

## **APPENDIX II**

### **Test Protocol for Determining PM Emissions from Under-fired Charbroilers**

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

PROTOCOL

**TEST PROTOCOL FOR  
DETERMINING PM EMISSIONS  
FROM UNDER-FIRED CHARBROILERS**

July 22, 2009

SOURCE TEST ENGINEERING BRANCH  
MONITORING AND ANALYSIS



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- Figure 3: Patty Internal Temperature Measurement

## **1.0 OVERVIEW AND APPLICABILITY**

The South Coast Air Quality Management District (AQMD) proposed amending Rule 1138 to fulfill requirements of Control Measure BCM-05 of the 2007 Air Quality Management Plan, which seeks to limit particulate matter (PM) less than or equal to 2.5 micron ( $PM_{2.5}$ ) from under-fired charbroilers. Restaurants which cook greater than 1250 pounds of meat per week will be required to install a control device that has been demonstrated to reduce PM emissions by at least 85 percent from an under-fired charbroiler. Previous research conducted by the University of California, Riverside indicates that the vast majority of PM emissions exist as  $PM_{2.5}$ . Hence, for the purposes of this appendix, quantification of  $PM_{2.5}$  emissions will be conducted using sampling and analytical methods for total particulate matter.

This protocol is based on ASTM F1695-03, and has been developed to support PAR 1138 to ensure standardization of compliance certification test procedures including the use of: specified test conditions, required test methods, specifications for test equipment, data collection/reporting, and quality assurance requirements.

An independent testing laboratory, approved by the South Coast Air Quality Management District, shall conduct the testing and prepare a report of findings, including all raw data sheets/charts and laboratory analytical data. This report and a request for product certification must be submitted to the Executive Officer. The testing must demonstrate to the satisfaction of the Executive Officer that emission reductions from the installation of a control on an under-fired charbroiler meets the requirements of PAR 1138 before product compliance certification is granted. Any control device for an under-fired charbroiler must achieve greater than or equal to 85 percent reduction in PM emissions.

When an under-fired charbroiler does not fall within the testing guidelines of this protocol, the protocol may be modified following an equivalency determination and written approval of the Executive Officer.

## 2.0 DEFINITIONS

For purposes of this test protocol, the following definitions shall apply:

### 2.1 **Hamburger**

For purposes of testing for Rule 1138, hamburger is defined as ground beef.

### 2.2 **Independent Testing Laboratory**

A testing laboratory that meets the requirements of South Coast Air Quality Management District's Rule 304, Subdivision (k), and is approved by the SCAQMD to conduct testing under this protocol.

### 2.3 **PM**

Any material, except uncombined water, which exists in a finely divided form as a liquid or solid at standard conditions.

### 2.4 **Standard Conditions**

A gas temperature of 60°F and a gas pressure of 760 mm Hg (14.7 pounds per square inch) absolute.

### 2.5 **Under-Fired Charbroiler**

A cooking device which has a grill, a high temperature radiant surface, and a heat source which is located below the food.

### 3.0 TEST KITCHEN AND INSTRUMENTATION

#### 3.1 Test Kitchen Details

##### 3.1.1 General Chamber Features

A test chamber equipped with natural gas, electricity, ventilation and fire suppression utilities shall be used to conduct the testing program. The dimensions of the chamber are 25 feet x 25 feet x 10 feet. Exhaust ventilation is provided by a hood that is ducted to a centrifugal-type upblast blower located on the roof of the chamber. Make-up air is supplied by an evaporative cooler and blower through four penetrations and eight diffuser panels in the test chamber ceiling. Access to the sampling locations shall be provided by a stairway outside of the chamber. A schematic of the chamber is shown in Figure 1.

##### 3.1.2 Natural Gas Supply

Natural gas shall be provided by piping inside the chamber, and shall have a higher heating value of  $1020 \pm 25$  Btu per standard cubic foot.

##### 3.1.3 Hood and Duct System

Emissions generated during the cooking process shall be captured by a 4 feet x 4 feet Captive-Aire (or equivalent) stainless steel wall canopy hood. The bottom face of the hood shall be positioned 6 feet, 6 inches above the floor. Emissions captured by the hood are drawn horizontally through a 12 inch x 12 inch duct across the roof of the test chamber to the upblast blower. The exhaust blower, equipped with a variable speed drive and controller, shall be adjustable for precise setting of the exhaust flow rate. Emissions samples are drawn from the horizontal section of the duct through access ports.

3.1.4 Sampling Ports

The access ports shall be located a minimum of 2 feet (2 duct diameters) downstream, and 0.5 feet (0.5 duct diameters) upstream of a flow disturbance, in accordance with Method 1.1. If VOC monitoring is desired, VOC ports shall be located a minimum of 2 feet (2 duct diameters) upstream from a flow disturbance. The ducting configuration without the control device is shown in Figure 2.

3.1.5 Data Acquisition/ Recording System

A computer or digital recorder may be used for recording measurement data. Sampling measurements shall be capable of recording at a minimum of 5 second intervals.

**3.2 Instrumentation**

3.2.1 Calibrations

All instrumentation within this section and pertaining to this protocol shall be calibrated as a minimum within the requirements set forth in SCAQMD Source Test Methods Chapter III, Calibrations.

3.2.2 Pressure Measurements

Pressure measurement instruments shall have an error no greater than the following values:

<u>Measurement</u>	<u>Accuracy</u>	<u>Precision</u>
Gas Pressure	± 0.1" of water column	± 0.05" of water column
Atmospheric Pressure	± 0.1" of Hg column	± 0.05" of Hg column

3.2.3 Temperature Measurements

Temperature measuring instruments shall have an error no greater than the following values:

<u>Measurement</u>	<u>Accuracy</u>	<u>Precision</u>
Ambient Temperature	$\pm 0.5^{\circ}$ F	$\pm 0.25^{\circ}$ F
Meat Temperature	$\pm 0.2^{\circ}$ F	$\pm 0.1^{\circ}$ F

3.2.4 Barometric Pressure

Use a mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 0.1 in. Hg.

3.2.5 Dry Gas Meter

The quantity of fuel used by the charbroiler shall be measured in cubic feet with dry gas meter and associated readout device that is accurate within  $\pm 1\%$  of the reading. The dry gas meter reading shall be corrected for gas pressure and temperature.

3.2.6 Mass Measurements

The weighing capacity of the scale shall be 6100 g, and be within a  $\pm 0.3$  g reproducibility. Mass measurements shall also be accurate to within  $\pm 1\%$  of measurement.

3.2.7 Time Measurements

The elapsed time measurement shall be measured with an instrument that is accurate within  $\pm 0.5$  seconds per hour.

### 3.2.8 Calorimeter

Heating value of the fuel must be measured. The repeatability of the measurement device shall be  $\pm 1\%$  of full scale, and the precision of the device shall be  $\pm 2$  Btu/dscf. Calibration shall be conducted weekly using the device manufacturer's directions.

Alternately, heating value may be calculated based on gas speciation of the fuel. Refer to ASTM Method D 1945, "Standard Method for Analysis of Natural Gas by Gas Chromatography" and D 3588, "Standard Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels."

## **4.0 ENVIRONMENTAL CRITERIA**

### **4.1 Ambient Temperature**

Testing shall be conducted indoors with the ambient air temperature of the test room maintained between 65°F and 85°F at all times during the test. The ambient temperature shall be monitored and recorded before and after the test.

### **4.2 Relative Humidity**

The relative humidity shall be between 20% and 65% during the test. It shall be recorded before and after the test.

### **4.3 Barometric Pressure**

The barometric pressure shall be monitored and recorded before and after each test.

### **4.4 Static Pressure**

The static pressure in the test chamber shall be recorded before and after each test.

## 5.0 PRE-TEST PREPARATIONS

### 5.1 Test Kitchen

#### 5.1.1 Grease Baffles

The grease baffles shall be cleaned with detergent and water prior to testing. The baffles need not be cleaned within a set of test runs, unless the cooking operations are impaired by grease build-up.

#### 5.1.2 Ducting

For test kitchens which have never performed certification testing, a cyclonic flow and stratification check are required. The absence of cyclonic flow shall be verified by Paragraph 2.4 of District Method 1.1; gas stratification shall be checked using the procedure in Chapter X, Section 13, in the District Source Test Manual.

### 5.2 Charbroiler

#### 5.2.1 Installation and Positioning

The under-fired charbroiler shall be installed per manufacturer's instructions, and shall be positioned below the hood such that the perimeter of the hood overlaps the outer edge of the charbroiler on the front and sides by at least 6 inches. In addition, both sides of the appliance shall be a minimum of 3 feet from any side wall, side partition, or other operating appliance. The vertical distance between the hood and the top of the charbroiler shall be per manufacturer specifications. It is recommended that preliminary testing be conducted to visually confirm that particulates emitted from the charbroiler are captured by the hood.

#### 5.2.2 Fuel Consumption

Install one or more instruments to measure the quantity of natural gas consumed in accordance with Section 3.2.5 of this protocol.

### 5.2.3 Control Device

The control device shall be installed such that the number of upstream and downstream distances to the inlet and outlet sampling ports meet the minimum requirements of Method 1.1. If space or other limitations do not allow for installation of both inlet and outlet ports, the test for control efficiency shall be conducted with the control device installed, and with the device removed.

However, the control device must be installed so that the outlet sampling port location satisfies the minimum upstream and downstream requirements of Method 1.1.

### 5.2.4 Cleaning

Prior to conducting a test set, the charbroiler unit shall be cleaned according to manufacturer's instructions.

## 5.3 **Meat**

### 5.3.1 Meat Specifications

The nominal specifications of the hamburger meat shall be one-third pound, finished grind, pure beef patties,  $20 \pm 2\%$  fat by weight, 58-62% moisture, 5/8 inch thick, and 5 inches in diameter. The fat and moisture content shall be analyzed in accordance with recognized laboratory procedures (AOAC Official Actions 960.39 and 950.46, respectively). One patty per test run shall be randomly selected for these analyses. A set of three test runs, for example, would require three patties be reserved for fat and moisture content analyses.

Depending on the test objectives, alternative meat specifications such as meat type, fat content, etc. may be tested following written approval of the Executive Officer.

### 5.3.2 Storage

Sheet pans shall be loaded with 24 patties (6 patties per level by 4 levels), separating each level by a double sheet of waxed freezer paper. Store the patties in a refrigerator maintained at approximately 38 - 40°F. The pans shall be stacked with approximately 1/4 inch spacers between each pan to allow air flow. The refrigerator temperature shall be continuously monitored, and a thermocouple placed in a hamburger patty to ensure the pre-cooked condition of the meat.

## 6.0 TEST PROCEDURE

### 6.1 Test Runs

A minimum of three test runs shall comprise a test set. Sampling at the inlet and outlet of the control device shall be performed concurrently. However, if space or other limitations do not allow for simultaneous testing, then one test set shall be conducted without a control device, and another test set shall be conducted with the control device installed. Unless otherwise approved by the Executive Officer, a test set shall be conducted within a span of one week.

Note that the minimum required runs are assumed for under-fired charbroilers cooking meat with the specifications in Section 5.3.1, using an electrostatic precipitator as the control. Additional test runs may be necessary for other meats or control devices based on the variability of the cooking process.

### 6.2 Sampling Set-Up And Calibration

#### 6.2.1 Air Flow Rate

The velocity in the duct shall be set at 1600 fpm (with the charbroiler on). This velocity corresponds to a hood flow rate of 400 cfm for each linear foot of hood length.

#### 6.2.2 Particulate Matter

The particulate matter sampling train and connecting equipment shall be prepared, calibrated, and checked in accordance with the protocol: "Determination of Particulate and Volatile Organic Compound Emissions From Restaurant Operations" (Sampling Protocol). Refer to the Sampling Protocol for Quality Assurance/ Quality Control Requirements.

### 6.2.3 Gas Sampling

The sampling systems and connecting equipment for oxygen, carbon monoxide, and carbon dioxide measurements shall be prepared, calibrated, and checked in accordance with District Method 10.1 or Method 100.1.

### 6.2.4 Refrigerated Hamburger Patty Temperature

Ensure the refrigerated hamburger patty internal temperature is stable, and is between 38 to 40°F. Adjust the refrigerator controls as necessary to maintain the internal patty temperature at the targeted value.

## **6.3 Charbroiler Set-Up**

### 6.3.1 Power Input

The firing rate shall be set to operate within 5% of the manufacturer's specified input rate (maximum input). Additionally, the burners shall be adjusted to within 2.5% of the specified operating pressure.

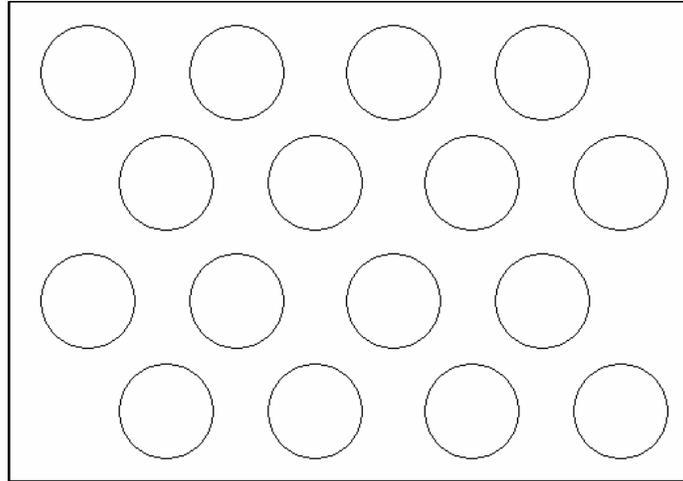
### 6.3.2 Warm-Up Period

The charbroiler unit shall be operated at the maximum input for a minimum of one hour. The flow meter shall be monitored at 15 minute intervals to verify that the firing rate is within the requirements of Section 6.3.1 during the warm-up period.

### 6.3.3 Temperature Distribution

For the purpose of this protocol, the cooking load shall correspond to two-thirds of the heavy load capacity, rounded up to the nearest patty. The heavy load capacity shall be determined in accordance with Paragraph 10.3.2 of ASTM F1695. Obtain the same number of temperature measurement disks as the number of patties that will be placed on the cooking surface during each load. Construct temperature measurement disks per Paragraph 10.3.1 of the ASTM F1695, and place the disks

in a pattern which is as symmetric and equally spaced as possible. For example, the disk placement pattern for a 36 by 24 inch cooking surface may be as follows:



Monitor the disk temperatures, and record the temperature of each disk at the 30 minute, 45 minute, and 60 minute mark following the start of the warm-up period. Calculate the average temperature for each disk, and determine the maximum difference between the highest and lowest average disk temperatures.

#### 6.3.4 Broiler Controls

Once the average temperatures have been calculated, set the broiler controls so that the temperature of each disk does not exceed 600°F, per Paragraph 10.6.2 of ASTM F1695. Monitor the temperatures of the disks at 15 minute intervals, and adjust the controls until three successive readings show each average disk temperature is between 550 - 600°F. Use the three readings to determine the maximum difference between the highest and lowest average disk temperatures. Mark the positions of the control knobs so that the same settings may be used in subsequent test runs.

#### 6.3.5 Multiple Testing Days

For a test series which must be conducted over several days, the procedures in Sections 6.3.3 and 6.3.4 need only be performed initially prior to the first test run,

but must be repeated at least once every seven calendar days. On multiple test days, warm up the charbroiler for a minimum of one hour at the control settings marked in Section 6.3.4. Verify that the temperature of the highest and lowest temperature locations (determined in Section 6.3.4) are within the 550 - 600°F range at the 30 minute, 45 minute, and 60 minute marks of the warm up period. Additionally, monitor and record the heat input to the charbroiler.

#### **6.4 Test Procedure**

After setting the broiler controls, begin cooking hamburger meat per ASTM F1695, Paragraphs 10.7.7 through 10.7.14, but do not begin sampling for particulate matter or fixed gases until the start of the third load (i.e., after two stabilization loads).

The minimum sampling times shall be as follows:

Particulate Matter	72 minutes; and,
CO, CO <sub>2</sub> , O <sub>2</sub> , methane	60 minutes.

The weight loss shall be verified every third tray using the procedures described in Section 6.5.2.

One cooked patty from each run shall be reserved for moisture analysis. If moisture analysis is not immediately conducted, place the cooked patties inside self-sealing plastic bags and store in a freezer maintained at -5°F.

#### **6.5 Internal Meat Temperature**

##### **6.5.1 Temperature Measurement Procedures**

Two procedures are available for determining the internal meat temperature of the cooked meat patties. The first is a direct measurement system using the device described in Section 6.5.2. The second procedure is based on studies indicating a correlation between weight loss and internal meat temperature. However, if this

second procedure is employed, the direct measurement system must be used to verify the correlation at least twice per test run (i.e., following the third and sixth loads after the stability loads). If the cooking times specified in ASTM F1695 Paragraphs 10.7.8 and 10.7.9 do not produce cooked patties at the desired internal meat temperature or weight loss, the cooking time shall be extended or reduced per Paragraph 10.7.13 of ASTM F1695 so that approximately 60% of the total cooking time is on the first side of the patty.

6.5.2 Direct Temperature Measurements

The internal meat temperature shall be determined with a stack of six to eight hamburger patties placed in a temperature measurement system. The system consists of an insulated container with a thermocouple bundle attached to the lid (see Figure 3). One thermocouple is located in the center, and the remaining four are arranged in a square pattern at a radial distance of 1 inch from the center. The dimensions tabulated below apply to Figure 3:

<b>Item</b>	<b>Dimension</b>
Outer Casing Diameter	8"
Inner Casing Diameter	4.75"
Center Thermocouple Length (Below Top Plug)	2.25"
Radial Thermocouple Lengths (Below Top Plug)	1.25", 1.5", 1.75", 2.5"
Depth of Inner Casing	6.5" *
Top Insulation Plug	1"
Bottom Plug Thickness	Varies **

\* Includes the thicknesses of the top and bottom plugs

\*\* Varies depending on the thickness of the hamburger patties. For 3/8 inch thick patties, the plug thickness was 2.25 inches.

The inner casing of the temperature measurement system shall be pre-warmed with cooked patties from a previous load. Patties shall then be inserted into the temperature measurement system immediately after removal from the charbroiler. A measurement shall be made at least once for every 24 patties cooked. The results must show that the internal meat temperatures are  $175 \pm 5^{\circ}\text{F}$ .

### 6.5.3 Correlation Procedures

Research conducted by Pacific Gas & Electric Company (PG&E Standard Test Method for the Performance of Underfired Broilers, 1995) has determined that the final internal temperature of cooked hamburger patties may be measured by the percent weight loss incurred during cooking. For hamburger patties specified in Section 5.3.1 of this protocol, an internal meat temperature of  $175^{\circ}\text{F}$  corresponds to a weight loss of  $35 \pm 5\%$ .

Weight loss measurements are determined as follows: measure the weight of a full pan (24 patties) prior to cooking. Subtract the weight of the pan to determine the initial weight of the patties. Once the patties have been cooked on the charbroiler, use tongs to spread the patties on a drip rack. After one minute, the patties are turned. After the second minute, transfer the patties to a clean, tared pan for weighing. Weight loss shall be determined on a full pan (24 patties) basis.

## 6.6 **Post-Test Calibration And Analysis**

### 6.6.1 Particulate Matter And Gaseous Emissions

Post test calibration checks and leak checks shall be conducted in accordance with the Sampling Protocol. Follow procedures referenced in the Sampling Protocol to analyze for PM, the corrected concentration for VOC, carbon monoxide, carbon dioxide, oxygen, and methane.

6.6.2 Fat/Moisture Content In Patties

Fat and moisture content of the patties shall be analyzed according to procedures specified in Section 5.3.1 of this protocol. The fat content shall be determined for the uncooked patties only. Identify the cooked and uncooked samples so that moisture loss may be calculated.

## 7.0 CALCULATIONS

PM and VOC calculations shall be in accordance with the Sampling Protocol, except the Pounds Per Day calculation, (Section 5.3 of the Sampling Protocol) shall be excluded.

Use weights of the uncooked meat for calculation and reporting purposes.

Report test results according to Section 6.0 of the Sampling Protocol. Destruction efficiency for the control device shall be calculated as follows:

$$\text{Destruction Efficiency} = \frac{\text{Without Control} - \text{With Control}}{\text{Without Control}} \times 100\%$$

where:

Without Control = Mass Emissions (lb/hr) from charbroiler without the control

With Control = Mass Emissions (lb/hr) from charbroiler with the control installed.

## 8.0 REPORTING

### 8.1 REPORT INFORMATION

The following information is to be included in the test report:

1. All printouts, must be included in the final report and must be clearly identified as to:

-location/source	-range changes
-operator initials	-range of measurement
-date/running times	-calibrations
-actual test interval	-cal gas concentration/cyl. no.
-contaminant/diluent	-range of calibration
2. A summary of the Source Test results.
3. A brief process description, including all information listed in Section 3.0.
4. A simple schematic diagram of the process, showing the sampling location, with respect to the upstream and downstream flow disturbances.
5. The sampling and analytical procedures. Be specific about all aspects of sampling and analysis. Include diagrams of test equipment and methods.
6. Complete raw field data, including production data indicative of the testing interval, analyses, and the test results (show all calculations).
7. Calibration data regarding all sampling and measuring equipment utilized during testing (see District Source Testing Manual, Chapter III).
8. A signed statement confirming that the testing laboratory satisfies all criteria for an independent laboratory, as defined by District Rule 304(k).
9. A manufacturer's specification sheet and/or abridged owner's manual which lists the features of the control device, including the theory of operation, operating capacity, installation requirements, and maintenance schedule.

## 8.2 REPORT FORMAT

The report shall be submitted in a hardcopy format. For ease of processing however, it is recommended that an electronic copy accompany the hardcopy report. In addition, each page of the final test report (including raw analytical and field data, as well as other third party reports) must have a unique and sequential page number which can be referenced in correspondences. The information in the final report shall be formatted as follows:

- I. Table of Contents
- II. Executive Summary
- III. Results Table
- IV. Introduction
- V. Equipment/ Process Description. Include results of the patty analysis of the fat and moisture content. This section shall include a statement that verifies acceptability of the method test location and the operating condition during the test.
- VI. Test Critique
- VII. List of Sampling and Analytical Methods Used. This section shall include a list of the test methods used. Do not include copies or descriptions of the source test methods if the methods were adhered to as written. If exceptions were made to the methods, submit only an explanation of the exceptions.
- VIII. Appendices
  - A. SCAQMD Method Results
  - B. Schematics of Stack Sampling Locations
  - C. Field Data Sheets - testing method and process data sheets shall be compiled in separate sections
  - D. QA/QC
  - E. Laboratory Analytical Data
  - F. Calibration Data and Calculations
  - G. Calibration Certificates
  - H. Chain of Custody Information (as necessary)
  - I. Process Operating Data Including Fuel Usage During Test
  - J. Certifications

## **FIGURES**

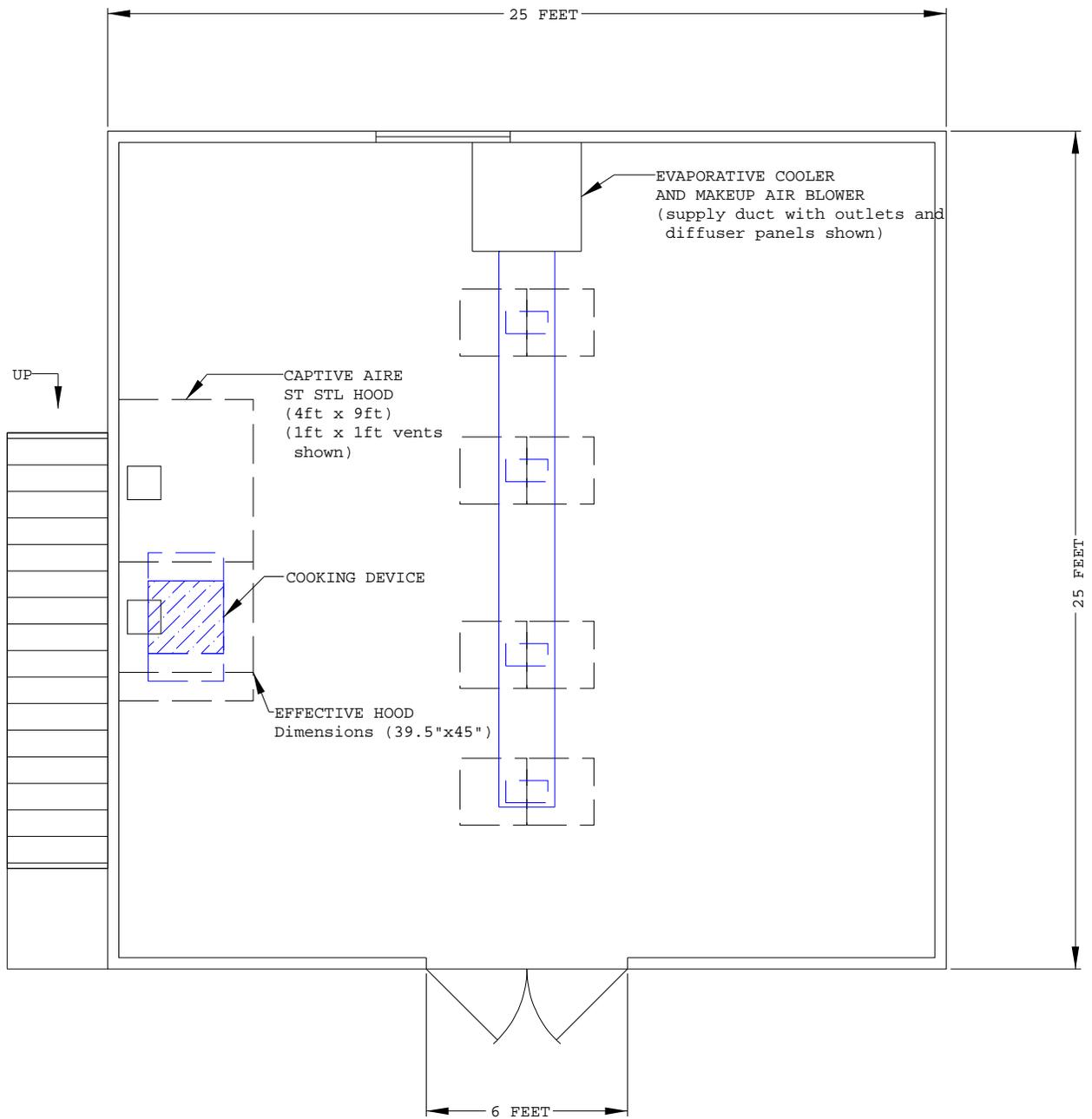


FIGURE 1  
TEST KITCHEN DETAILS

CE-CERT  
TEST KITCHEN FACILITY

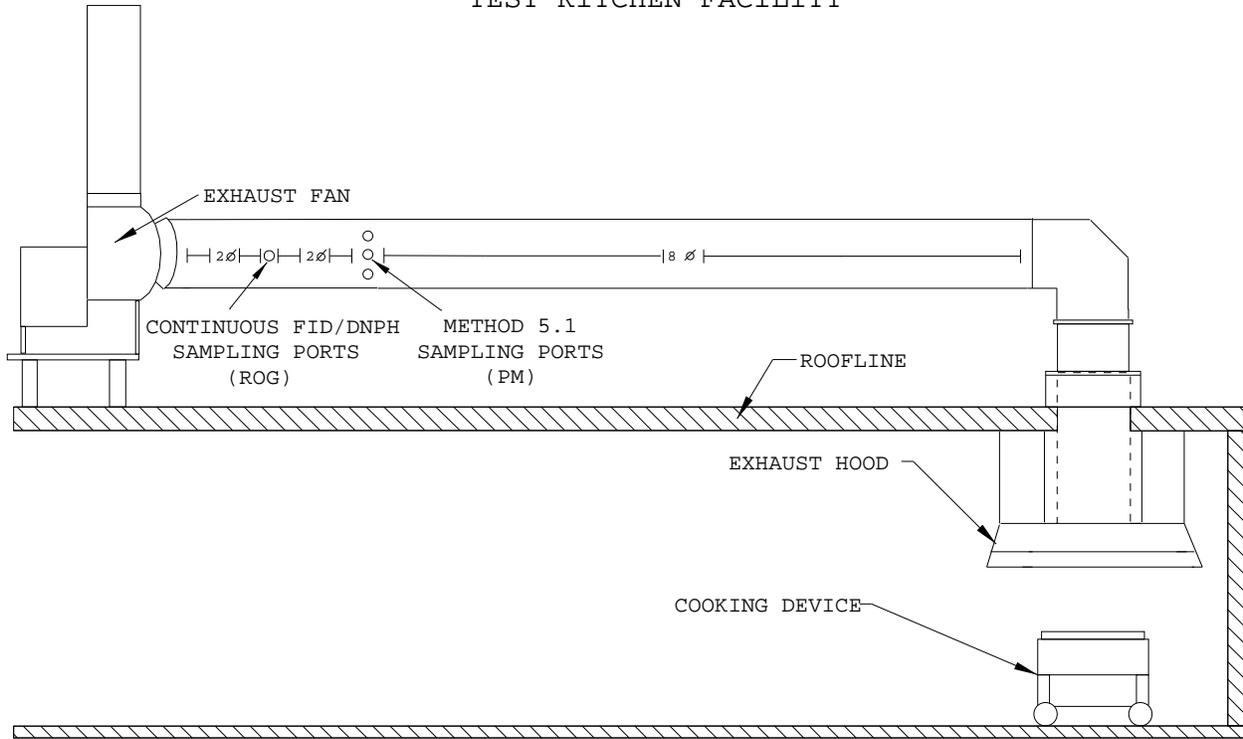


FIGURE 2  
DUCT DETAILS

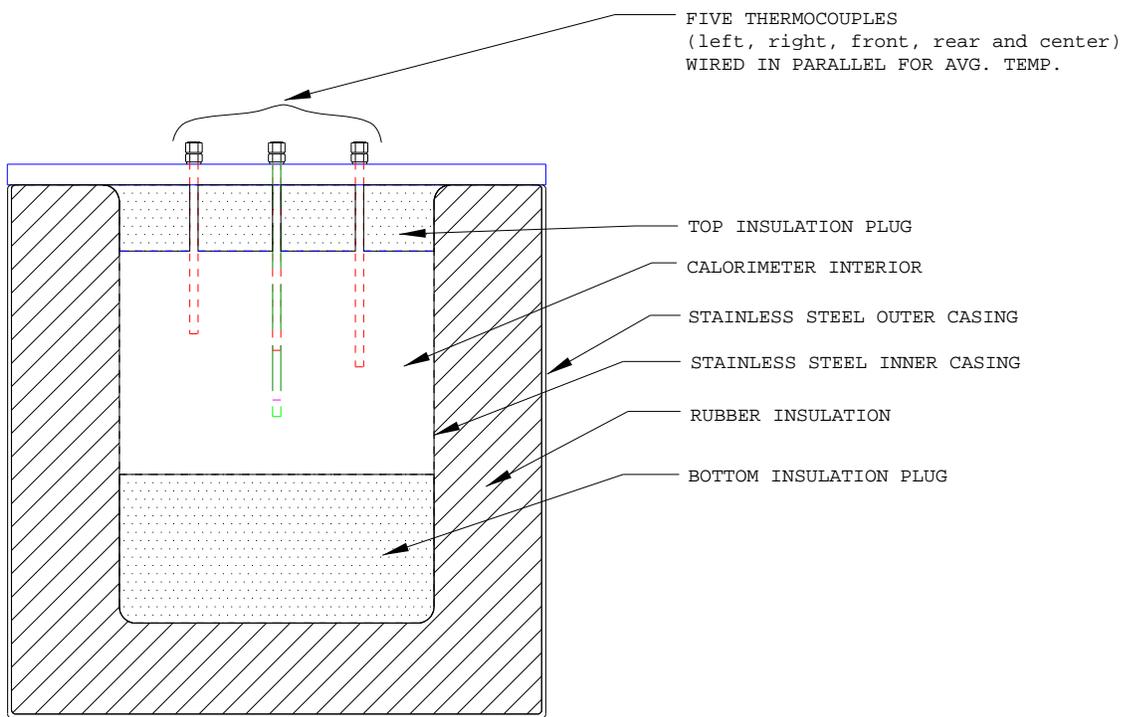


FIGURE 3  
PATTY INTERNAL TEMPERATURE MEASUREMENT