71.2	6.4
			Acetaldehyde	50.0	35.9	59.9	5.4
			Propanal	15.8	11.4	18.9	1.7
			Butanal	6.7	4.8	8.1	0.7
			Benzaldehyde	1.8	1.3	2.1	0.2
			Pentanal	11.3	8.1	13.5	1.2
			Hexanal	15.9	11.4	19.0	1.7
25	Pork Roast	Gas	Formaldehyde	6.9	10.8	3.6	2.0
			Acetaldehyde	0.0[a]	N/A	N/A	N/A
			Propanal	0.4	0.7	0.2	0.1
			Butanal	0.2	0.4	0.1	0.1
			Benzaldehyde	0.0	0.0	0.0	0.0
			Pentanal	0.6	1.0	0.3	0.2

Test No.	Type	Range	Conditions	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				mg/hr	µg/g	µg/g/hr	µg/BTU
			Hexanal	2.0	3.1	1.0	0.6
27	Pork Roast	Gas	Formaldehyde	10.5	16.1	5.3	2.9
			Acetaldehyde	3.9	6.0	2.0	1.1
			Propanal	0.6	0.9	0.3	0.2
			Butanal	0.3	0.5	0.2	0.1
			Benzaldehyde	0.0	0.0	0.0	0.0
			Pentanal	0.9	1.4	0.4	0.2
			Hexanal	3.0	4.7	1.5	0.8
			N	6	6	6	6
			Minimum	0.0	0.0	0.0	0.0
			Maximum	59.5	42.7	71.2	9.9

[a] Data correction for outdoor data resulted in zero or negative value.

Table 3-36. PAH Emission Rates

Test No.	Type	Range	Compound	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				µg/hr	ηg/g	ηg/g/hr	ηg/BTU
21	Stovetop Stir Fry	Gas	naphthalene	253.1	91.4	140.6	31.1
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	0.0	0.0	0.0	0.0
			fluorene	13.7	4.9	7.6	1.7
			phenanthrene	19.9	7.2	11.0	2.4
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	8.4	3.0	4.6	1.0
			pyrene	6.9	2.5	3.8	0.8
			benz(a)anthracene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			chrysene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			benzo(b+j+k)phenanthrene	1.7	0.6	1.0	0.2
			BeP	1.4	0.5	0.8	0.2
			BaP	1.0	0.3	0.5	0.1
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.0	0.0	0.0	0.0
			coronene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
17	Stovetop Stir Fry	Gas	naphthalene	109.6	51.6	60.7	13.5
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	1.6	0.7	0.9	0.2
			fluorene	6.0	2.8	3.3	0.7
			phenanthrene	3.8	1.8	2.1	0.5
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	0.0	0.0	0.0	0.0
			pyrene	4.9	2.3	2.7	0.6
			benz(a)anthracene	0.0	0.0	0.0	0.0
			chrysene	1.0	0.5	0.6	0.1
			benzo(b+j+k)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BeP	0.6	0.3	0.3	0.1
			BaP	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.0	0.0	0.0	0.0
			coronene	1.3	0.6	0.7	0.2
30	Stovetop Stir Fry	Gas	naphthalene	307.7	100.0	171.4	39.3
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	0.0	0.0	0.0	0.0
			fluorene	13.4	4.4	7.5	1.7
			phenanthrene	16.0	5.2	8.9	2.0
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	0.3	0.1	0.2	0.0
			pyrene	8.3	2.7	4.6	1.1
			benz(a)anthracene	8.4	2.7	4.7	1.1
			chrysene	0.0	0.0	0.0	0.0
			benzo(b+j+k)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BeP	0.4	0.1	0.2	0.0
			BaP	0.3	0.1	0.2	0.0
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.2	0.1	0.1	0.0
			coronene	0.0	0.0	0.0	0.0
18	Bacon	Gas	naphthalene	113.6	118.6	124.8	20.5
			acenaphthylene	0.0	0.0	0.0	0.0

Test No.	Type	Range	Compound	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				µg/hr	ηg/g	ηg/g/hr	ηg/BTU
			acenaphthene	0.0	0.0	0.0	0.0
			fluorene	6.4	6.7	7.0	1.2
			phenanthrene	3.1	3.2	3.4	0.6
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	0.0	0.0	0.0	0.0
			pyrene	2.4	2.5	2.6	0.4
			benz(a)anthracene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			chrysene	3.2	3.3	3.5	0.6
			benzo(b+j+k)phenanthrene	1.5	1.5	1.6	0.3
			BeP	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BaP	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.0	0.0	0.0	0.0
			coronene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
19	Broil Fish	Gas	naphthalene	293.7	302.1	362.6	27.9
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	0.0	0.0	0.0	0.0
			fluorene	10.7	11.1	13.3	1.0
			phenanthrene	6.6	6.7	8.1	0.6
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	0.0	0.0	0.0	0.0
			pyrene	8.8	9.1	10.9	0.8
			benz(a)anthracene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			chrysene	0.3	0.3	0.4	0.0
			benzo(b+j+k)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BeP	4.3	4.4	5.3	0.4
			BaP	10.7	11.1	13.3	1.0
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	4.8	4.9	5.9	0.5
			coronene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
20	Full Meal	Gas	naphthalene	23.5	4.2	1.8	1.6
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	0.0	0.0	0.0	0.0
			fluorene	2.7	0.5	0.2	0.2
			phenanthrene	1.1	0.2	0.1	0.1
			anthracene	0.0	0.0	0.0	0.0
			fluoranthene	0.1	0.0	0.0	0.0
			pyrene	0.5	0.1	0.0	0.0
			benz(a)anthracene	0.0	0.0	0.0	0.0
			chrysene	0.9	0.2	0.1	0.1
			benzo(b+j+k)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BeP	0.5	0.1	0.0	0.0
			BaP	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.1	0.0	0.0	0.0
			coronene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
22	French Fries	Gas	naphthalene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			acenaphthylene	0.0	0.0	0.0	0.0
			acenaphthene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			fluorene	3.0	0.8	0.6	0.4
			phenanthrene	0.0	0.0	0.0	0.0
			anthracene	0.0	0.0	0.0	0.0

Test No.	Type	Range	Compound	Emission Rate	Source Strength (per gram of food)	Food-specific Emission Factor	Power-specific Emission Factor
				µg/hr	ηg/g	ηg/g/hr	ηg/BTU
			fluoranthene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			pyrene	0.8	0.2	0.2	0.1
			benz(a)anthracene	0.0	0.0	0.0	0.0
			chrysene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			benzo(b+j+k)phenanthrene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			BeP	0.0	0.0	0.0	0.0
			BaP	0.0	0.0	0.0	0.0
			indeno[123-cd]pyrene	0.0	0.0	0.0	0.0
			benzo(ghi)perylene	0.0	0.0	0.0	0.0
			coronene	0.0[a]	0.0[a]	0.0[a]	0.0[a]
			N	7	7	7	7
			Minimum	0.0	0.0	0.0	0.0
			Maximum	307.7	302.1	362.6	39.3

[a] Correction for outdoor data resulted in zero or negative value.

Table 3-37. Element Emission Rates (μg/hr)

Test Type	Oven Cleaning	Oven Cleaning	Pork	Fry Beef	Fry Beef	Fry Beef	Full Meal
Conditions	Gas	Electric	Gas	Gas	Gas	Gas	Gas
Compound/Test No.	1R	8	25	24	24R	31	20
Sodium	61.1	84.1	67.6	693.7	214.6	380.4	4.1
Magnesium	37.7	0.0[a]	0.0[a]	541.8	74.7	0.0[a]	10.5
Aluminum	0.0[a]	30.7	41.1	647.5	85.2	186.1	52.0
Silicon	2726.7	202.1	153.3	1008.9	787.2	330.0	1359.9
Phosphorous	2545.2	13.4	5.9	200.5	106.4	47.5	93.4
Sulfur	693.6	76.7	67.7	46.2	208.5	72.4	506.1
Chlorine	2058.5	176.8	0.0[a]	118.3	41.6	54.3	80.4
Potassium	1224.2	126.0	0.0[a]	0.0[a]	108.7	90.8	43.1
Calcium	108.1	27.0	73.5	400.2	419.1	295.6	147.6
Titanium	0.0[a]	8.7	0.0[a]	11.5	39.1	9.2	0.4
Vanadium	0.0[a]	0.0[a]	0.0[a]	0.0[a]	20.9	16.1	3.7
Chromium	392.1	42.5	5.3	24.3	4.4	0.0	11.4
Manganese	0.0[a]	0.0	0.0	0.0[a]	0.0	0.0	0.0
Iron	28.2	17.9	30.5	54.7	83.8	35.8	28.1
Cobalt	0.0	0.0	1.3	8.4	0.0	0.3	0.5
Nickel	12.0	8.8	1.8	0.0	0.3	0.0[a]	0.3
Copper	87.4	13.3	31.7	77.9	69.7	79.4	29.0
Zinc	18.8	13.3	12.2	79.1	47.4	41.9	9.2
Gallium	0.0	0.0	0.0[a]	8.6	13.1	0.0	0.0[a]
Arsenic	0.0	0.0	0.7	4.8	0.0	0.0	0.0[a]
Selenium	0.0[a]	0.0	1.6	0.0	0.0[a]	0.0	0.0
Bromine	1101.1	2.2	0.9	21.1	9.2	3.8	63.3
Rubidium	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Strontium	0.0	0.3	1.6	8.0	4.7	0.1	0.0
Yttrium	0.0	2.1	3.4	2.2	2.4	0.0	0.0[a]
Zirconium	0.0[a]	2.6	3.0	27.3	17.4	14.7	7.0
Molybdenum	0.0[a]	3.7	5.9	5.8	26.9	19.9	4.0
Palladium	0.0[a]	0.0	0.0[a]	0.0[a]	0.0	0.0	2.4
Silver	28.7	0.0	5.9	0.0[a]	0.0	0.0[a]	0.0
Cadmium	0.0[a]	16.3	12.7	92.3	31.5	87.7	8.1
Indium	0.0[a]	0.0	0.0	169.3	0.0	0.0	1.8
Tin	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Antimony	0.0	0.0[a]	0.0	0.0	0.0	0.0	0.0
Barium	0.0	35.3	87.0	740.8	0.0	0.0	49.0
Lanthanum	40.9	88.3	187.0	0.0	0.0	0.0[a]	14.1
Gold	0.0	13.3	9.0	0.0	9.5	0.0	0.0
Mercury	0.0[a]	8.0	6.5	0.0	0.0	0.0	0.0
Thallium	0.0	0.0[a]	2.2	40.3	0.0	3.0	1.4
Lead	0.0[a]	7.0	1.0	0.0	26.2	5.3	0.0[a]
Uranium	0.0[a]	1.1	4.9	39.9	11.5	0.0[a]	1.5

[a] Correction for outdoor data resulted in zero or negative value.

3.10 QA DATA SUMMARY

3.10.1 Data Quality Indicator Goals for Critical Measurements

Data Quality Indicator (DQI) goals in terms of accuracy, precision, and completeness were established for critical measurements in the study plan. Established goals are presented in Table 3-38. Accuracy, expressed as percent bias, was determined by obtaining measurements for standards of a known concentration. Precision is expressed as percent relative standard deviation (%RSD) and is calculated by taking the standard deviation of a set of replicate measurements and dividing by the mean. In cases where duplicate measurements were made, precision is expressed as a relative standard deviation (%RSD). Completeness was determined by comparing the number of measurements that fell within DQI goals to the total number of measurements taken for a particular parameter. The following sections summarize calculated DQI's for critical measurements and discuss data limitations if DQI goals were not met.

Accuracy is expressed as:

$$Percent\ Bias = \frac{R - C}{C} x\ 100 \qquad 1$$

Where:

R = instrument response or reading
C = calibration standard or audit sample value

Precision is expressed as:

$$RPD = \frac{100\ x\ |Q - B|}{(Q + B)/2} \qquad 2$$

Where:

Q = results from 1 duplicate run
B = results from second duplicate run
RPD = relative percent difference

3.10.1.1 Air Exchange Rates

Air exchange rates in the test house were determined using the SF_6 trace gas decay method described in ASTM E-741. The GC used to measure SF_6 concentrations was calibrated by injecting a calibration standard in concentration from 0.5 to 100 ppb. Daily calibration checks were performed prior to each test using the 100 ppb standard. Full 6-point calibrations were performed on 2/3/00, 2/8/00, and 2/23/00 and resulted in the linear regressions data presented in Table 3-39. Using the equation y= mx + b, concentrations for daily calibration checks were calculated and the results are presented in Table 3-40. Acceptance criteria for accuracy and precision were established as ±10% and the completeness goal was 100%. Precision goals for replicate analysis were met, and accuracy goals were met for all but one daily calibration check. All planned air exchange measurements were performed during the main study.

Table 3-38 DQI Goals for Critical Measurements

Measurement	Method	Accuracy (% Bias)	Precision (% RSD)	Completeness (%)
Air Exchange Rates	Tracer Gas Decay	±10	±10	100
Particulate (gravimetric)	Impactors/Filters	±25	±25	95
Particulate (continuous)	Electrical Low Pressure Impactor (ELPI)	NA[a]	NA[a]	95
Elemental Analysis	X-Ray Fluorescence	±20	±15	95
CO	Non-dispersive infrared	±1% FS	±1% FS	95
NO2	Chemiluminescence	±1% FS	±1% FS	95
Temperature	Resistance Temperature Detector	±0.3 °C	±0.5 °C	95
Relative Humidity	Thin Film Capacitance Sensor	±5	±5	95
Aldehydes	DNPH/Silica Gel/HPLC	±20	±15	
PAH/Cooking Oils	GC/MS	±25	±25	95
PAH/Gas+Particulate	GC/MS	±25	±25	95

[a] - Accuracy and precision data currently not available for this instrument.

Table 3-39. Linear Regressions for 6-Point SF_6 Calibrations

Calibration Date	Correlation Coefficient	Slope (m)	Y-intercept (b)
02/03/00	0.9993	1.82E-05	-0.91
02/08/00	0.995	2.96E-06	4.25
02/23/00	0.995	2.82E-06	4.65

Table 3-40. SF_6 Daily Calibration Checks for 100 ppb Standard

Date	Area Counts (x)	Concentration (ppb)	% Bias
02/03/00	5603097	98.9	1.1
02/05/00	5657343	102.1	2.1
02/09/00	33543580	103.5	3.5.
02/10/00	33020144	102	2.0
02/11/00	33232244	102.6	2.6
02/13/00	33191915	102.5	2.5
02/15/00	33811088	104.3	4.3
02/16/00	41862741	128.2	28.2
02/24/00	30420565	90.1	9.1
02/25/00	31227019	92.7	7.3
02/26/00	30800011	91.2	8.8
02/27/00	30566693	90.8	9.2
02/28/00	31447851	93.3	6.7
Average	100.2		
Standard Deviation	10		
% RSD	9.9		
Completeness	13/14 passed = 93%		

3.10.1.2 Particulate Matter

The calibration of the microbalance used to weigh particulate filters was checked using a NIST-certified 10 μg standard weighed after every 10 filters.

Collocated samples were used to assess precision for $PM_{2.5}$ and PM_{10} gravimetric measurements. Only PEMs, used for PM sampling in the kitchen, were available for collocated sampling to determine method precision. Precision of the MS&T samplers used in the LR, MBR, and outdoors could not be determined due to the limited number of samplers available. Collocated measurements were performed with PEMs and the MS&T samplers during a number of tests. But, because these were different sampling methods, the collocated measurements did not represent true method precision measurements, and the results are not reported.

Results for the collocated PEM samples collected in the kitchen are presented in Table 3-41. The $PM_{2.5}$ duplicate sample collected during Test No. 1 was lost due to high loading on the filter, which resulted in a pump failure. The RSD for the other $PM_{2.5}$ duplicate was 30%, which did not meet the precision goal of 25% RSD. Three duplicate samples for PM_{10} collected with the PEMS had RSDs of 32, 12, and 96%. Only one of the three samples met the data quality goal of 25% RSD. The completeness goal of 90% was not met. During Test No. 23, for which the RSD was 96%, there was only 16 μg of PM mass on the filter.

Table 3-41. Precision Summary of Duplicate Particulate Filters

Test No. – Location	Type	Primary ($\mu g/m^3$)	Duplicate ($\mu g/m^3$)	%RSD	Notes
1 (oven cleaning)– K	$PM_{2.5}$	3651	--	--	Invalid – Pump failed
1R (oven cleaning) – K	$PM_{2.5}$	2459	1604	30	--
Completeness (0/2 passed) = 0%					
2 (stovetop stir fry) – K	PM_{10}	329	209	32	66 μg on filter
20 (full meal) – K	PM_{10}	888	745	12	--
23 (bake lasagna) – K	PM_{10}	167	31.6	96	16 μg on PEM filter
Completeness (1/3 passed) = 33%					

The poor precision may be related to problems with maintaining the target flow rate for the PEM samplers. Throughout the main study, there was poor stability of the flow rate for the pumps used on the PEMs. The flow rates for the MS&T and PEM samplers are listed in Tables 3-42 ($PM_{2.5}$) and 3-43 (PM_{10}). The values listed are the percent differences between the flow rate at the start of sampling and that measured at the end of the sampling period. As shown in the tables, the flows were relatively stable for the pumps used with the MS&T impactors, with the difference between the starting and ending flow rates generally lower than 5%. However, the difference was substantially higher for the pumps used on the PEMs. The starting and ending flows generally differed by greater than 20%. In some cases, such as in Test No. 1 (oven

cleaning), the flow decreased substantially during the test due to high particle loading on the filter. In other cases, the change in flow cannot be easily explained based simply on the amount of mass on the filters. The substantial decrease in the pump flow rates during sampling may be related to accumulation of grease droplets on the filters, but there is no data available to document that hypothesis. In general, the flow differences between the start and end of sampling were lower when samples were collected with the PEMs at locations other than in the kitchen. The problem persisted throughout the main study. Three different pumps were used for sample collection with the PEMs. Because the problem occurred with all three pumps, the field team leader elected to continue the testing despite the problem.

The poor performance of the pumps used for particle sampling with the PEMs in the kitchen is recognized to be a serious problem in this study. The problem adversely impacts the quality of the data from a quantitative standpoint because the accuracy of the data cannot be determined. For calculating the sample volumes, it was necessary to assume that the decrease in flow over time was linear. If this is not the case, the results could be substantially different. If the flow rate decreased in the early phase of a test, the sample volume would be over-estimated, resulting in calculated concentrations that are lower than actual. However, if the flow dropped off near the end of a test, due to particle or grease loading on the filter, the sample volume would be under-estimated, causing the concentrations to be over-estimated.

The precision problems with the PEM may also be related to the type of aerosol, which in the kitchen most likely consisted of large amounts of water and grease droplets. Data for collection efficiency for this type of aerosol with the PEM inlets has not been published.

Table 3-42. Variation in $PM_{2.5}$ Sampler Pump Flow Rates during The Cooking Tests

Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]
MS&T Samplers (20 L/min Flow Rate)								
1	OUT	4%	11	MBR	2%	23	MBR	1%
1	LR	92%	11	OUT	9%	24	OUT	7%
1	MBR	87%	12	LR	1%	24	LR	2%
2	LR	1%	12	MBR	2%	24	MBR	2%
2	MBR	0%	13	LR	3%	25	LR	0%
3	LR	4%	13	MBR	2%	25	MBR	3%
3	MBR	4%	13	OUT	6%	26	LR	2%
3	OUT	12%	14	OUT	0%	26	MBR	0%
4	OUT	8%	14	LR	3%	26	OUT	9%
4	LR	0%	14	MBR	2%	27	LR	1%
4	MBR	0%	17	LR	3%	27	MBR	1%
5	LR	0%	17	MBR	1%	28	MBR	2%
5	MBR	0%	18	LR	3%	28	LR	4%
6	LR	75%	18	MBR	2%	28	OUT	-1%
6	MBR	77%	18	OUT	0%	29	LR	3%

Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]
7	OUT	4%	19	MBR	2%	29	MBR	1%
7	LR	6%	19	LR	0%	30	OUT	10%
7	MBR	3%	20	LR	5%	30	LR	3%
8	OUT	8%	20	MBR	4%	30	MBR	2%
8	LR	6%	20	OUT	14%	31	MBR	2%
8	MBR	2%	21	LR	0%	31	OUT	3%
9	LR	0%	21	MBR	1%	31	LR	4%
9	MBR	2%	22	OUT	5%	1R	OUT	8%
10	LR	1%	22	LR	4%	1R	LR	71%
10	MBR	3%	22	MBR	4%	1R	MBR	93%
11	LR	1%	23	LR	-2%	24R	LR	2%
						24R	MBR	2%
						24R	OUT	12%
PEM Samplers (4 L/min Flow Rate)								
1	K	78%	11	K	49%	23	K	18%
1	K	56%	12	K	49%	24	K	33%
2	K	14%	13	K	17%	25	K	18%
3	K	33%	14	K	69%	26	K	45%
4	K	32%	14	LR	19%	27	K	26%
4	LR	34%	17	K	13%	28	K	24%
5	K	26%	17	K-Cook	9%	29	K	28%
6	K	26%	18	K	8%	30	K	18%
7	K	55%	19	K	8%	30	OUT	14%
8	K	53%	20	K	27%	30	K-Cook	8%
9	K	9%	21	K	15%	31	K	5%
9	MBR	30%	22	MBR	15%	1R	K	29%
10	K	52%	22	K	5%	1R	K	28%
						24R	K	14%

[a] [(Start flow rate minus end flow rate)/start flow rate] x 100

Table 3-43. Variation in PM_{10} Sampler Pump Flow Rates during The Cooking Tests

Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]
MS&T Samplers (20 L/min Flow Rate)								
1	LR	-4%	11	MBR	1%	24	LR	3%
1	MBR	90%	11	OUT	5%	24	MBR	2%
1	OUT	7%	12	LR	1%	24	OUT	6%
2	LR	0%	12	MBR	3%	25	LR	4%

Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]	Test No.	Location	% Diff.[a]
2	MBR	2%	13	LR	2%	25	MBR	3%
3	LR	4%	13	MBR	5%	26	LR	4%
3	MBR	9%	13	OUT	4%	26	MBR	7%
3	OUT	16%	14	LR	0%	26	OUT	10%
4	LR	0%	14	MBR	4%	27	LR	2%
4	MBR	3%	14	OUT	0%	27	MBR	1%
4	OUT	8%	17	LR	4%	28	LR	3%
5	LR	-2%	17	MBR	1%	28	MBR	3%
5	MBR	6%	18	LR	3%	28	OUT	1%
6	LR	82%	18	MBR	8%	29	LR	-2%
6	MBR	100%	18	OUT	7%	29	MBR	0%
7	MBR	8%	19	LR	0%	30	LR	2%
7	LR	6%	19	MBR	1%	30	MBR	3%
7	OUT	0%	20	LR	6%	30	OUT	25%
8	LR	19%	20	MBR	5%	31	LR	4%
8	MBR	91%	20	OUT	14%	31	MBR	4%
8	OUT	13%	21	LR	2%	31	OUT	7%
9	LR	1%	21	MBR	-1%	1R	LR	14%
9	MBR	2%	22	LR	5%	1R	MBR	9%
10	LR	0%	22	MBR	8%	1R	OUT	12%
10	MBR	2%	22	OUT	7%	24R	LR	4%
11	LR	1%	23	LR	0%	24R	MBR	3%
			23	MBR	0%	24R	OUT	14%
PEM Samplers (4 L/min Flow Rate)								
1	K	23%	23	K	7%	23	K	69%
2	K	32%	11	K	52%	24	K	32%
2	K	23%	12	K	13%	25	K	20%
3	K	40%	13	K	49%	25	MBR	9%
4	K	-2%	14	K	49%	26	K	10%
5	K	43%	17	K	33%	27	K	10%
5	LR	21%	17	K-Cook	27%	28	K	27%
6	K	33%	17	LR	7%	28	OUT	29%
7	K	20%	18	K	39%	29	K	10%
8	K	34%	19	K	11%	30	K	28%
9	K	-4%	20	K	8%	30	K-Cook	15%
10	K	51%	20	K	44%	31	K	26%
10	MBR	41%	21	K	10%	1R	K	41%
			22	K	29%	24R	K	25%

[a] [(Start flow rate minus end flow rate)/start flow rate] x 100

Additional method performance evaluation and validation would be required for this type of aerosol if additional sampling work is performed on cooking emissions and exposure. In addition, measurements are being made in ambient sampling studies to determine the effects of positive and negative sampling artifacts with SVOCs (Cui et al., 1998) and negative artifacts from nitrate losses (Ashbaugh, et al., 1998). Although effects such as these likely influenced the results of this study, the basic differences between these studies make comparisons and overall losses difficult to estimate.

Another source of variability for the PM samples could be the loss of VOCs and SVOCs during sampling or handling. The samples were collected over periods of 1.5 to 5 hours, during which loss of SVOCs could occur. Losses may also have occurred during shipping and handling. Although the samples were stored in the freezer following sample collection and transported under refrigeration, SVOCs losses may have occurred during shipment on commercial aircraft.

Although the quality of the data for gravimetric PM samples collected with the PEMs does not meet the project criteria, the data are still useful for addressing the primary objective of the study, which was to gain a better understanding of the impact of cooking on indoor air concentrations and human exposure. As will be discussed in Section 4.0, the house was generally very well mixed during the tests. The concentrations of CO and NO, inert gases emitted during cooking, were very similar in the kitchen, LR, and MBR. The air exchange rates measured in the individual rooms were also very similar, suggesting good mixing in the house. Although the particles generated during cooking cannot be treated as inert gases, the PM concentrations in the kitchen may not be substantially higher than in the other rooms because the house appeared to be so well mixed. It can be expected that the concentrations would be somewhat higher in the kitchen because of losses due to deposition. Although the data cannot be used for quantitative estimates of human exposure in the kitchen, the data are still useful for assessing the potential impact of cooking on human exposure.

3.10.1.3 Continuous Emissions Monitors (CO, NO_X)

Continuous emissions monitors were used to measure CO, NO, and NO_2 for each test. Daily QC checks were run for each monitor and recorded in the project notebook. Results from daily QC checks are summarized in Tables 3-44 and 3-45. DQI goals were met for all CEM measurements with the instrument that cycled through the four measurement locations.

3.10.1.4 Elemental Analysis

Spiked performance evaluation samples were not planned for this measurement parameter. Internal quality control samples were performed by the laboratory, and all acceptance criteria were met. Precision was assessed by comparing results of duplicate samples. One set of duplicate samples was submitted for elemental analysis, and the results are presented in Table 3-46. The established goal for %RSD was 15%, and the completeness goal was 95%. As can be seen from the table, 7 of 9 elements met the precision goal for a completeness value of 78%.

3.10.1.5 PAH and Aldehydes

PAH performance evaluation samples were submitted to the laboratory to assess the accuracy of the analysis during the pre-test. There were two duplicate samples taken for PAH analysis to assess method precision, but the majority of compounds fell below the laboratory's calculated uncertainty. Compounds detected above the MDL are presented in Table 3-47.

Table 3-44. CO CEM Daily QC Checks

Date	CO (ppm)		% Bias
	Actual	Measured	
02/03/00	19.4	19.5	0.5
02/04/00	19.4	19.4	0
02/05/00	19.4	19.8	2.1
02/06/00	19.4	19.0	-2.1
02/08/00	19.4	19.4	0
02/09/00	19.4	19.4	0
02/10/00	19.4	19.5	0.5
02/11/00	19.4	19.4	0
02/13/00	19.4	19.6	1.0
02/15/00	19.4	19.6	1.0
02/16/00	19.4	19.1	-1.6
02/17/00	19.4	19.6	1.0
02/24/00	19.4	19.4	0
02/25/00	19.4	19.4	0
02/26/00	19.4	19.4	0
02/27/00	19.4	19.4	0
02/28/00	19.4	19.1	-1.6
02/29/00	19.4	19.6	1.0
Average		19.4	
Standard Deviation		0.2	
Precision (%RSD)		1.0	
% Completeness		100	

Table 3-45. NO_X Monitor Daily QC Checks

Date	Actual (ppb)	NO		NO_2		NO_X	
		Measured (ppb)	% Bias	Measured (ppb)	% Bias	Measured (ppb)	% Bias
02/03/00	1000	990	-1.0	1053	5.3	991	-0.9
02/04/00	1000	999	-0.1	1023	2.3	996	-0.4
02/05/00	1000	1006	0.6	1015	1.5	1007	0.7
02/06/00	1000	1001	0.1	1013	1.3	1006	0.6
02/08/00	1000	1023	2.3	1042	4.2	1028	2.8
02/09/00	1000	970	-2.9	919	-8.1	968	-3.2
02/10/00	1000	969	-3.1	930	-7.0	969	-3.1
02/11/00	1000	1018	1.8	993	-0.7	1019	1.9
02/13/00	1000	995	-0.5	990	-1.0	992	-0.8
02/15/00	1000	1007	0.7	974	-2.6	1010	1.0
02/16/00	1000	1017	1.7	991	-0.9	--	--
02/17/00	1000	1020	2.0	1082	8.2	1025	2.5
02/24/00	1000	1008	0.8	1054	5.4	1001	0.1
02/25/00	1000	1004	0.4	1048	4.8	998	-0.2
02/26/00	1000	998	-0.2	1042	4.2	990	-1.0
02/27/00	1000	993	-0.7	1021	2.1	997	-0.3
02/28/00	1000	1022	2.2	1062	6.2	1012	1.2
02/29/00	1000	994	-0.6	1034	3.4	989	-1.1
AVG		1002		1016		1000	
SD		15.6		43.7		16.7	
Precision (%RSD)		1.6		4.3		1.7	
% Completeness		100		100		100	

Table 3-46. Calculated Precision for Elemental Analysis of Duplicate Sample

Element	Test 20 (ng/m^3)	Test 20-Dup (ng/m^3)	%RSD
Silicon	3902	3458	8.5
Phosphorous	263	240	6.7
Sulfur	1521	1286	11.9
Chlorine	804	721	7.7
Potassium	130	147	8.5
Calcium	447	399	8.0
Iron	105	84	16.2
Copper	92	65	24.2
Bromine	183	158	10.6

Table 3-47. Calculated Precision for PAH Analysis of Duplicate Samples

XAD-ID	11	7				6	1			
Site	K	K				K	K			
Test #	17	17				20	20			
Primary/Duplicate Sample	Primary	Duplicate				Primary	Duplicate			
Type	Stovetop Stir Fry	Stovetop Stir Fry				Full Meal	Full Meal			
Range	Gas	Gas				Gas	Gas			
Conditions	Worst Case	Worst Case				Standard	Standard			
	Peanut Oil	Peanut Oil								
Compound	ηg/m^3	ηg/m^3	avg	stdev	%RSD	ηg/m^3	ηg/m^3	avg	stdev	%RSD
fluorene[b]	23.3	21.8	22.5	1.1	4.8	34.2	12.6	23.4	15.3	65.5
pyrene[b]	19.1	9.0	14.1	7.1	50.7	15.4	0.4	7.9	10.7	135.0
BeP[b]	9.6	0.8	5.2	6.2	119.0	8.1	2.9	5.5	3.7	67.6
coronene[b]	6.2	1.2	3.7	3.5	94.8	2.5	0.0[a]	2.5	NA	NA
2-methylnaphthalene	27.4	22.2	24.8	3.7	15.0	167.6	18.3	92.9	105.5	113.6
1-methylnaphthalene	53.6	20.9	37.3	23.1	62.0	174.3	33.4	103.9	99.6	95.9
biphenyl	28.3	37.8	33.0	6.7	20.4	69.6	15.8	42.7	38.0	89.1
1+2-ethylnaphthalene	28.7	23.4	26.0	3.7	14.3	40.4	0.0[a]	40.4	NA	NA
2,6+2,7-dimethylnaphthalene	18.7	27.1	22.9	5.9	25.9	49.7	24.8	37.2	17.6	47.3
1,3+1,6+1,7-dimethylnaphthalene	56.5	68.2	62.3	8.2	13.2	92.1	47.8	69.9	31.3	44.8
1,4+1,5+2,3-dimethylnaphthalene	20.0	14.8	17.4	3.7	21.1	37.9	15.1	26.5	16.1	60.9
1,2-dimethylnaphthalene	0.8	0.0[a]	0.8	NA	NA	15.7	24.4	20.1	6.2	30.7
3-methylbiphenyl	298.5	220.9	259.7	54.8	21.1	0.0[a]	0.0[a]	NA	NA	NA
A-trimethylnaphthalene	19.5	63.6	41.6	31.2	75.0	11.5	78.3	44.9	47.2	105.2
C-trimethylnaphthalene	10.0	17.2	13.6	5.1	37.8	30.3	21.5	25.9	6.2	23.9
E-trimethylnaphthalene	9.6	18.1	13.8	6.0	43.5	25.0	14.7	19.9	7.3	36.5
F-trimethylnaphthalene	5.0	8.6	6.8	2.6	37.8	16.0	5.4	10.7	7.5	70.2
2,3,5+I-trimethylnaphtalene	13.3	25.5	19.4	8.6	44.4	30.9	13.6	22.3	12.2	54.7
J-trimethylnaphthalene	22.4	28.3	25.4	4.2	16.4	32.0	0.0[a]	32.0	NA	NA
1,2,8-trimethylnaphthalene	16.6	9.0	12.8	5.4	41.9	4.5	0.4	2.4	2.9	120.5
A-methylfluorene	27.0	5.7	16.4	15.0	91.8	27.5	10.4	19.0	12.1	63.7
1-methylfluorene	3.3	14.4	8.8	7.8	88.3	0.0[a]	0.0[a]	NA	NA	NA
B-methylfluorene	6.2	2.5	4.3	2.7	61.3	3.4	2.2	2.8	0.9	31.1
B-MePy/MeFl	10.8	0.0[a]	10.8	NA	NA	2.2	8.3	5.3	4.3	81.0
4-methylpyrene	0.0[a]	11.1	11.1	NA	NA	4.2	1.1	2.6	2.2	83.8
7-methylbenz(a)anthracene	2.5	1.2	1.9	0.9	47.9	114.5	20.5	67.5	66.5	98.5
benz(a)anthracene-7,12-dione	0.4	0.0[a]	0.4	NA	NA	1.1	5.7	3.4	3.3	95.2
5+6-methylchrysene	0.0[a]	0.0[a]	NA	NA	NA	49.7	20.5	35.1	20.7	58.9

[a] Correction with background data resulted in zero or negative value.
[b]Compounds in bold letters are PAHs.

No aldehyde performance evaluation samples were planned for the study because of the limited scope of sampling. Quality control samples prepared in the laboratory for other on-going tests were analyzed to assess the accuracy of the analysis. The laboratory performed internal quality control checks that resulted in recoveries that met method acceptance criteria. The data for the accuracy of the QC lab samples are presented in Table 3-48. The precision of the method could not be assessed at the field site because the sampling pump failed during collection of the one duplicate sample that was planned for collection.

Table 3-48. Calculated Accuracy for Aldehydes Analysis of QC Samples

Date	%Recovery			Avg.	STD	%RSD
	2/17/00	2/18/00	2/26/00			
Formaldehyde	102	101	102	102	0	0.3
Acetaldehyde	107	105	106	106	1	0.9
Acrolein	106	104	105	105	1	1.0
Propanal	107	105	105	106	1	1.3
Butanal	112	106	110	109	3	2.6
Benzaldehyde	116	106	110	111	5	4.6
Pentanal	109	106	109	108	1	1.3
Hexanal	105	104	106	105	1	1.1

3.10.2 Duplicate Cooking Tests

Three cooking tests were repeated to assess the variability of emissions during the tests. The following cooking tests were performed in duplicate:

- Stovetop Stir Fry/Gas (Test 2 and Test 21)
- French Fries/Gas (Test 5 and Test 22)
- Baked Lasagna/Gas (Test 7 and Test 23)

In addition to the planned tests, Test 24 was repeated because of a problem with the DAS. The CO, NO, and NO_2 data were lost for Test No. 24, but data were collected for PM by the gravimetric and ELPI methods and environmental data. Results for these tests are presented in the tables in this section and are discussed in Section 4.