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AMERICAN SOCIETY FOR TESTING AND MATERIALS

1916 Race St., Philadelphia, Pa., 19103

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Standard Method for MEASURING THE DENSITY OF SMOKE FROM THE BURNING OR DECOMPOSITION OF PLASTICS[1]

This Standard is issued under the fixed designation D 2843; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This method covers a laboratory procedure for measuring and observing the relative amounts of smoke produced by the burning or decomposition of plastics. It is intended to be used for measuring the smoke producing characteristics of plastics under controlled conditions of combustion or decomposition. Correlation with other fire conditions is not necessarily implied. The measurements are made in terms of the loss of light transmission through a collected volume of smoke produced under controlled, standardized conditions. The apparatus is constructed so that the flame and smoke can be observed during the test.[2]

NOTE 1—The values stated in U.S. customary units are to be regarded as the standard. The metric equivalents of U.S. customary units may be approximate.

2. Significance

2.1 Tests made on a material under conditions herein prescribed can be of considerable value in comparing the relative smoke generating characteristics of plastics.

2.2 This method serves to determine the extent to which plastic materials are likely to smoke under conditions of active burning and decomposition in the presence of flame.

NOTE 2—The visual and instrumental observations from this test compare well with the visual observations of the smoke generated by plastic materials when added to a freely burning, large outdoor fire.[3]

2.3 The usefulness of this test procedure is in its ability to measure the amount of smoke produced in a simple, direct, and meaningful manner under the specified conditions. The degree of obscuration of vision by smoke generated by combustibles can be substantially affected by changes in quantity and form of material, humidity, draft, temperature, and the supply of oxygen.

3. Summary of Method

3.1 The test specimen is exposed to flame for the duration of the test and the smoke is substantially trapped in the chamber in which combustion occurs. A 25 by 25 by 6-mm (1 by 1 by $^1/_4$-in.) specimen is placed on a supporting metal screen and burned in a laboratory test chamber (Fig. 1) under active flame conditions using a propane burner operating at a pressure of 2.8 kgf/cm^2 (40 psi). The 300 by 300 by 790-mm (12 by 12 by 31-in.) test chamber is instrumented with a light source, a photoelectric cell, and a meter to measure light absorption horizontally across the 300-mm (12-in.) light beam path. The chamber is closed during the 4-min test period except for the 25-mm (1-in.) high ventilation openings around the bottom.

3.2 The light absorption data are plotted versus time. A typical plot is shown in Fig. 2.

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[1] This method is under the jurisdiction of ASTM Committee D-20 on Plastics. A list of committee members may be found in the ASTM Yearbook. This standard is the direct responsibility of Subcommittee D-20.30 on Thermal Properties.

Effective Jan. 30, 1970.

[2] Anonymous, "A Method of Measuring Smoke Density," *NFPA Quarterly*, QNFPA, Vol 57, January 1964, p. 276. Reprint NFPA Q57-9. NFPA, 60 Batterymarch St., Boston, Mass. 02110.

[3] Rarig, F. J., and Bartosic, A. J., "Evaluation of the XP2 Smoke Density Chamber," *Symposium on Fire Test Methods—Restraint & Smoke, ASTM STP 422*, Am. Soc. Testing Mats., 1966.

Two indexes are used to rate the material: maximum smoke produced, and the smoke density rating.

4. Apparatus

4.1 The smoke chamber shall be constructed essentially as shown in Fig. 1.[4]

4.1.1 *Chamber:*

4.1.1.1. The chamber shall consist of a 14-gage (B & S) 300 by 300 by 790-mm (12 by 12 by 31-in.) aluminum box to which is hinged a heat-resistant glass glazed door. This box shall be mounted on a 350 by 400 by 57-mm (14 by 16 by 2 1/4-in.) base which houses the controls. Dependent upon the materials tested, the metal may require protection from corrosion.

4.1.1.2 The chamber shall be sealed except for 25 by 230-mm (1 by 9-in.) openings on the four sides of the bottom of the chamber. A 1700-liters/min (60-ft^3/min) blower shall be mounted on one side of the chamber. The inlet duct to the blower shall be equipped with a close fitting damper. The outlet of the blower shall be connected through a duct to the laboratory exhaust system. If the chamber is in a ventilated hood, no connection to the lab exhaust system through a duct is needed.

4.1.1.3 The two sides adjacent to the door shall be fitted with 70-mm (2 3/4-in.) diameter smoke-tight glazed areas centered 480 mm (19 3/4 in.) above the base. At these locations and outside the chamber, boxes containing the optical equipment and additional controls shall be attached.

4.1.1.4 A removable white plastic plate shall be attached to the back of the chamber. There shall be a 90 by 150-mm (3 1/2 by 6-in.) clear area centered about 480 mm above the bottom of the chamber through which is seen an illuminated white-on-red exit sign. The white background permits observation of the flame, smoke, and burning characteristics of the material. The viewing of the exit sign helps to correlate visibility and measured values.

4.1.2 *Specimen Holder:*

4.1.2.1 The specimen shall be supported on a 64-mm (2 1/2-in.) square of 6 by 6-mm, 0.9-mm gage (1/4 by 1/4-in., 0.035-in. gage) stainless steel wire cloth 220 mm (8 3/4 in.) above the base and equidistant from all sides of the chamber. This screen shall lie in a stainless steel bezel supported by a rod through the right side of the chamber. From the same rod, a similar bezel shall be located 76 mm (3 in.) below, and it shall support a square of asbestos paper which catches any particles that may drip from the specimen during the test. By rotating the specimen holder rod, the burning specimen can be quenched in a shallow pan of water positioned below the specimen holder.

4.1.3 *Ignition System:*

4.1.3.1 The specimen shall be ignited by a propane flame from a burner operating at a pressure of 2.8 kgf/cm^2 (40 psi). The fuel (Note 3) shall be mixed with air which has been propelled through the burner by the venturi effect of the propane as it passes from a 0.13-mm (0.005-in.) diameter orifice (Note 4), and the burner shall be assembled as shown in the exploded view of the burner in Fig. 3. The burner must be designed to provide adequate outside air.

NOTE 3—Commercial grade 85.0 percent minimum, gross heating value 23,000 cal/liter (2590 Btu/ft^3) propane meets the requirements.

NOTE 4—Since the orifice provides the metering effect proportionate to the supply pressure, care must be taken that the orifice is the only means of fuel egress.

4.1.3.2 The burner shall be capable of being positioned quickly under the specimen so that the axis of the burner falls on a line passing through a point 8 mm /3/10 in.) above the base at one back corner of the chamber extending diagonally across the chamber and sloping upward at 45 deg with the base. The exit opening of the burner shall be 260 mm (10 1/4 in.) from the reference point at the rear of the chamber.

4.1.3.3 A duct at least 150 mm (6 in.) outside of the chamber shall provide the air piped to the burner.

4.1.3.4 Propane pressure shall be adjustable and preferably automatically regulated. Propane pressure shall be indicated by means of a Bourdon tube gage.

4.1.4 *Photometric System:*

4.1.4.1 A light source, a barrier-layer photoelectric cell, and a temperature compen-

[4] The smoke chamber made by George Eysenbach, 315 Western Avenue, Bristol, Pa. 19007, meets the requirements of this method. Detailed drawings of the smoke chamber are also available at a nominal cost from the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

sated meter shall be used to measure the proportion of a light beam which penetrates a 300-mm (12-in.) path through the smoke. The light path shall be arranged horizontally as shown in Fig. 4.

4.1.4.2 The light source shall be mounted in a box (*4 B1* in Fig. 1) extending from the left side of the chamber at the mean height of 480 mm (19 3/4 in.) above the base. The light source shall be a compact filament microscope lamp No. 1493[5] operated at 5.8 V and a spherical reflector, with power supplied by a voltage regulating transformer. A 60 to 65-mm (2 1/2-in.) focal length lens shall focus a spot of light on the photocell in the right instrument panel.

4.1.4.3 Another box containing the photometer (*4 B2* in Fig. 1) shall be attached to the right side of the chamber. The barrier-layer photoelectric cell shall have standard observer spectral response. An egg-crate grid in front of the photocell shall be used to protect the cell from stray light. The grid shall be finished in dull black and have openings at least twice as deep as they are wide. The current produced by the photocell is indicated in terms of percent light absorption on a meter. The photocell linearity decreases as the temperature increases; compensations shall therefore be made.

NOTE 5—Photocell manufacturers recommend operating the photocell at temperatures not exceeding 50 deg C.

4.1.4.4 The meter shall have two ranges. The range change shall be accomplished by shunting the meter to one tenth of its sensitivity. When smoke accumulates to absorb 90 percent of the light beam, a momentary switch shall be depressed returning the meter to its basic sensitivity. By doing this the meter scale now reads from 90 to 100 percent instead of 0 to 100 percent.

4.1.5 *Timing Device*—A clock to indicate 15-s intervals shall be used. If the time intervals are audibly marked it will be convenient for the operator to record his observations. A clutch shall be used to reset the clock at the start of a test. The block shall be coupled to the burner-positioning device and it shall start when the burner is swung into test position.

4.1.6 *Planimeter*—A planimeter or other suitable means shall be used for measuring the area under the light-absorption curve.

5. Test Specimen

5.1 The standard specimen shall be 25.4 ± 0.3 by 25.4 ± 0.3 by 6.2 ± 0.3 mm (1 ± 0.01 by 1 ± 0.01 by 1/4 ± 0.01 in.). Thicknesses other than 6.2 mm (1/4 in.) may be used and their size must be reported with the smoke density values (Note 6). Material thinner than 6.2 mm (1/4 in.) may be tested either in its normal use thickness or by stacking and forming a composite specimen approximately 6.2 mm (1/4 in.) thick. Material thicker than 6.2 mm (1/4 in.) may be tested either in its normal use thickness or by machining the material down to a thickness of 6.2 mm (1/4 in.).

NOTE 6—If specimens other than the standard specimen are to be used, cooperating laboratories should agree upon preparation procedures and dimensions of the specimen. The results in such cases may vary from the results obtained with the standard specimen.

5.2 The specimens shall be sanded, machined, or die cut in a manner that produces a cut surface that is free from projecting fibers, chips, and ridges.

5.3 The test sample shall consist of three specimens.

6. Conditioning

6.1 *Conditioning*—Condition the test specimens at 23 ± 2 C (73.4 ± 3.6 F) and 50 ± 5 percent relative humidity for not less than 40 h prior to test in accordance with Procedure A of ASTM Methods D 618, Conditioning Plastics and Electrical Insulating Materials for Testing,[6] for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ±1 C (±1.8 F) and ±2 percent relative humidity.

6.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 23 ± 2 C (73.4 ± 3.6 F) and 50 ± 5 percent relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be ±1 C (±1.8 F) and ±2 percent relative humidity.

6.3 Tests shall be conducted in a hood that has a window for observing the test.

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[5] The microscope lamps No. 1493 are manufactured by General Electric Company, Westinghouse, and others.

[6] *Annual Book of ASTM Standards*, Part 27.

7. Procedure

7.1 Turn on the photometer lamp, exit sign, and exhaust blower.

7.2 Turn on the propane, ignite the burner, and adjust the propane pressure to 2.8 kgf/cm^2 (40 psi). **Caution**—Do not fail to light the burner immediately.

7.3 Set the temperature compensation.

7.4 Adjust the lamp control to zero percent light absorption.

7.5 Lay the test specimen flat on the screen in such a position that the burner flame will be directly under the specimen when the burner is swung into position.

7.6 Set the timer to zero.

7.7 Shut off the exhaust blower, close the smoke chamber door, and immediately position the burner under the specimen and start the timer.

7.8 If in a hood, shut off the hood fan and close the hood door to within 50 mm (2 in.) of the bottom of the hood.

7.9 Record the percent light absorbed at 15-s intervals for 4 min.

7.10 Record observations during the conduct of the test. Include the time it takes for the sample to burst into flame, the time for flame extinguishment or specimen consumption, the obscuration of the exit sign by smoke accumulation, and any general or unusual burning characteristics noted such as melting, dripping, foaming, or charring.

7.11 Upon completion of the test, turn on the exhaust blower to ventilate the combusion products from the chamber.

NOTE 7—It should be noted that for some materials the products of burning may be toxic, and care should be taken to guard the operator from the effects of these gases. The ventilating fan in the hood should be turned on and the damper opened immediately after the test is completed before opening the hood door in order to remove any irritating products of the test. The exhaust fan is turned off and the hood damper closed during the test to prevent back draft.

7.12 Open the door and clean the combustion deposits from the photometer, exit sign, and door glass with detergent and water. Burn off any material remaining on the screen or replace the screen and asbestos square for the next test.

7.13 Run all tests in triplicate.

7.14 At the beginning of each series or at least once a day, check the light absorption of the meter against a calibrated neutral filter of approximately 50 percent absorption.[7] Check the 100 percent absorption point against an opaque plate.

8. Optional Procedures

8.1 The output of the photocell may be recorded versus time on an appropriate graphic recorder.[8]

8.2 With a suitably sensitive meter, more than one decade change may be used to separate readings in the very dense smoke range.

9. Treatment of Data

9.1 Average the readings at 15-s intervals of light absorption for the three specimens in each group. Plot the average light absorption against time on linear paper. Fig. 2 is a sample curve.

9.2 Read the maximum smoke density as the highest point on the curve.

9.3 Determine the total smoke produced by measuring the area under the curve. The smoke density rating represents the total amount of smoke present in the chamber for the 4-min time interval. Measure the total smoke produced by the area under the curve of light absorption versus time, divided by the total area of the graph, 0–4 min, 0–100 percent light absorption, times 100.

NOTE 8: *Example*—In the light absorption-time plot in Fig. 2, the plot has been made using 10 mm (0.39 in.) equal to 10 percent as the ordinate and 10 mm (0.39 in.) equal to 0.25 min as the absicca. The graph area for 4 min is found to be 16,000 mm^2 (24.80 in.^{2}). The area under the curve is found to be 12,610 mm^2 (19.55 in.^{2}). The smoke density rating is then computed as follows:

Smoke density rating, percent
$= (12610/16000 \times 100 = 78.8$
(dimensions in millimeters)

$= (19.55/24.80) \times 100 = 78.8$
(dimensions in inches)

10. Report

10.1 The report shall include the following:

10.1.1 Identification of the material,

[7] Jena Glass Neutral Filter NG-5 from Fish-Schurman Corporation, 70 Portman Road, New Rochelle, N. Y. 10802, and No. 96 Wratten Neutral Density Filter (Neutral Density 0.3) 3 in. by 3 in. cemented in glass and recalibrated for density from Eastman Kodak Stores, Inc., 3202 Race St., Philadelphia, Pa. 19104, have proven suitable.

[8] The Honeywell Electronic 19 Recorder Model 19301-01-01 from Honeywell, Inc., Industrial Park, King of Prussia, Pa., has proven suitable.

10.1.2 Dimensions of the specimen,

10.1.3 Readings of light absorption at 15-s intervals for each test and average,

10.1.4 Plots of average light absorption versus time,

10.1.5 Maximum smoke density in percent light absorption,

10.1.6 Area in percent under the light absorption-time curve (smoke density rating),

10.1.7 Observations on behavior of material,

10.1.8 Observations on obscurement of exit sign, and

10.1.9 The details of any departure from the specifications of the method for testing.

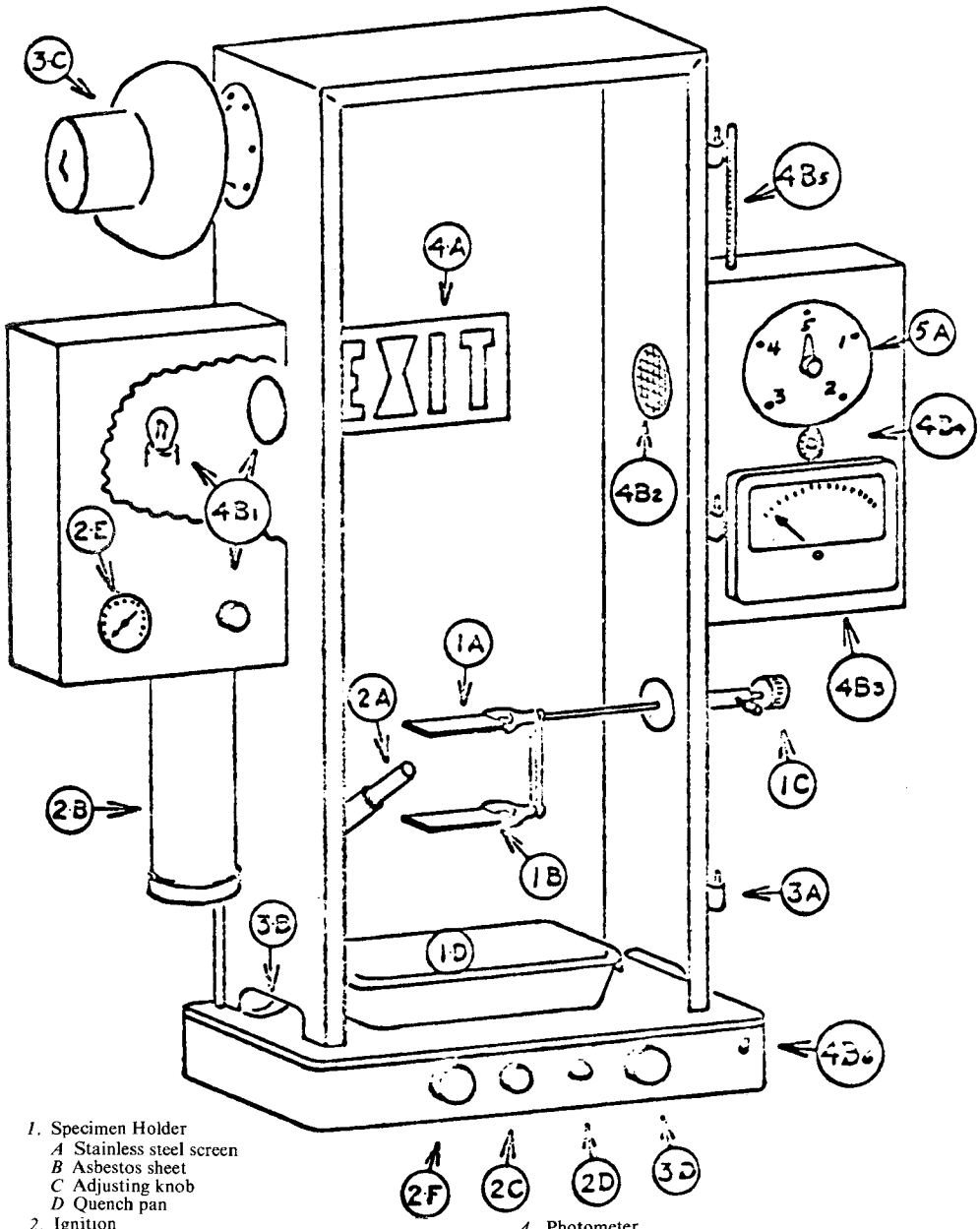
11. Precision

11.1 The following criteria should be used in judging acceptability of smoke density rating data.[9]

11.2 *Repeatability*—Two individual results (not averages) determined by a single operator in one laboratory should not be considered suspect (at 95 percent confidence level) unless they differ by more than 18 percent absolute.

11.3 *Reproducibility*—Two results from different laboratories (based on the average of three tests) should not be considered suspect (at 95 percent confidence level) unless they differ by more than 15 percent absolute.

[9] The basis for judging significance is the summary of data from the second round robin performed by five laboratories now filed under Research Reports File Number RR 77: D-20 at the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.



1. Specimen Holder
   - *A* Stainless steel screen
   - *B* Asbestos sheet
   - *C* Adjusting knob
   - *D* Quench pan
2. Ignition
   - *A* Burner
   - *B* Propane tank
   - *C* Gas shut-off valve
   - *D* Pressure regulator adjustment
   - *E* Pressure indicator
   - *F* Burner-positioning knob
3. Cabinet (shown without door)
   - *A* Hinges (door gasketed three sides)
   - *B* Vents (25-mm (1-in.) high opening four sides)
   - *C* Blower (damper on mounting side)
   - *D* Control (blower on when damper is open)
4. Photometer
   - *A* Visual system (exit sign)
   - *B* Measuring system
     - *1* Light source and adjusting transformer
     - *2* Photronic cell and grid (to block stray light)
     - *3* Meter (indicating percent of light absorbed)
     - *4* Temperature compensation
     - *5* Photocell temperature monitor
     - *6* Range change
5. Timer
   - *A* Indicator, 0 to 5 min (friction reset)

FIG. 1 Schematic Diagram of Smoke Chamber.

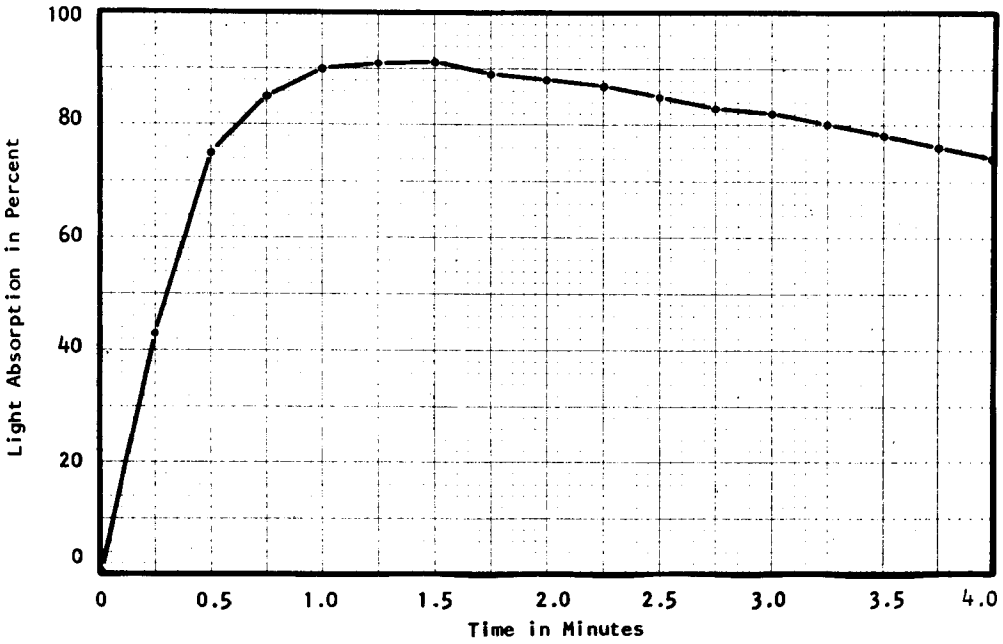


FIG. 2 Light Absorption versus Time.

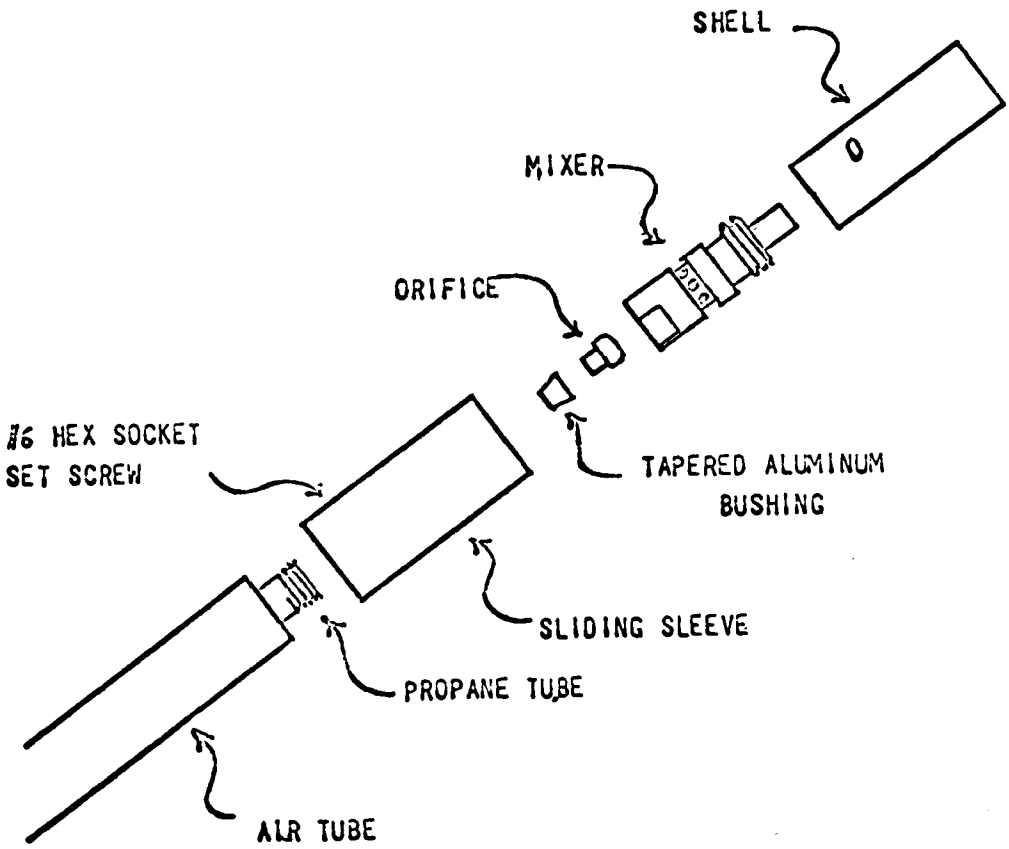
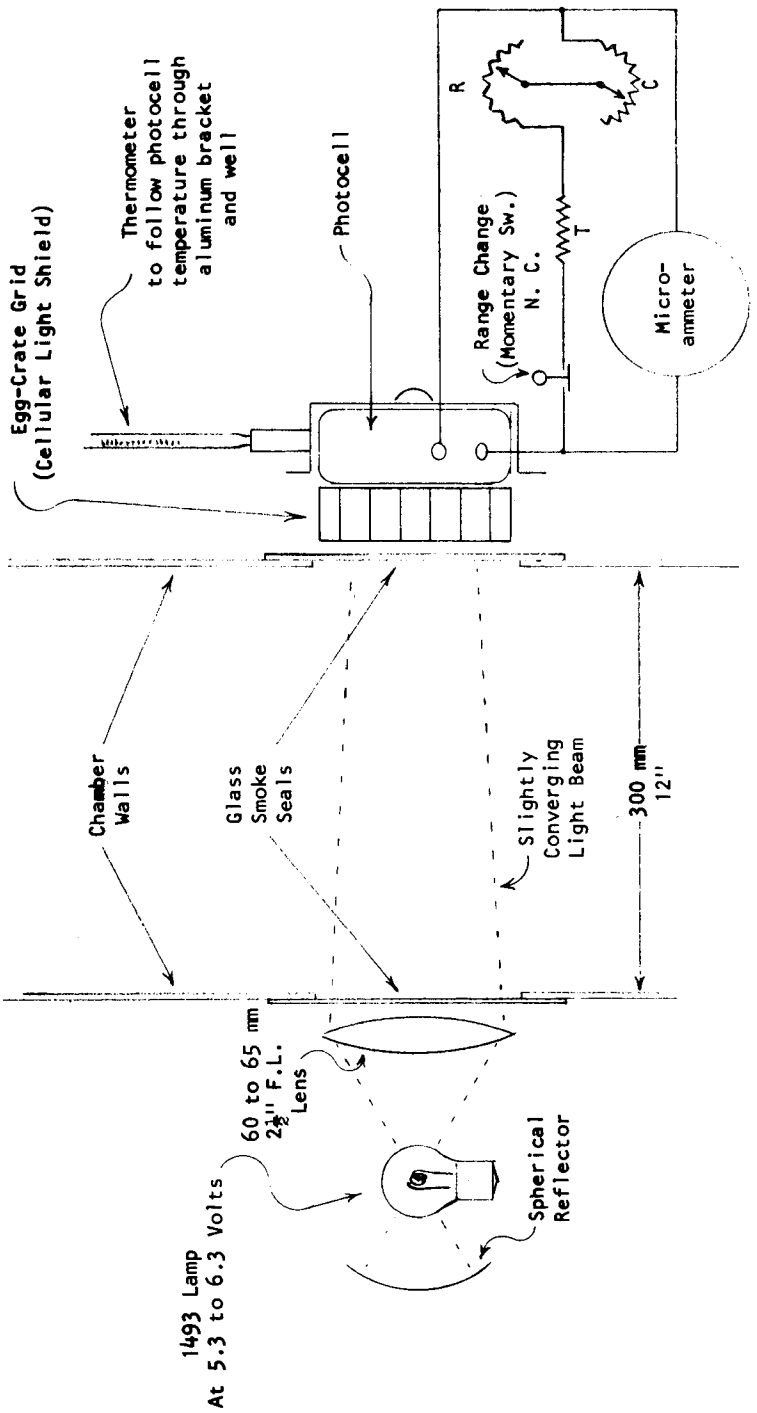


FIG. 3 Exploded View of Burner.



T = Temperature-sensitive winding in or on meter case to increase in resistance in proportion to increase in meter resistance with temperature.
R = Potentiometer with calibrated scale to reduce resistance in proportion to decrease in photocell output with rise in temperature.
C = Potentiometer to calibrate total resistance of shunt to change meter sensitivity exactly by 10:1 ratio.

FIG. 4 Smoke Density Test Chamber Photometer.