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ACCEPTANCE CRITERIA FOR INSULATED GARAGE DOORS WITH FOAM PLASTIC CORES

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PREFACE

Evaluation reports issued by the ICBO Evaluation Service, Inc. (ICBO ES), are based upon performance features of the *Uniform Building Code*[™], *ICBO Uniform Mechanical Code*[™] and related codes. Section 104.2.8 of the Uniform Building Code is the primary charging section upon which evaluation reports are issued. Section 104.2.8 reads as follows:

The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.

The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with the provisions of this code and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.

The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

The attached acceptance criteria for the general code sections noted have been issued to provide all interested parties with guidelines on implementing performance features of the codes. The attached acceptance criteria were developed and adopted following public hearings conducted by the Evaluation Committee. These criteria may be revised from time to time as the need dictates.

ICBO ES may consider alternate criteria, provided the proponent submits valid data demonstrating that the alternate criteria are at least equivalent to the attached criteria and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a material, type or method of construction, or equipment, meets the attached acceptance criteria, or it can be demonstrated that valid alternate criteria are equivalent and otherwise meet the applicable performance requirements of the codes, if the material, product, system or equipment is such that either unusual care with its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use thereof, ICBO ES retains the right to refuse to issue or renew an evaluation report.

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1. INTRODUCTION

Scope: Garage doors with foam plastic cores that do not comply with U.B.C. Section 2602.5.4 can be evaluated under Section 2602.6 of the code, provided: (1) The foam plastic complies with Sections 2602.1, 2602.2 and 2602.3. (2) The foam plastic has a minimum self-ignition temperature of 650°F. when tested in accordance with ASTM D 1929. (3) Room fire tests in accordance with U.B.C. Standard 26-3 demonstrate acceptable performance; the door specimen may be installed with the normal headroom height of the door as specified by the manufacturer. (4) Doors tested in accordance with the room fire test protocol described in this acceptance criteria, and demonstrating compliance with the acceptance criteria, may be considered in lieu of testing under Item 3 above.

2. SUMMARY OF METHOD

A 7-foot-high (2.13 m) by 8-foot-wide (2.4 m) foam plastic insulated garage door is mounted adjacent to the rear wall of an 8-foot-wide (2.4 m), 12-foot-long (3.6 m) by 8-foot-high (2.4 m) room enclosure. The test specimen covers the rear wall from floor level to a height of 7 feet (2.13 m).

This method uses a gas burner to produce a diffusion flame. The burner is located in the corner of the test room adjacent to the test specimen. The burner produces a prescribed rate of heat release output of 40 kW (38 Btu/s) for 5 minutes, followed by 150 kW (142 Btu/s) for 10 minutes, for a total exposure period of 15 minutes. The contribution of the test specimen to room fire hazard is measured via constant monitoring of the rate of heat release, the smoke release rate, the temperature of the gases in the upper part of the room, the temperature rise in the core of the test sample, the incident heat flux on the center of the floor and the time to flashover. The test is conducted with natural ventilation to the room provided by a single doorway 30 inches (0.76 m) wide by 80 inches (2.03 m) high.

The combustion products are collected in a hood feeding into a plenum connected to an exhaust duct in which measurements are made of the gas velocity, temperature, percent light transmission, and concentration of selected gases.

3. DEFINITIONS

For purposes of this standard, the following terms are defined as indicated:

3.1 Average Upper Gas Layer Temperature: This temperature shall be based on the average of the four ceiling quadrant thermocouples and the center-of-the-room ceiling thermocouple.

3.2 Flashover: Flashover shall be determined to have occurred when any of the following conditions has been attained:

3.2.1 Heat flux onto the floor reaches 20 kW/m² (1.76 Btu/ft²-s).

3.2.2 Average upper air temperature reaches 1112°F. (600°C.).

3.2.3 Flames exit doorway.

3.2.4 Spontaneous ignition occurs of paper target on floor.

4. IGNITION SOURCE

4.1 Burner Dimensions: The ignition source for the test shall be a gas burner with a nominal 12-inch by 12-inch (0.3 m by 0.3 m) porous top surface of refractory material. See Figure 1. A burner shall be constructed with a 1-inch-thick (25.4 mm) porous ceramic fiberboard over a 6-inch (152 mm) plenum, or else a minimum 4-inch (102 mm) layer of Ottawa sand shall be used to provide the horizontal surface through which the gas is supplied.

4.2 Burner Location: The top surface of the burner through which the gas is applied shall be 12 inches (0.3 m) above the floor,

and the burner enclosure shall be located such that the edge of the diffusion surface is located 2 inches (51 mm) from both walls, in the left rear corner of the room, as viewed from the door. See Figure 2.

4.3 Burner Gas Supply: The gas supply to the burner shall be of C. P. grade propane (99 percent purity). The burner shall be capable of producing a gross heat output of 40 kW ± 1 kW (38 Btu/s ± 1 Btu/s) for 5 minutes followed by a gross heat output of 150 kW ± 5 kW (142 Btu/s ± 5 Btu/s) for 10 minutes. Flow rates shall be calculated using propane's net heat of combustion, which is 85 MJ/m³ (2280 Btu/ft³) at 68°F. (20°C.) throughout the test. The burner design shall allow switching from 40 kW (38 Btu/s) to 150 kW (142 Btu/s) within 10 seconds. Burner controls are permitted for automatic shutoff of the gas supply if flameout occurs. Two arrangements for a gas supply are illustrated by Figure 3.

4.4 Burner Ignition: The burner shall be ignited by a pilot burner or a remotely controlled igniter.

5. COMPARTMENT GEOMETRY AND CONSTRUCTION

5.1 Fire Room Dimensions: The interior dimensions of the floor of the fire room, when the specimens are in place, shall measure 8 feet ± 3.9 inches by 12 feet ± 3.9 inches (2.44 m ± 0.1 m by 3.66 m ± 0.1 m). The finished ceiling shall be 8 feet ± 3.9 inches (2.44 m ± 0.1 m) above the floor. There shall be four walls at right angles defining the compartments. See Figure 4.

5.2 Doorway: There shall be a doorway measuring 30 inches ± 0.25 inch by 80 inches ± 0.25 inch (0.76 m ± 6.4 mm by 2.03 m ± 6.4 mm) in the center of one of the 8-foot by 8-foot (2.44 m by 2.44 m) walls, and there shall be no other wall, floor or ceiling openings that allow ventilation. The door frame shall be constructed to remain unchanged during the test period to a tolerance of ± 1 percent in height and width.

5.3 Fire Room Construction: The fire room shall be a framed or masonry structure. The floor, ceiling and walls of the test compartment shall be covered by calcium silicate board or by gypsum wallboard. The inside surface of the wall containing the door shall be calcium silicate board of 736 kg/m³ (46 lb/ft³) density and nominal 1/2-inch (12 mm) thickness, or 1/2-inch (12 mm) gypsum wallboard.

6. SPECIMEN MOUNTING

Specimen mounting details shall be comparable to those intended for the actual product. Specimens shall consist of full garage door assemblies incorporating inside and outside facings, gaskets, framing members, insulation, air gaps, and other details, as appropriate to the product being evaluated, and as follows:

6.1 A minimum 8-foot-wide (2.4 m) by 7-foot-high (2.13 m) test specimen shall be mounted adjacent to the gypsum wallboard rear wall of the fire room enclosure, as shown in Figure 2.

6.2 The garage door shall be mounted in the fire room so that the bottom of the door rests on the floor of the fire room and the top of the door is not more than 12 inches (305 mm) below the underside of the ceiling. Where a garage door in an actual installation may be installed with less than a 12-inch (305 mm) separation between the top of the door and the underside of the ceiling, the door shall be mounted in the fire room using the minimum separation contemplated for the actual installation.

6.3 Test specimens are attached to the gypsum wallboard fire room enclosure using metal stud screws and fender washers at the edges of panels, as indicated on Figure 2. Angle brackets are located at panel edges, so that one bracket attaches to, and secures, two panels in place. See Figure 5. The screws and angle brackets located directly above the burner are tightened to hold the test specimen securely in place. The angle bracket and metal stud screws, placed in

the slots of the angle bracket on the end of the panels remote from the burner, are lightly tightened, allowing the specimen to expand during tests. The right side of the test specimen, as viewed from the room door, is to be separated up to a maximum of 1½ inches (38.1 mm) from the right-side wall of the test room enclosure, to allow for thermal expansion.

6.4 Test specimens are oriented such that the normally inside face of the garage door assembly faces the burner.

7. SPECIMEN CONDITIONING

Prior to testing, specimens shall be conditioned for a minimum of seven days or until the sample reaches a rate of weight change of less than 0.1 percent per day at a temperature of 70°F. ± 5°F. (49°C. ± 2.8°C.) and a relative humidity of 50 percent ± 5 percent.

8. ENVIRONMENTAL CONDITIONS

8.1 Fire Room Air Supply: The building in which the fire room is located shall have vents for the discharge of combustion products and shall have provision for fresh air intake, so that no oxygen-deficient air is introduced into the fire room during the test. Prior to the start of the test, the ambient air at the mid-height entrance to the fire room shall have a velocity of less than 0.5 m/s (100 ft/min) in any direction. The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire room.

8.2 Ambient Temperature: The ambient temperature in the test building around the fire room shall be above 40°F. (4°C.) and the relative humidity shall be less than 75 percent for the duration of the test.

8.3 Ambient Conditions: If test samples are installed within the fire room for two or more hours prior to test, the following ambient conditions shall be maintained:

8.3.1 The ambient temperature in the fire room, measured by one of the thermocouples specified in Paragraph 9.2.3, shall be 65°F. to 75°F. (18°C. to 24°C.).

8.3.2 The ambient relative humidity in the fire room shall be 50 percent ± 5 percent.

9. INSTRUMENTATION

The following instrumentation shall be provided for this test:

9.1 Total Heat Flux Gage:

9.1.1 Location: The gage shall be mounted a maximum of 2 inches (51 mm) above the floor surface, facing upward in the geometric center of the fire room. See Figure 6.

9.1.2 Specification: The gage shall be of the Gardon or Schmidt-Boetler type, with a circular, flat-black surface ½ inch (13 mm) in diameter and with a 180-degree view angle. In operation, the gage shall be maintained at a constant temperature within ± 5°F. (2.8°C.) of the dewpoint by water supplied at a temperature of 120°F. to 150°F. (50°C. to 65°C.). This will normally require a flow rate of at least 0.38 L/min (0.1 gal/min). The full-scale output range for the gage shall be 50 kW/m².

9.2 Thermocouples:

9.2.1 Specification: Bare Type K thermocouples, 20 mils (0.5 mm) in diameter, shall be used at each required location. The thermocouple wire within ½ inch (13 mm) of the bead shall be run along expected isotherms to minimize conduction errors. The insulation between the chromel and alumel wires shall be stable to at least 2000°F. (1100°C.), or the wires shall be separated.

9.2.2 Location in Doorway: A thermocouple shall be located in the interior plane of the door opening on the door centerline, 4 inches (100 mm) from the top. See Figure 6.

9.2.3 Location in Room: Thermocouples shall be located 4 inches (100 mm) below the ceiling, at the center of the ceiling, at the center of each of the four ceiling quadrants, and directly over

the center of the ignition burner. The thermocouples shall be mounted on supports or shall penetrate through the ceiling with their junctions 4 inches (100 mm) away from the solid surface. See Figure 6. Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wire.

9.2.4 Location in Canopy and Exhaust Duct: One pair of thermocouples shall be placed a minimum of 8.25 duct diameters downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and the two thermocouples shall be separated 2 inches (50 mm) from each other. See Figure 7.

9.2.5 Location in Specimen Foam Core: One thermocouple shall be placed near the center of the foam plastic core, approximately 3 inches (76.2 mm) from the right side and 13 inches (330 mm) below the ceiling of the fire room. See Figure 2.

9.3 Canopy Hood and Exhaust Duct:

9.3.1 Location and Design: A hood shall be installed immediately adjacent to the door of the fire room. The bottom of the hood shall be level with the top surface of the room. The face dimensions of the hood shall be a minimum of 8 feet by 8 feet (2.44 m by 2.44 m), and the minimum depth shall be 3.5 feet (1.1 m). The hood shall feed into a plenum having a minimum 3-foot by 3-foot (0.92 m by 0.92 m) cross section. The plenum shall have a minimum height of 3 feet (0.92 m). This height shall be permitted to be increased to a maximum of 6 feet (1.8 m) to satisfy building constraints. The exhaust duct connected to the plenum shall be a minimum of 16 inches (0.4 m) in diameter, horizontal, and shall have a circular aperture of at least 12 inches (0.3 m) at its entrance or mixing vanes in the duct. See Figures 7 and 8 for additional details.

9.3.2 Exhaust Flow Rate: The hood shall have sufficient draft to collect all the combustion products leaving the room. This draft shall be capable of moving up to 3.4 m³/s (7,000 standard ft³/min) equivalent to 7.25 m³/s (16,100 ft³/min) at 750°F. (399°C.) during the test. Provision shall be made so that the draft can operate at 0.47 to 3.4 m³/s (1,000 to 7,000 standard ft³/min.). Mixing vanes shall be provided in the duct if concentration gradients are found to exist.

9.3.3 Alternative Exhaust Design: An alternative exhaust system design may be used if it meets the requirements of Section 9.3.2.

9.4 Duct Gas Velocity: Specification: A bi-directional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. The probe shall consist of a short, stainless steel cylinder, 1.75 inches (44 mm) long with a 0.875-inch (22 mm) inside diameter and with a solid diaphragm in the center, or shall be some other design shown capable of measuring gas velocity in the duct. See Figure 9. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall run along the centerline of the duct a minimum of 8.25 duct diameters downstream from the entrance. See Figure 7. The taps shall be connected to a pressure transducer that is able to resolve pressure differences of 0.25 Pa (0.001 inch H₂O).

9.5 Oxygen Depletion Measurements:

9.5.1 Determination of Rate of Heat Release: A stainless steel gas sampling tube shall be located a minimum of 8.63 duct diameters downstream from the entrance to the duct, at the geometric center of the duct ± ½ inch (13 mm), to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. See Figure 7. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring oxygen concentration in a range of 21 percent to 15 percent, with a relative accuracy of 50 ppm in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value and shall occur within 30 seconds of a step

change being introduced in the composition of the gas stream flowing past the inlet to the sampling tube.

9.5.2 Duct Carbon Dioxide Concentration: The gas sampling tube, described in Paragraph 9.5.1 above, shall be used to provide a continuous sample for measurement of the carbon dioxide concentration, using an analyzer with a range of 0 to 20 percent with a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds.

9.5.3 Duct Carbon Monoxide Concentration: The gas sampling tube, defined in Paragraph 9.5.1 above, shall be used to provide a continuous sample for measurement of the carbon monoxide concentration, using an analyzer with a range of 0 to 10 percent with a maximum relative error of 2 percent of full scale. The signal from the analyzer shall be within 5 percent of its final value and shall occur within 30 seconds of a step change being introduced in the composition of the gas stream flowing past the inlet to the sampling tube.

9.6 Smoke Obscuration Measurement:

9.6.1 Optical System: An optical system shall be provided for measurement of light obscuration across the centerline of the exhaust duct. The system shall be located a minimum of 9 duct diameters downstream from the entrance to the duct. See Figure 7. The optical density of the smoke shall be determined by measuring the light transmitted across the centerline of the exhaust duct with a photometer system consisting of a white light source and a photocell/detector or laser system.

9.6.2 Specifications: The optical system shall consist of a lamp, plano convex lenses, an aperture, a photocell, and an appropriate power supply. The lenses, lamp and photocell shall be mounted inside two housings, located on the exhaust duct, diametrically opposite each other. The system shall be constructed such that soot deposits on the optics during a test do not reduce the light transmission by more than 5 percent.

9.6.3 Lamp: A lamp of the incandescent filament type, which operates at a color temperature of $2,900 \pm 100$ K, shall be used. Supply the lamp with stabilized direct current, stable within ± 0.2 percent (including temperature, short-term and long-term stability). Center the resultant light beam on the photocell.

9.6.4 Lens System: Select the lens system such that lens L_2 has a diameter, d , chosen with regard to the focal length, f , of L_2 so that $d/f \geq 0.04$. Place the aperture in the focus of lens L_2 . See Figure 10.

9.6.5 Detector: Use a detector with a spectrally distributed response according to the CIE photopic curve and linear within 5 percent over an output range of at least 3.5 decades. Periodically check this linearity over the entire range of the instrument with calibrated optical filters.

9.6.6 Optical System: Optical system design shall be one that is purged easily against soot deposits. Holes shall be provided in the periphery of the two housings as a means of achieving this objective.

9.7 Paper Targets: Two paper target flashover indicators shall be placed on the floor of the test room. See Figure 12. The targets shall consist of a single piece of newsprint crumpled into an approximate 6-inch-diameter (152 mm) ball.

9.8 Photographic Documentation: Photographic or video equipment shall be used to record the fire spread in the fire room and the fire projection from the door of the room. The cameras shall be located so as to avoid interference with airflow. The interior wall surfaces of the fire room adjacent to the corner in which the burner is located shall be clearly marked. A clock shall appear in all photographic records, showing the time to at least the nearest 1 second from the start of the test. This clock shall be accurately synchronized with all other measurements, or other provision shall be made to correlate the photo record with time. Color slides or photographs shall

be taken at intervals for the duration of the test, or a continuous video recording shall be made.

10. CALIBRATION

Heat Release, Temperature and Velocity: A calibration test shall be performed prior to and within 30 days of any fire test. The calibration test shall last for a minimum of 15 minutes. Take measurements a minimum of once every six seconds. The standard ignition source shall be used with inert wall and ceiling materials—calcium silicate board of 56 lb/ft^3 (736 kg/m^3) density and $1/2$ -inch (13 mm) thickness, or gypsum wallboard. The standard ignition source shall be operated at a minimum of two heat release rates—40 kW and 150 kW—during the calibration test.

10.1 Calibration Factor: The data resulting from a calibration test shall provide:

10.1.1 The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test.

10.1.2 The maximum extension of the burner flame, as recorded by still photographs taken at approximately 30-second intervals or continuous video recording.

10.1.3 The temperature and velocity profiles across the duct cross section at the location of the bi-directional probe. These profiles shall be used to determine the factor, k , in the following equation:

$$V_s = 0.926kA(2\Delta pT/P_oT_o)^{1/2}$$

Where:

0.926 = Suitable calibration factor for air velocities in excess of 10 ft/s (3.0 m/s) in a 16-inch (0.4 m) duct.

k = Ratio of the average duct gas mass flow per unit area, as determined by measuring the velocity and temperature at the centerline where the bi-directional probe is located during the test.

A = Cross-sectional area of the duct at the location of the probe, m^2 .

Δp = Differential pressure measured with the probe, P_a .

P_o = Density of air, kg/m^3 , at the reference temperature T_o , K.

T = Duct gas temperature, K.

10.1.4 Calculated Heat Release: The total rate of heat production as determined by the oxygen consumption calculation, independent measurement of the volumetric flow rate, and weight loss of propane supply shall agree to within 5 percent. The net heat of combustion is 85 MJ/m^3 ($2,280 \text{ Btu/ft}^3$) for propane at 68°F . (20°C .) and 100 kPa (14.70 psia). This value shall be used for this calculation.

10.2 Smoke Obscuration: The smoke meter shall be calibrated to read correctly for two neutral-density filters at 0.5 and 1.0 values of optical density and also at 100 percent transmission. The 0 value of extinction coefficient (100 percent transmission) shall be verified each day prior to testing.

10.3 Gas Analysis: Gas analyzers shall be calibrated daily prior to testing, in accordance with ASTM E 800-88, Standard Guide for Measurement of Gases Present or Generated During Fires.

11. TEST PROCEDURE

The test procedure shall consist of the following:

11.1 Establish an initial volumetric flow rate of at least 1,000 ft^3/min ($0.47 \text{ m}^3/\text{s}$) through the duct, and increase the volume flow rate of 7,000 ft^3/min ($3.4 \text{ m}^3/\text{s}$) as required to keep the oxygen content above 14 percent and to capture all effluents from the fire room.

11.2 Turn on all sampling and recording devices and take measurements a minimum of once every six seconds. Establish steady-state baseline readings for a minimum of one minute prior to starting a test.

11.3 Ignite the gas burner and simultaneously start the clock and increase the flow rate to provide a rate of heat release of $40 \text{ kW} \pm$

1 kW (38 Btu/s \pm 1 Btu/s) by the burner. Continue the exposure at the 40 kW \pm 1 kW (38 Btu/s \pm 1 Btu/s) level for 5 minutes. Within 10 seconds following the 5-minute exposure, increase the gas flow to provide a rate of heat release by the burner of 150 kW \pm 5 kW (142 Btu/s \pm 1 Btu/s) exposure for 10 minutes.

11.4 Take 35 mm color photographs at approximately 30-second intervals, or provide a continuous video recording to document the growth of the fire.

11.5 Provide a voice or written record of the fire, which documents the times of all significant events, such as time of ignition, escape of flames through the doorway, and flashover.

11.6 The ignition burner shall be shut off 15 minutes after the start of the test and the test shall be terminated at that time, unless safety considerations dictate an earlier termination.

11.7 Document damage after the test, using words, pictures and drawings.

12. CALCULATIONS

12.1 Heat Release: The calculation methods to determine the gross (total) rate of heat release (burner and specimen) shall be as follows:

Flow rate:

$$m_e = C \cdot (\Delta p / T_e)^{1/2} \quad (1)$$

Velocity measurement (Equation 2):

$$m_e = 26.54 \cdot A \cdot k_c / f \cdot (R_e) \cdot (\Delta p / T_e)^{1/2} \quad (2)$$

If Equation 2 is used, k_c shall be determined whenever the bi-directional probe or the duct is replaced. Determine k_c by correlating the velocity measured by the directional probe with a reference method, such as a pitot-static tube.

Also calculate the Reynolds number $f(R_e)$, Equation 3:

$$f(R_e) = 1.533 - 1.366 \cdot 10^{-3} R_e + 1.688 \cdot 10^6 R_e^2 - 9.705 \cdot 10^{11} R_e^3 + 2.555 \cdot 10^{-13} R_e^4 - 2.484 \cdot 10^{-17} R_e^5 \quad (3)$$

(3) If $R_e > 3800$, then $f(R_e) = 1.08$

Case 1: Only O₂ concentration measurements are used.

Calculate the mass flow rate according to Equations 1 or 2, and the oxygen depletion factor according to Equation 4:

$$\phi = \frac{X_{O_2}^{Ao} - X_{O_2}^A}{\left[1 - X_{O_2}^A \right] \cdot X_{O_2}^{Ao}} \quad (4)$$

Then calculate the rate of heat release (q) according to Equation 5:

$$q = E \cdot \frac{M_{O_2}}{M_a} \cdot \frac{\phi}{1 + \phi \cdot (a - 1)} \cdot m_e \cdot X_{O_2}^{Ao} \quad (5)$$

If only O₂ is measured, Equation 5 simplifies to Equation 6:

$$q = E \cdot 1.10 \cdot C \cdot \sqrt{\frac{\Delta p}{T_e}} \cdot \left[\frac{X_{O_2}^{Ao} - X_{O_2}^A}{1.105 - 1.5 \cdot X_{O_2}^A} \right] \quad (6)$$

Calculation of C factor: The C factor in Equation 6 shall be determined as follows: Place the sand burner below the hood calorimeter. Set the methane flow to provide heat release rate of 250 kW. Ignite the gas, and continue the burner for 5 minutes, and then switch off the gas. Then calculate the C factor as:

$$C = 75000 / \int_0^{300} E \cdot 1.1 \cdot \sqrt{\frac{\Delta P}{T_e}} \cdot \left[\frac{X_{O_2}^{Ao} - X_{O_2}^A}{1.105 - 1.5 \cdot X_{O_2}^A} \right] dt$$

where the numerator is the total heat (kJ) provided by the sand burner, and the denominator is the total heat captured (kJ) by the hood calorimeter in 5 minutes (300 seconds).

12.2 Smoke Release Rate: Smoke measurement calculation methods shall be as follows:

Optical density (OD) (Equation 7):

$$OD = \log[I_o/I] \quad (7)$$

The volumetric flow rate is calculated as the product of the mass flow rate and the density of air, at the corresponding temperature. Both the volumetric flow and the density of air shall undergo temperature corrections. The volumetric duct flow rate (V) is adjusted because it is measured in the exhaust duct, but required at the temperature near the photodetector, as shown in Equation 8:

$$V_s = V_e \cdot \left(\frac{T_s}{T_e} \right) \quad (8)$$

The density of air is adjusted between the literature value, measured at 273.15 K, and the value at the temperature in the exhaust duct, as shown in Equation 9:

$$\rho = \rho_o \cdot 273.15 / T_e \quad (9)$$

Then the final equation for the volumetric flow rate is Equation 10:

$$V_e = (m_e / \rho_o) \cdot (T_e / 273.15) \quad (10)$$

Rate of smoke release (RSR) is defined by Equation 11:

$$RSR = V_s \cdot OD \cdot 1 / L_p \quad (11)$$

Total smoke released (TSR) is defined by Equation 12:

$$TSR = \int RSR dt \quad (12)$$

Symbols:

- A: cross-sectional area of duct (m²)
- C: orifice plate coefficient (kg^{1/2} m^{1/2} K^{1/2})
- E: net heat released for complete combustion, per unit of oxygen consumed (13 100 kJ/kg O₂)
- E_{CO}: net heat released for complete combustion per unit of oxygen consumed, for CO (17 600 kJ/kg O₂)
- f(R_e): Reynolds number correction (nondimensional)
- I: light intensity for a parallel light beam having traversed a certain length of smoky environment and reaching photodetector (nondimensional)
- I_o: light intensity for a beam of parallel light rays, measured in a smoke-free environment, with a detector having the same spectral sensitivity as the human eye and reaching the photodetector (nondimensional)
- k_c: velocity profile shape factor (nondimensional)
- L_p: light path length of beam through smoke environment (m)
- m_e: C(Δp/T_e)^{1/2} (mass flow rate, by measurement of pressure drop, in kg/s, according to Equation 1)
- m_e: (26.54 x A x k_c / f(R_e)) · (Δp/T_e)^{1/2} (mass flow rate, by measurement of velocity drop, in kg/s, according to Equation 2)
- M_a: molecular weight of incoming and exhaust air (29 kg/kmol)
- M_{CO}: molecular weight of carbon monoxide (28 kg/kmol)
- M_{CO₂}: molecular weight of carbon dioxide (44 kg/kmol)
- M_{H₂O}: molecular weight of water (18 kg/kmol)
- M_{N₂}: molecular weight of nitrogen (28 kg/kmol)
- M_{O₂}: molecular weight of oxygen (32 kg/kmol)
- OD: optical density (nondimensional)
- Δp: pressure drop across the orifice plate or bi-directional probe (Pa)
- q: rate of heat release (kW)
- RSR: rate of smoke release (m²/s)
- T_e: combustion gas temperature at the orifice plate (K)
- T_s: combustion gas temperature (near photodetector) (K)

- TSR : total smoke released (m^2)
- V_e : volumetric flow rate in exhaust duct (at measuring location of mass flow rate) (m^3/s)
- V_s : volumetric flow rate at location of smoke meter (value adjusted from smoke measurement calculations) (m^3/s)
- $X_{CO_2}^A$: measured mole fraction of CO_2 in exhaust flow (nondimensional)
- X_{CO}^A : measured mole fraction of CO in exhaust flow (nondimensional)
- $X_{CO_2}^{Ao}$: measured mole fraction of CO_2 in incoming air (nondimensional)
- $X_{O_2}^A$: measured mole fraction of O_2 in exhaust flow (nondimensional)
- $X_{O_2}^{Ao}$: measured mole fraction of O_2 in incoming air (nondimensional)
- α : combustion expansion factor (nondimensional; normally a value of 1.105)
- ρ : density of air at the temperature in exhaust duct (kg/m^3)
- ρ_a : density of air at 273.15 K ($1.293 kg/m^3$)
- ϕ : oxygen depletion factor (nondimensional)

13. TEST REPORT

The test report shall include the following:

- 13.1** Name and address of testing laboratory.
- 13.2** Date and identification number of the report number.
- 13.3** Name and address of the test sponsor.
- 13.4** Materials:
- 13.4.1 Production Description:** Identification of the product; foam plastic thickness, type, and density; door facing materials, including type and thickness; all other details of door construction necessary to accurately describe the product being tested.
- 13.4.2** Product mounting details, including the height of the door tested.
- 13.4.3** Product conditioning and time between removal of the specimen from the conditioning room and the start of testing.
- 13.4.4** Relative humidity and temperature of the room and test building prior to, and during, the test.
- 13.5 Burner Gas Flow:** The burner gas flow is the fuel gas flow to the ignition burner and its calculated rate of heat output.
- 13.6 Time History of the Total Heat Flux to Floor:** The time history of the total heat flux to floor is the total incident heat flux at the center of the floor for the heat flux gage as a function of time, starting a minimum of one minute prior to the test.
- 13.7 Time History of the Gas Temperature:** The time history of the gas temperature is the temperature of gases in the room, in the doorway, and in the exhaust duct for each thermocouple, as a function of time starting a minimum of one minute prior to the test.
- 13.8 Time History of the Total Rate of Heat Production of the Fire, Including Burner Output and Specimen Burning:** The total rate of heat production is calculated from the measured oxygen concentration and the temperature and volumetric flow rate of the gas in the duct.
- 13.9 Time History of the Net Rate of Heat Release from Burning of the Test Specimen:** The net rate of heat release is calculated

by subtracting the burner output from the total rate of heat production computed in accordance with Paragraph 13.8 above.

13.10 Time History of the Smoke Release Rate: The time history of the smoke release rate is calculated from the measured reduction in light transmission in the exhaust duct as a function of time, starting a minimum of one minute prior to the test.

13.11 Time History of the Specimen Core Temperature: The time history of the specimen core temperature is the temperature measured by the thermocouple in the specimen foam core as specified in Paragraph 9.2.5, as a function of time starting a minimum of one minute prior to test.

13.12 Time History of the Fire Growth: The time history of the fire growth is a transcription of the visual, photographic, audio, and written records of the fire test. The records shall indicate the time of ignition of the test specimen, the approximate location of the flame front most distant from the ignition source at approximately 30-second intervals during the fire test and, if they occur, the time of flash-over and the time at which flames extend outside the doorway. In addition, still photographs taken at approximately 30-second intervals or continuous video recording shall be supplied.

13.13 Drawings and photographs or video recording shall be supplied to show the extent of the damage to the materials after the test.

13.14 Table of numerical results containing the following:

- 13.14.1** Peak total rate of heat release (in kW), and the time at which it occurred.
- 13.14.2** Peak net (specimen only) rate of heat release (in kW), and the time at which it occurred.
- 13.14.3** Total heat released (in MJ).
- 13.14.4** Maximum heat flux at floor level (in kW/m^2), and the time at which it occurred.
- 13.14.5** Peak rate of smoke release (in m^2/s), and the time at which it occurred.
- 13.14.6** Total smoke released (m^2).
- 13.14.7** Total smoke released at 5 minutes and at 10 minutes (m^2).
- 13.14.8** Peak specimen core temperature and the time at which it occurred.
- 13.14.9** Peak fire room temperatures ($^{\circ}C$.) and the time at which they occurred.
- 13.14.10** Equation used to calculate rate of heat release.

14. ACCEPTANCE CRITERIA

Foam plastic insulated garage doors shall be considered as demonstrating satisfactory performance if the following conditions are met:

- 14.1** The maximum instantaneous net peak rate of heat release of the test sample shall not exceed 250 kW (237 Btu/s).
- 14.2** Flames shall not propagate for the full width of the test specimen. Propagation for the full width of the specimen shall be judged to occur:
- 14.2.1** If flames are visually observed to spread for the full width of the specimen, or
- 14.2.2** If the test specimen core temperature rise, determined by the thermocouple specified in Paragraph 9.2.5, exceeds $750^{\circ}F$. ($400^{\circ}C$.)
- 14.3** The total smoke released shall not exceed $670 ft^2$ ($60 m^2$) 5 minutes after the start of the test, nor shall the total smoke release exceed $1,670 ft^2$ ($150 m^2$) 10 minutes after the start of the test.

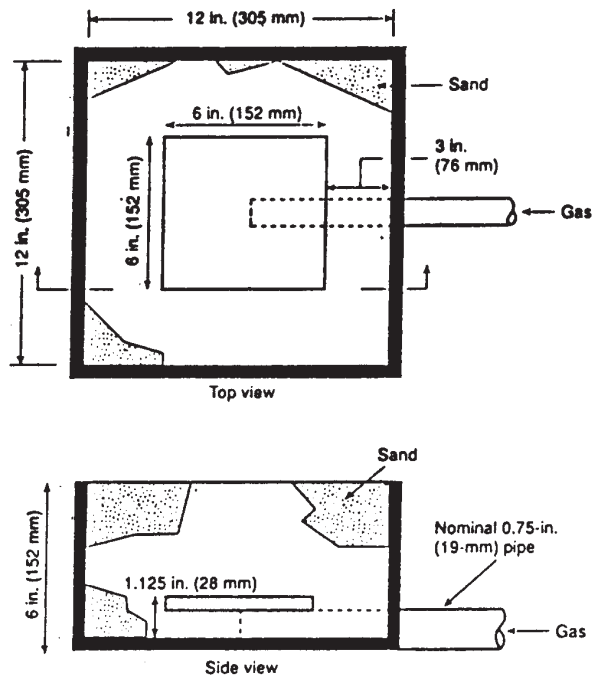


FIGURE 1—GAS BURNER

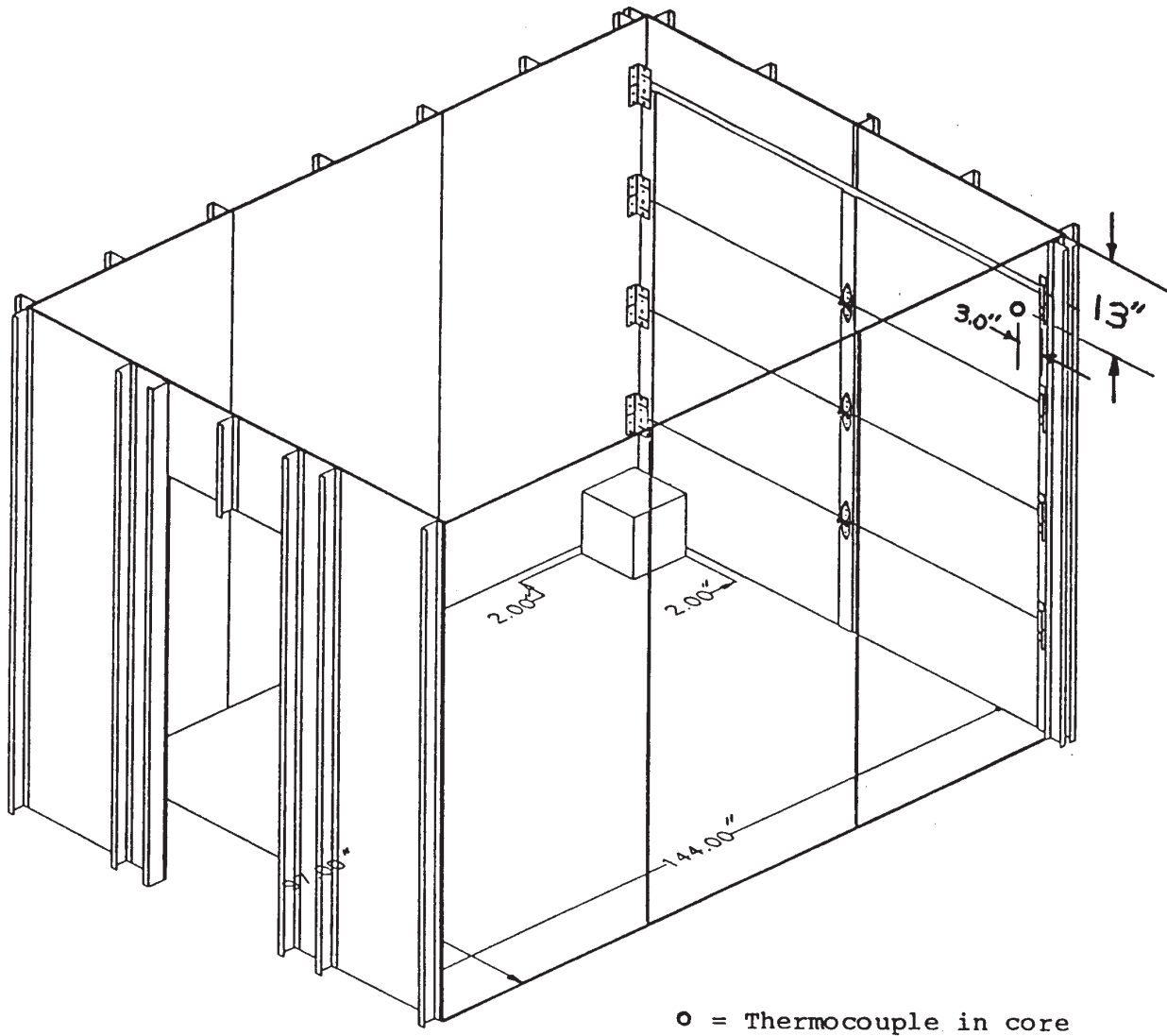
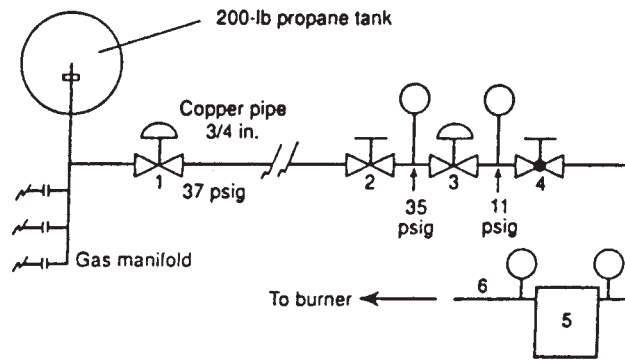
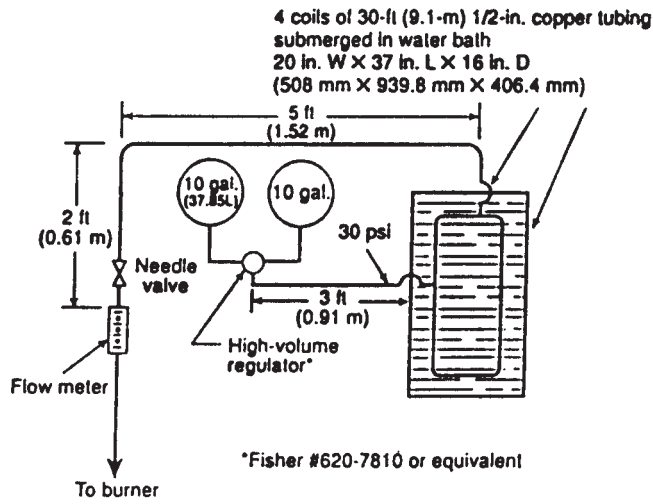


FIGURE 2—BURNER LOCATION AND SPECIMEN MOUNTING DETAILS



- 1 - Propane gas regulator (high pressure) (main gas supply)
 - 2 - Shutoff valve
 - 3 - Regulator (low pressure)
 - 4 - Adjustable valve for flow impedance
 - 5 - Volume meter
 - 6 - Steel braid over tubing to burner
- Line pressures are shown

FIGURE 3—GAS FLOW REGULATION SYSTEMS

Note: For tolerance in dimensions
see Section 4.0

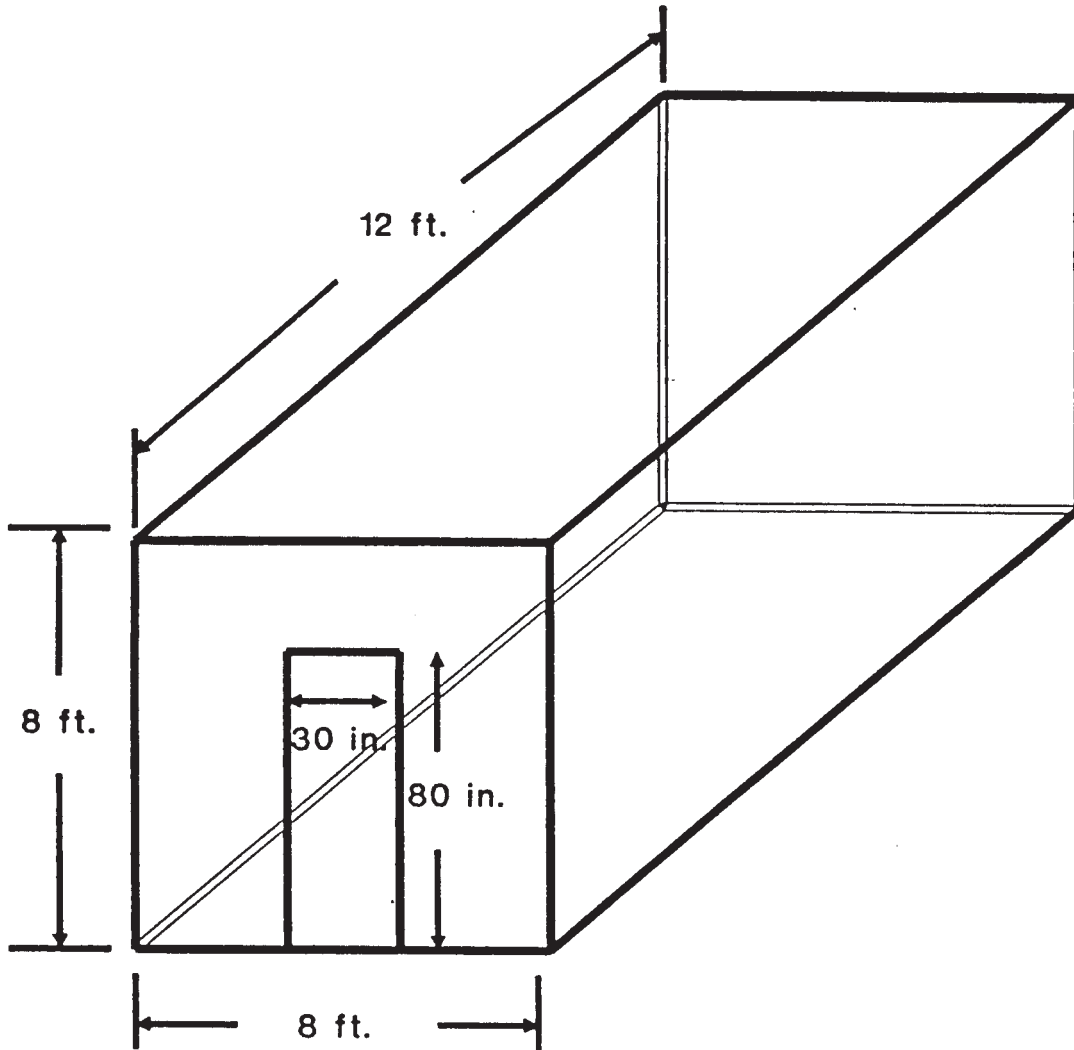


FIGURE 4—INTERIOR ROOM AND DOORWAY DIMENSIONS

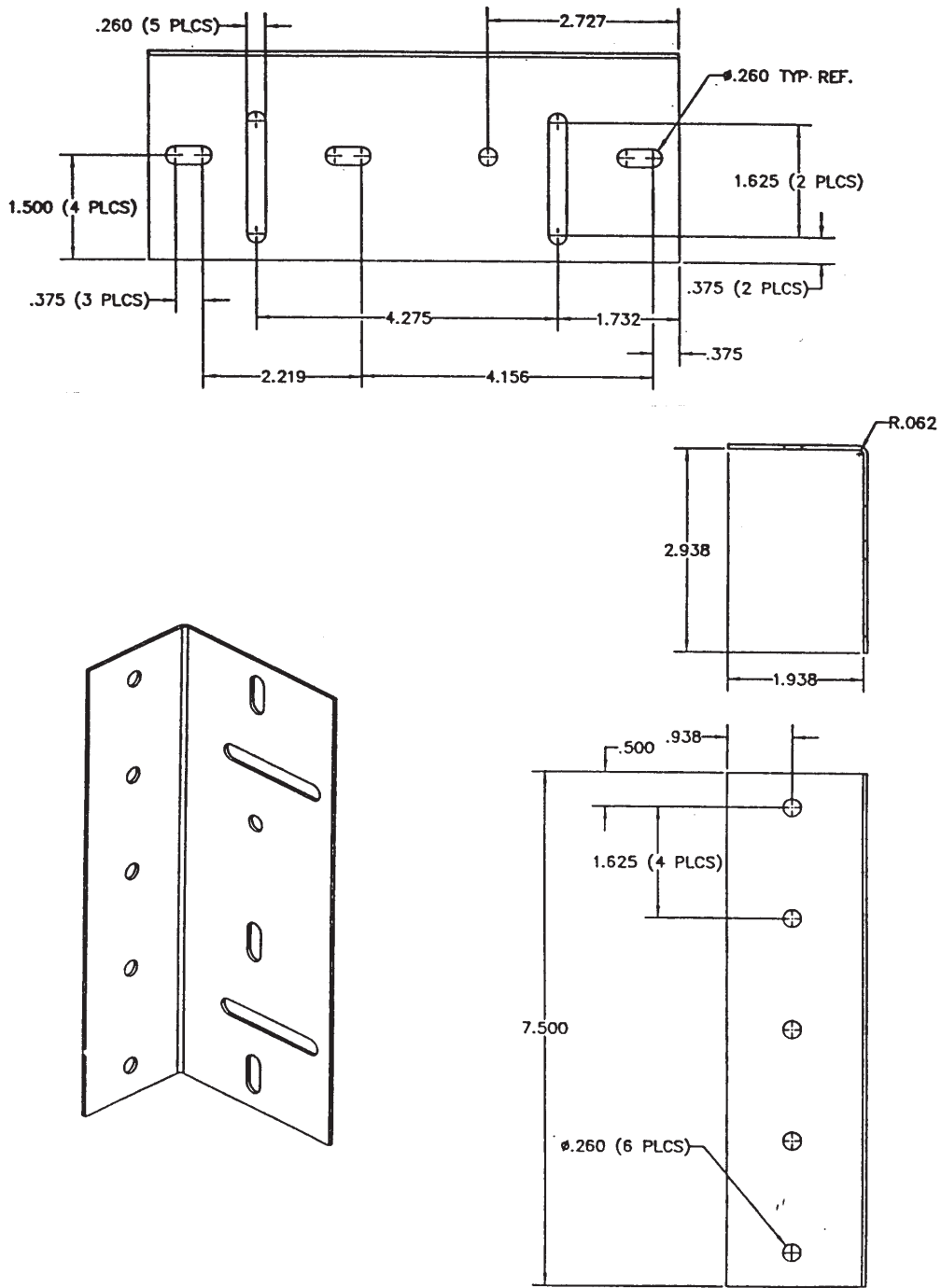
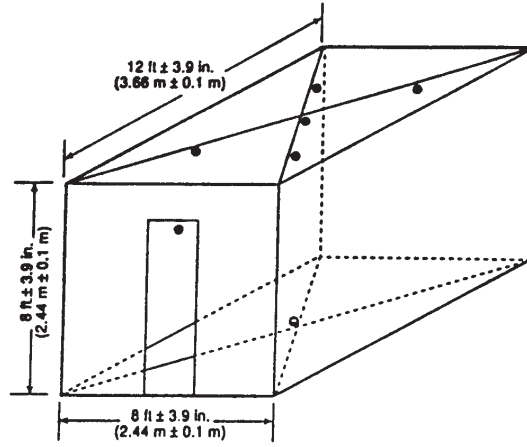


FIGURE 5—ANGLE BRACKETS



- = Thermocouples—Each 4 in. (102 mm) below ceiling. Also one additional thermocouple over the burner and 4 in. (102 mm) below the ceiling.
- = Calorimeter on floor—2 in. (51 mm) above floor.

FIGURE 6—THERMOCOUPLE AND CALORIMETER PLACEMENT

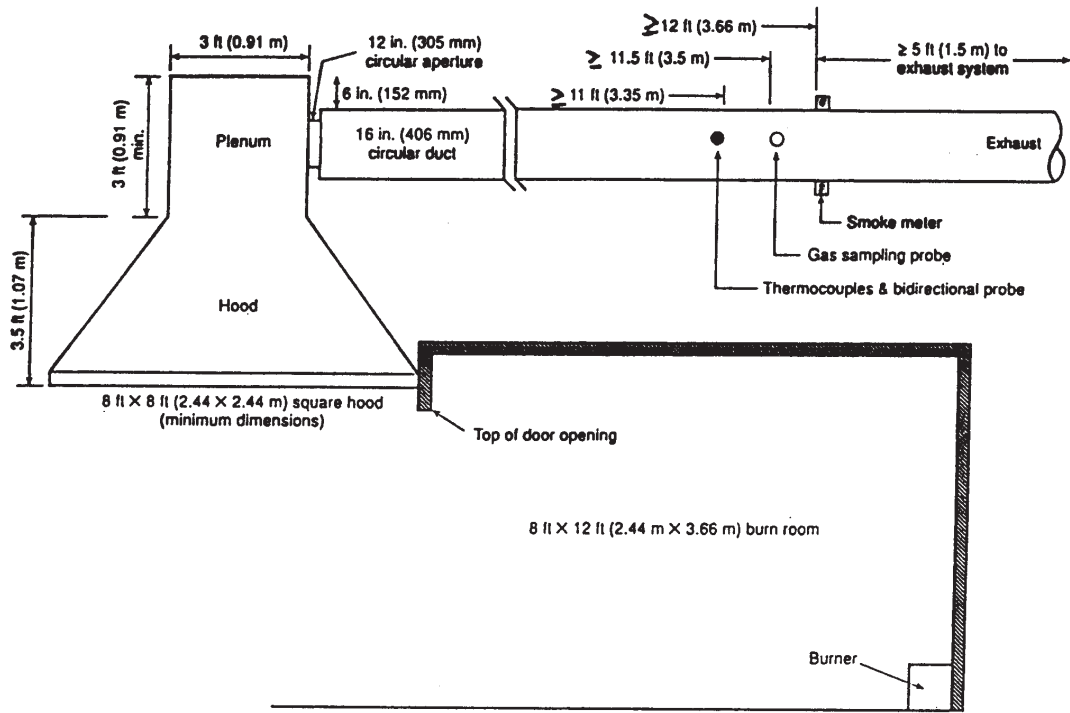


FIGURE 7—CANOPY HOOD AND EXHAUST DUCT

Note: Duct instrumentation locations are minimum for 16 inch duct.

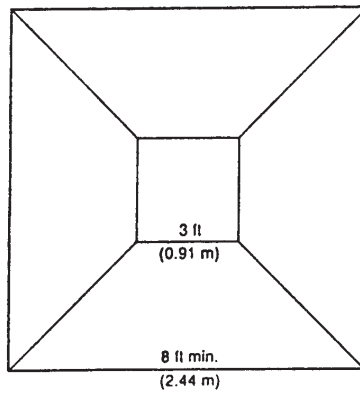


FIGURE 8—PLAN VIEW OF CANOPY HOOD

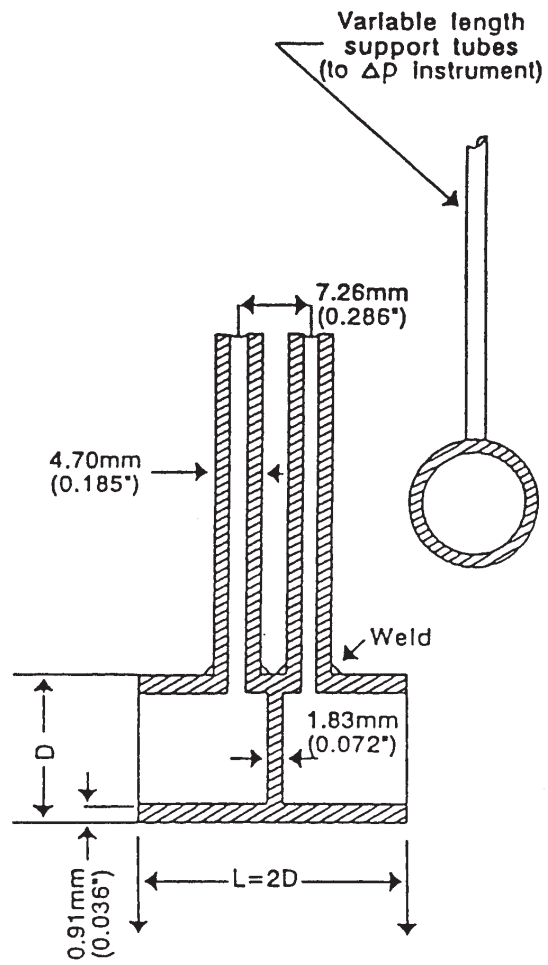


FIGURE 9—BIDIRECTIONAL PROBE

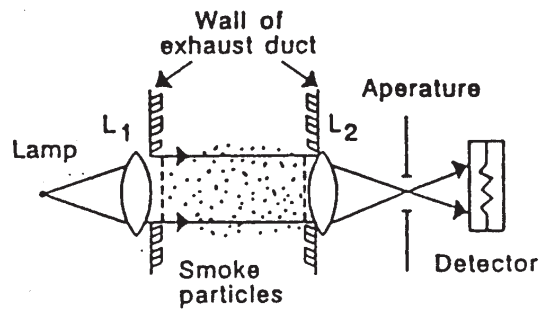
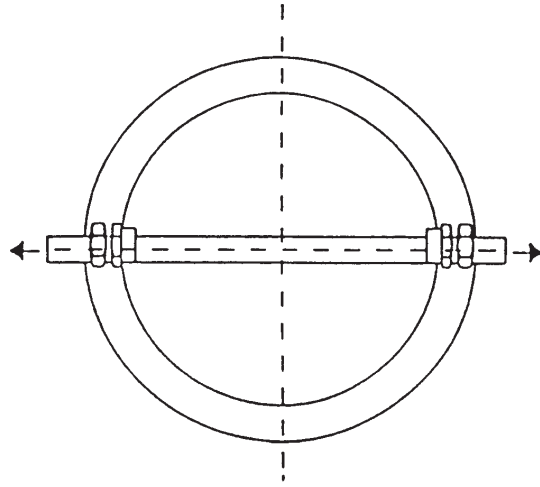
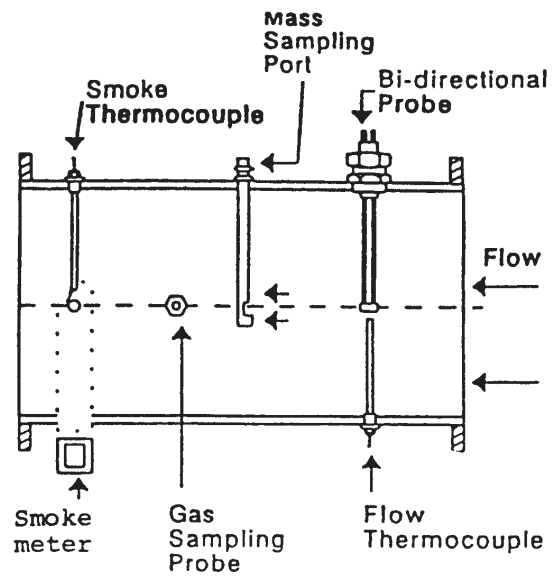


FIGURE 10—OPTICAL SYSTEM, USING A WHITE LIGHT



View of Gas Sampling Probe. Holes Downstream to Avoid Clogging

FIGURE 11—MOUNTING DETAILS FOR INSTRUMENTATION IN DUCT

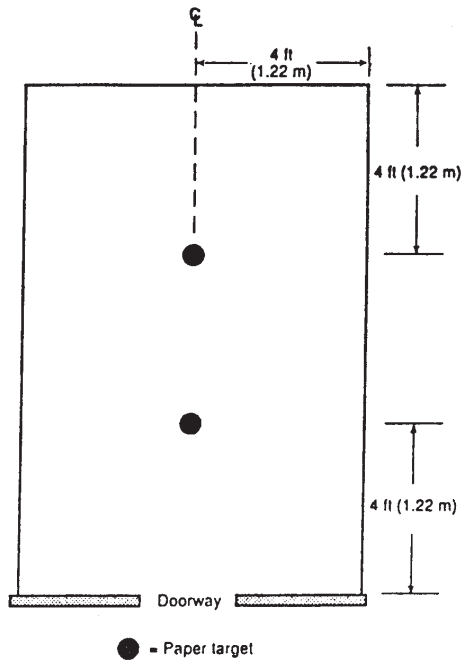


FIGURE 12—PAPER TARGET ARRANGEMENT—PLAN VIEW