Designation: D 2985 – 92 (Reapproved 2002)

Standard Test Method for Color of Asbestos[1]

This standard is issued under the fixed designation D 2985; 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. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of color, whiteness, and yellowness of asbestos by means of a photoelectric reflectometer.

1.2 The test method is applicable to all grades and varieties of homogeneous milled asbestos.

1.3 This test method may be applied to samples that are not dry or homogeneous, or that contain impurities or adulterants. However, in such cases, results may not be comparable with those obtained on clean dry samples.

1.4 To obtain similar results from spectrophotometers, see Test Method E 308.

1.5 The values stated in SI (metric) units are to be regarded as standard. The inch-pound (customary) units are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[2]

D 2590 Test Method for Sampling Chrysotile Asbestos[3]

D 2946 Terminology Relating to Asbestos[3]

D 3879 Test Method for Sampling Amphibole Asbestos[3]

E 3 Guide for Preparation of Metallographic Specimens[4]

E 259 Practice for Preparation of Pressed Powder, White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries[2]

E 308 Practice for Computing the Colors of Objects by Using the CIE System[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:* [5]

3.1.1 *black, adj, adj*—color name applied to opaque objects that are highly absorbing throughout the visible spectrum.

3.1.2 *CIE, n*—acronym for International Commission on Illumination, which in French is Commission Internationale de l'Eclairage.

3.1.3 *CIE observer, n*—See **observer, standard, CIE 1931** and **observer, supplementary, CIE 1964.**

3.1.4 *CIE source C, n*—See **standard source**.

3.1.5 *color, psychophysical, n*—characteristics of a color stimulus (that is, light producing a sensation of color) denoted by three dimension values such as three tristimulus values.

3.1.6 *daylight 0.785 rad, 0 rad (45°, 0°) luminous directional reflectance*—daylight 0.785 rad, 0 rad (45°, 0°) luminous directional reflectance (for brevity called reflectance) is the ratio of the luminous flux from a specimen illuminated at an angle of 0.785 rad (45°) by CIE standard source C[6] (average daylight) and viewed perpendicularly by the CIE standard observer, to the luminous flux from the standard magnesium oxide layer, similarly illuminated and viewed (Note 1). The combination of illumination at 0.785 rad (45°) and viewing at 0 rad (0°) (perpendicularly) has been selected as being representative of average conditions of illuminating and viewing. The property of reflectance determines which of two specimens will appear lighter when viewed in average daylight at an angle at which the observation of highlights is avoided.

NOTE 1—These conditions of illumination and observation may be interchanged without affecting the results.

3.1.7 *glos, n*—angular selectivity of reflectance of surface-reflected light responsible for the degree to which reflected highlights or images of objects may be seen as superimposed on a surface.

3.1.8 *gloss, specular, n*—ratio of flux reflected in a specular direction to incident flux for specific source and receptor apertures (usually measured relative to a standard of specified index of refraction).

3.1.9 *gray, n*—color name applied to achromatic stimuli of moderate relative luminance.

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[1] This test method is under the jurisdiction of ASTM Committee C17 on Fiber-Reinforced Cement Products and is the direct responsibility of Subcommittee C 17.03 on Asbestos–Cement Sheet Products and Accessories.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 04.05.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] Taken in part from Procedure No. B5-9 of Socíeté Asbestos Ltée, with permission.

[6] CIE standard sources and functions are defined in Test Method E 308.

3.1.10 *green*, *adj*—hue name applied to light of wavelengths from 495 to 550 nm.

3.1.11 *hue*, *n*—attribute of color perception by means of which objects are judged to be red, yellow, blue or intermediate between some adjacent pair of these. Hue is a matter of social consensus as opposed to an assigned frequency range.

3.1.12 *ideal black*, *n*—object or material that absorbs all light impinging on it.

3.1.13 *illuminant*, *n*—incident luminous flux specified only by its spectral distribution. (The spectral composition of an illuminant may differ from the source because of spectral modification by such means as absorption or refraction by mediae enclosing the source or by reflection from other objects. See definition of **source**. The CIE standard illuminants are Illuminant C and Illuminant D6500, each representing average daylight, and Illuminant A, 2854K).

3.1.14 *light*, *n*—electromagnetic radiation in the spectral range detectable by the normal human eye (approximately 380 to 760 nm).

3.1.15 *light*, *n*—radiant energy evaluated according to the CIE photopic spectral luminous efficiency function.

3.1.16 *light*, *adj*—highly reflecting, as in the term light green.

3.1.16.1 *Discussion*—For given conditions of illumination and surface texture, a more reflective surface is perceived as lighter in color than a less reflective but otherwise identical surface.

3.1.17 *luminous*, *adj*—indicates that the radiant flux is evaluated by weighting according to the luminous efficiency function of the CIE 1931 standard observer.

3.1.18 *luminous reflectance*, *n*—See **reflectance, luminous**.

3.1.19 *observer, standard*, CIE 1931,, *n*—hypothetical observer based on color mixture data obtained for a 2° field of view for 17 observers, adopted by the CIE in 1931.

3.1.20 *observer, supplementary, CIE 1964*, *n*—hypothetical observer based on color mixture data obtained for a 10° field of view for 76 observers, adopted by the CIE in 1964.

3.1.21 *photoelectric color meter*, *n*—color-stimulus-measuring instrument using photoelectric detectors in which source-filter-detector response characteristics are adjusted so that the instruments read directly the tristimulus values or related quantities.

3.1.22 *preferred white*, *n*—the white color, usually bluish, that is judged by a given group of observers looking at a given series of specimens to be the whitest color attainable.

3.1.23 *reflectance, luminous*, *n*—ratio of luminous flux reflected by a specimen to that incident on it.

3.1.24 *reflection*, *n*—processes by which incident flux leaves a surface or a medium from the incident side.

3.1.25 *reflection, diffuse*, *n*—process by which incident flux is distributed by reflection over a wide range of angles.

3.1.26 *regular*, *adj*—used to indicate flux transmitted or reflected in the image-forming state (the adjective specular is usually used to indicate regular mirror-reflected flux).

3.1.27 *source*, *n*—that which furnishes light or other radiation; real device by which radiant flux is produced. (See **illuminant**.)

3.1.28 *source*, *CIE standard*, *n*—See **standard source**.

3.1.29 *spectral*, *adj*—indicates either a function of wavelength as in spectral transmittance, or spectral concentration, as in spectral flux.

3.1.30 *specular*, *adj*—same as regular when applied to reflection.

3.1.31 *specular gloss*, *n*—See **gloss, specular**.

3.1.32 *standard observer*, *n*—See **observer, standard**.

3.1.33 *standard*, *primary*, *n*—one whose calibration is determined by measurement according to specified parameters.

3.1.34 *standard*, *secondary*, *n*—standard calibrated by reference to another standard such as a primary, reference, laboratory or working standard.

3.1.35 *standard source*, *n*—light source whose spectral energy distribution is known or defined. (The CIE standard sources to represent incandescent-lamp light, sunlight, and daylight, are designated A, B, and C, respectively.)

3.1.36 *texture*, *adj*—in evaluating the color of a surface, structural quality of a surface determined by the topography of its constituents.

3.1.37 *viewing conditions*, *n*—the conditions under which a visual observation is made, including the angular substance of the specimen at the eye; the geometric relationship of source, specimen and eye; the photometric and spectral character of the field of view surrounding the specimen; and the state of adaptation of the eye.

3.1.38 *white*, *adj*—color name most usually applied to opaque, highly reflecting, highly diffusing, visually hueless specimens.

3.1.39 *whiteness*—the term "whiteness" is widely used to designate the degree to which a near-white surface approaches "perfect white," defined as a 100 % reflectance over the whole visible spectrum. Other terms used for this property are "lightness" or" luminous apparent reflectance." The concept of whiteness is not only applicable to near-white surfaces but also to dark and colored surfaces. Whiteness may be defined as the grading which an observer would assign to the surface, irrespective of its color or hue, when compared under daylight conditions against a scale of grays ranging from white to black.

3.1.40 *yellow*, *adj*—hue name applied to light wavelengths from 572 to 783 nm and to visually similar stimuli.

3.1.41 *yellowness*—a yellowed or tan discolored asbestos may have the same degree of whiteness on the gray scale as a gray asbestos. It is thus necessary to measure an index of yellowness for such cases, and this may be calculated arbitrarily from reflectance measurements using tristimulus filters. Use the following relationship for asbestos:

$$\text{yellowness factor} = (A - B)/G \tag{1}$$

where:

A = reflectance with the amber tristimulus filter,[7]
B = reflectance with the blue tristimulus filter, and
G = reflectance with the green tristimulus filter.

3.1.42 For terms relating to asbestos fibers, refer to Terminology D 2946.

[7] Tristimulus filters are described in the following reference: Lih, M. M., *Chemical Engineering*, Vol 75, No. 17, August 12, 1968, pp. 146–156.

4. Summary of Test Method

4.1 Specimens are pressed into a pellet and the luminous reflectance is measured by means of a simple reflectometer fitted with an incandescent source, and a photoelectric reflectometer.

4.2 Instructions are included for use of the suppressed zero technique to improve precision.

4.3 The use of tristimulus color filters permitting the determination of whiteness, yellowness, and CIE[8] color-order values, is covered.

5. Significance and Use

5.1 The color of asbestos is of commercial significance when it is to be incorporated into products, the color of which is affected by the color of the asbestos, and for which color specifications must be met.

5.2 Whiteness is required of asbestos for use in white or pale-colored products.

5.3 Yellowness is significant in asbestos for use in pastel-colored products where discolored asbestos may prevent attainment of certain shades and hues detector.

6. Apparatus

6.1 The apparatus[9] shall consist of a photoelectric reflectometer having source, filter, and receptor characteristics such that it will measure reflectance accurately to within 1.0 % of full-scale reading. The reflectometer shall have the following characteristics:

6.1.1 *Spectral Characteristics*—The spectral energy distribution of the illuminator and the spectral sensitivity of the receptor, in combination, shall provide the equivalent of illumination by CIE standard source C and observation by the CIE standard observer.

6.1.2 *Geometric Characteristics*—Illumination shall be within 0.0698 rad (4°) of, and centered about, a direction of 0.785 rad (45°) from the perpendicular to the test surface; viewing shall be within 0.262 rad (15°) of, and centered about, the perpendicular (Note 1).

6.1.3 Any instrument that meets the apparatus specifications and the precision requirements stated in Section 13 may be used. In general, commercial instruments do not conform exactly to the apparatus requirements. The suitability of a given instrument depends in large measure on its response to the spectral selectivity range of asbestos, and on the availability of standards of similar reflectance and spectral character. Instruments that have been found satisfactory include: the Hunter Multi-purpose Reflectometer; the Gardner (Hunter) Photometric Unit with 0.785 rad, 0 rad (45°, 0°) reflectance head; and the General Electric Reflection Meter.

6.2 *Standards*:

6.2.1 *Primary Standard*—The primary standard for reflectance measurements is a layer of MgO freshly prepared in accordance with Practice E 259. It is assigned a value of 100 for the conditions of 0.785 rad (45°) illumination and perpendicular view (Note 1).

6.2.2 *Secondary Standards*—Porcelain enameled metal plaques or other materials known to be reasonably permanent in reflectance, and of uniform surface, may be calibrated and used as secondary reflectance standards.

NOTE 2—Secondary standards of porcelain enamel may be obtained from the National Bureau of Standards,[10] the Henry A. Gardner Laboratory,[11] or the Photovolt Corp. Experience has shown that these secondary reflectance standards are reasonably permanent if abrasion is avoided. Plaques stored for a year or more may develop efflorescence (bloom) noticeable on black plaques, which can be removed by washing with mild soluble soap and water.

6.2.3 Standards with reflectance values as close as possible to the values of the unknowns are recommended.

6.3 *Tristimulus Filters*,[7] including amber, blue, and green, to fit the reflectometer source and detector.

6.4 *Piston and Cylinder Mold*, for pressing the asbestos specimens into pellets with a diameter of approximately 28.6 mm (1.125 in.). The height of the mold cavity may be approximately 63 mm (2.5 in.). The piston face must be polished. Any slight texture or presence of oxidation at the piston face may impress a texture onto the asbestos specimen (particularly to very highly fiberized grades of asbestos), and such texture may affect light reflectance significantly. The polish of the piston face may be restored by rubbing with successively finer abrasive papers as described in Methods E 3.

6.5 *Press*,[12] for molding specimens, capable of applying and holding a load of 7250 kg (16 000 lb).

6.6 *Blackbody Cavity*.

6.7 *Polished Black Glass Standard*, 50 by 50 mm (2 by 2 in.).

7. Sampling

7.1 Take a sample in accordance with Test Methods D 2590 or D 3879 for chrysotile or amphibole types of asbestos, respectively, as defined by Terminology D 2946. Twenty grams are required for duplicate specimens. (**Warning—**When handling asbestos fibers, use reasonable precautions to avoid creating dust. Prolonged or frequent breathing of significant concentrations of airborne asbestos dust may cause serious bodily harm.)

8. Test Specimen

8.1 Weigh out 10 g of asbestos and press at 70 kN (15 000 lbf) in the pellet mold for 60 s.

8.2 Note which side of the pellet was against the polished piston face since only that surface is suitable for color testing.

9. Calibration and Standardization

9.1 Follow the instructions given in the instruction manual for each type of apparatus. In addition, the following precautions may apply:

[8] Commission International de l'Eclairage (International Commission on Illumination). The CIE color-order system is the most important of those used in connection with instruments for color measurement. Refer to Test Method E 308.

[9] Photovolt Reflection Meter, Model 670, available from Photovolt Corp., 1115 Broadway, New York, NY 10010, or its equivalent, has been found suitable for this purpose.

[10] National Bureau of Standards, Washington, DC 20234.

[11] Gardner Laboratory Inc., Box 5728, Bethesda, MD 20014.

[12] The Carver laboratory press supplied by F. S. Carver Inc., 1 Chatham Road, Summit, NJ, or its equivalent, has been found suitable for this purpose.

9.2 Make sure that the electric circuit has been energized in advance to warm the components to constant temperature.

9.3 Tobacco smoke and any other fumes in the atmosphere may interfere with some types of apparatus.

9.4 Use a voltage regulator if the power source fluctuates. Alternatively, energize the reflectometer by means of a storage battery. A battery is necessary to obtain stability on some types of apparatus, at high scale expansion. For Photovolt Model No. 610 battery operation is recommended, whereas Model No. 670 contains its own regulated voltage supply.

9.5 Protect the reflectometer from drafts since these can cause rapid temperature fluctuations which may affect precision.

9.6 Protect the apparatus from excessive vibrations which may be present in mill buildings since these can cause substantial errors.

9.7 Avoid strong sources of light near the apparatus to prevent stray light from reaching the photoelectric receptor.

9.8 Avoid parallax errors in reading needle—galvanometer type instruments.

9.9 When samples are in the lower range of reflectance values, the internal stray light effect in the reflectometer may be taken into consideration. Refer to operating instructions, and to X1.6.

9.10 Make sure that the source lamp is still within specifications since spectral characteristics change with age. See Test Method E 308.

9.11 Before use, always wash standards with mild soluble soap and water, rinse, and dry with a clean towel. Handle standards carefully to avoid abrading surfaces.

10. Procedure

10.1 The following procedure applies more specifically to the Photovolt Model 670 reflectometer and is given by way of example:

NOTE 3—Detailed procedures for the use of Photovolt reflection meters Model No. 610 and 670 are given in the Appendixes Appendix X1 and Appendix X2, respectively.

10.2 For the sake of brevity, the reflectometer controls will be identified by the following symbols:

D_c = coarse sensitivity control,
D_f = fine sensitivity control,
B_c = coarse zero suppressor control, and
B_f = fine zero suppressor control.

10.3 Before energizing the reflectometer, adjust the galvanometer to read zero by means of the zero adjustment galvanometer control.

10.4 Energize the reflectometer, source, and receptor circuit, and allow to warm up.

10.5 Mount the required tristimulus filter and place the calibrating standard against the specimen aperture. Choose a standard slightly more reflectant than the test specimen, but as close as available to that value.

10.6 *Normal Scale Determination* (without suppressed zero or expanded galvanometer scale):

10.6.1 Turn the zero suppressor controls B_c and B_f all the way clockwise (until they click, on some equipment) and leave them in this position except when taking suppressed zero measurements as described in 10.7.

10.6.2 Turn the fine sensitivity control D_f to its center position and set the galvanometer approximately to the standard value of the working standard for the tristimulus filter being used, using D_c. Then make fine adjustments with D_f.

10.6.3 Remove the calibrating standard and place the test specimen with the face formed by the mold piston against the specimen aperture.

10.6.4 Note the galvanometer reading.

10.6.5 Replace the specimen by the standard and check to see if the standard reading has remained constant. If not, readjust the setting and repeat 10.6.2-10.6.5 until reproducible results are obtained.

NOTE 4—After some time of operation, the operator will find that he can measure a number of samples in succession before going back to the standard.

10.6.6 Repeat this procedure using each of the other two tristimulus filters.

10.7 *Suppressed Zero Technique*:

10.7.1 Select two standards one of which is only slightly darker, and the other which is only slightly lighter than the specimen to be measured.

10.7.2 Proceed as in 10.3-10.5. Place the darker standard against the specimen aperture after having turned D_c all the way clockwise and D_f and B_f approximately to their center positions.

10.7.3 Set the galvanometer approximately on zero with B_c. Then make fine adjustments with B_f.

10.7.4 Replace the darker standard by the lighter standard and adjust the galvanometer to approximately 100 % reflectance (full scale) with D_c. Then make fine adjustments with D_f. The instrument is thus standardized to give a reading of zero for the darker standard and a reading of 100 for the lighter standard.

10.7.5 Place the test specimen with the face formed by the piston against the specimen aperture and read the galvanometer.

10.7.6 Recheck the darker and lighter standard settings and, if necessary, readjust these two settings repeating 10.7.2-10.7.5. In readjusting the two settings, it will be noted that readjusting of the zero setting will always require readjusting of the 100 setting. However, readjusting of the 100 setting does not require readjusting of the zero setting. Therefore, always readjust zero first and 100 next.

10.7.7 The instrument is designed so that it is possible to set the galvanometer on zero for a dark standard of any reflectance value. However, if the difference between the reflectance of the lighter standard and the darker standard is very small, it may happen that the 100 setting cannot be reached even though the sensitivity control knobs are turned all the way clockwise. In this case determine the highest even value that can be easily reached, and set the galvanometer to this value rather than to 100 in 10.7.4.

10.7.8 On worn instruments, where the response of the compensating photocell no longer matches that of the receptor, it may be impossible to attain the zero setting as described in 10.7.3. In that case determine the lowest even value that can be easily reached, and set the galvanometer to this value rather than zero. The required computations are described in 11.3.3. However, consideration should be given to repairing or replacing such defective equipment.

10.8 *Yellowness Factor*—Take measurements by the suppressed zero method as described in 10.7 and calculate the yellowness factor as described in 11.5.

11. Calculation

11.1 If the instrument is not calibrated directly in percent reflectance, then calculate these values for each specimen on amber, blue, and green tristimulus filters, using the conversion factor appropriate to the instrument in use.

11.2 If CIE color-order values are required, calculate these from the reflectance values using the parameters given in Test Method D 2244.

11.3 If the suppressed zero method is used for taking reflectance measurements, calculate the reflectance values as follows:

11.3.1 For cases where no problems are encountered in expanding the instrument scale, use the following equation:

$$r_x = r_d + g_x (r_1 - r_d)/100 \quad (2)$$

where:
r_x = reflectance of specimen, %,
r_d = reflectance of darker standard, %,
r_1 = reflectance of lighter standard, %, and
g_x = galvanometer reading of the instrument, %.

11.3.2 For cases where the scale cannot be expanded to reach 100 for the lighter standard, use the following equation:

$$r_x = r_d + g_x (r_1 - r_d)/g_1 \quad (3)$$

where:
g_1 = galvanometer setting for the lighter standard, %.

11.3.3 For cases where the scale cannot be expanded to reach 100 for the lighter standard and to reach zero for the darker standard, use the following equation:

$$r_x = r_d + g_x (r_1 - r_d)/(g_1 - g_d) \quad (4)$$

where:
g_d = galvanometer setting for the darker standard,

11.4 Whiteness is equal to the reflectance value obtained on the green tristimulus filter.

11.5 Yellowness factor is calculated from the following equation:

$$YF = (A - B)/G \quad (5)$$

where:
YF = yellowness factor, expressed in terms of the submultiple 10^{-2},
A = amber tristimulus filter reflectance, %,
B = blue tristimulus filter reflectance, %, and
G = green tristimulus filter reflectance, %.

11.5.1 Calculate the relative possible error in yellowness factor by the following equation:

$$\text{Possible error (relative), \%} = \pm[(a + b) \times 100]/(A - B) \quad (6)$$

where:
a = possible absolute error in the amber percent reflectance value,
b = possible absolute error in the blue percent reflectance value,
A = amber percent reflectance value, and
B = blue percent reflectance value.

12. Report

12.1 Fully identify the sample as to designation and origin.

12.2 Identify the apparatus used if other than the Photovolt reflectometer.

12.3 Report amber, blue, and green tristimulus reflectance, to the nearest 0.1 %.

12.4 If required, report CIE color order values, whiteness, and yellowness, including the possible relative error in the latter value.

NOTE 5—Since yellowness factor involves the relatively small difference of two larger numbers, even slight errors in the latter will result in very large errors in the yellowness index. Thus, it may be appropriate to report the possible relative error when reporting yellowness factors.

13. Precision and Bias

13.1 Results obtained on the same pressed specimen on the same instrument are generally repeatable to within ±0.5 %.

13.2 Results obtained on different specimens from homogeneous samples on the same instrument are generally repeatable to within ±0.8 %.

13.3 Results obtained on the same pressed specimens measured on different instruments employing calibrated standards of nearly the same reflectance may be expected to be reproducible to within ±1.2 %.

13.4 Suppressed zero measurements permit better precision.

13.5 On the longer spinning grades of asbestos, it may be impossible to achieve the above bias due to local inhomogeneity caused by the coarser texture of the pressed specimens.

14. Keywords

14.1 asbestos; color; photoelectric reflectometer; reflectance; tristimulus; whiteness; yellowness

APPENDIXES

(Nonmandatory Information)

X1. PROCEDURE FOR USE OF THE PHOTOVOLT REFLECTION METER[10] MODEL NO. 610

X1.1 Preliminary Steps

X1.1.1 Insert the plug of the search unit cable into socket *F* (Fig. X1.1) on the instrument panel.

X1.1.2 Operation on 110 V a-c.

X1.1.2.1 Do *not* connect the battery cable clamps. Throw switch *E* shown on Fig. X1.1 to "ac" and plug the power cable on the instrument to a grounded 110 V60-Hz ac outlet (preferably into a stabilized voltage supply outlet).

X1.1.3 *Battery Operation*:

X1.1.3.1 When equipped for operation from both power line and battery, Model 610 is provided with the following additional controls located at the far right-hand corner of the panel:

E Change-over switch,
H Push button, and
G Lamp control knob.

X1.1.3.2 The two positions of the change-over switch are marked "AC" and "BATT." Pressing the button *H* causes the galvanometer to act as a voltmeter for the voltage on the lamp in battery operation when ten divisions on the scale are equivalent to one volt. (For example, a reading of 60 indicates 6 V). The control knob *G* operates the lamp rheostat by means of which the lamp voltage can be adjusted in operation from a battery. Turning the knob clockwise increases the light intensity and turning it counterclockwise decreases it. The push button and the lamp control knob are inoperative when operating from the a-c power line.

X1.1.3.3 For measuring asbestos with tristimulus filters, the choice of voltage is not critical except that it is advisable to set the lamp always to approximately the same voltage within the range from 7.0 to 7.2 for valid tristimulus results. The voltage should be set just high enough within that range to reach the rated value for the working standard being used. In this way a wider margin is secured for the battery to wear down before recharging. An example is given below:

X1.1.3.4 If the operator can easily reach a galvanometer deflection of 60 for a working standard that is rated at 60 when the lamp voltage is set at 7.1 V, then he should maintain this voltage for routine testing. To do so, he must press the push button and adjust the lamp control knob until the galvanometer reads 71. As the battery becomes discharged, the control knob will have to be turned further clockwise to maintain this setting. When the clockwise end position is reached, the battery must be recharged.

X1.1.3.5 A single automobile or motorcycle type 6-V storage battery is suitable to attain lamp voltages up to 6.3 V when fully charged. For higher voltages or better battery life, a 12-V automobile battery may be used provided it is tapped so that only four cells are in series at a time. This can be done by inserting a copper screw through the top of the casing to contact the fourth cell electrode plates, and using the screw as one of the terminals.

X1.1.3.6 Test the voltage of the battery under load by turning the lamp control fully clockwise and pressing the button. The load in this case includes the lamp and wiring resistance.

X1.1.3.7 Test the voltage of the battery without load by disconnecting the search unit cable. Pressing the button will then show the open-circuit voltage of the battery, irrespective of the lamp control knob.

X1.1.3.8 When an 8-V battery is used, take care to prevent the control knob from reaching its clockwise end position since lamp voltage may reach 8.5 V with a fully charged battery. For satisfactory lamp life, keep the lamp voltage below 7.5 V at all times.

X1.1.3.9 For suppressed zero measurements, the amplification of the scale is dependent upon the photocurrent which can be increased by higher lamp voltages. Voltages up to 8 V may be applied for short periods at the cost of shorter lamp life (30 h at 8 V), and deviation from true tristimulus values. Such a procedure is acceptable for yellowness measurements, but the individual color measurements may not be reported as tristimulus values.

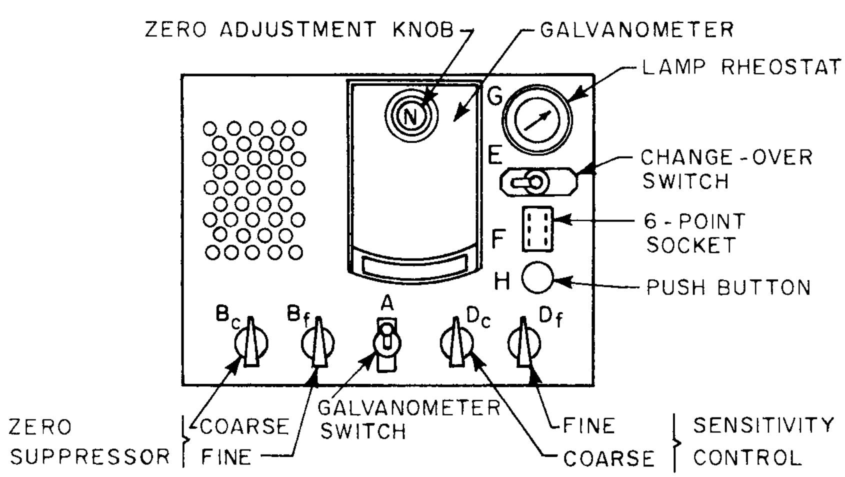

FIG. X1.1 Photovolt Model No. 610 Instrument Panel

X1.2 Procedure

X1.2.1 With the switch *A* at "OFF" set the galvanometer on zero by means of knob *N* on top of the galvanometer housing. This must be checked from time to time and readjusted if necessary.

X1.2.2 Insert the appropriate tristimulus color filter into the search unit and throw switch *A* to "ON."

X1.2.3 Proceed as in 10.5-10.8 of the test method.

X1.3 Transportation of Instrument

X1.3.1 Before carrying the instrument throw switch *A* to "OFF", thereby damping the galvanometer to prevent damage.

X1.4 Lamp Replacement

X1.4.1 Remove the three screws which hold the crackle-finished tubular part of the search unit to the bottom part.

X1.4.2 Observe that two coiled wires emerging from the lamp socket are soldered to a terminal strip. Unsolder these leads by means of a soldering iron.

X1.4.3 Remove the large hexagonal ring nut that holds the lamp socket in its bracket.

X1.4.4 Remove the lock washer and spacing collar.

X1.4.5 Loosen the four screws which hold the bracket to the two uprights and tilt the bracket so that the lamp with socket and wire coils can be removed.

X1.4.6 Replace this by a new lamp with socket and wire coils using the reverse procedure. These replacement assemblies are available from the supplier (Catalog No. 6152).

X1.5 Lamp Adjustment

X1.5.1 After replacement of the lamp, it is essential to readjust the position of the lamp bracket. There are elongated holes in the uprights for adjustment in all directions.

X1.5.2 Tighten the four screws just sufficiently to permit shifting of the bracket.

X1.5.3 Place a thin piece of paper over the sample opening and observe the light spot in the opening.

X1.5.4 Adjust the lamp bracket until the light spot shows approximately even illumination and appears in the center of the opening (the spot is slightly oval).

X1.5.5 Focus the lamp so that the long diameter of the light spot is 15.9 mm (0.625 in.).

X1.6 Internal Stray Light Effect

X1.6.1 A slight amount of light is scattered in the search unit and registers on the photocell without being reflected from the test surface.

X1.6.2 To test for stray light effect, set the galvanometer to zero by means of knob *N* with switch *A* at "OFF." Next set the instrument, by means of a working standard, so that the 100 point on the scale represents 100 % reflectance. Then place a black body cavity over the sample opening. Instead of indicating zero, the galvanometer will now show a slight deflection. If the lamp is properly focused, the reading should be about one division line or even less.

X1.6.3 If the stray light effect amounts to more than two division lines even though the lamp is properly focused as in X1.5.5, return the search unit to the manufacturer for inspection.

X1.6.4 The stray light effect can be disregarded for lighter specimens. For example, if the 100 point represents 100 % reflectance and the sample reads 60 (a typical asbestos) and if we deduct the stray light effect (two units) from the 100 setting and from the measured value, the corrected value becomes (60-2)/(100-2) = 0.592.

X1.7 Effect of Specular Gloss

X1.7.1 Reflected light is a true measure of the diffuse reflectance, without any error due to gloss, only if the lamp is properly focused. To test the gloss effect of the search unit, a piece of polished black glass can be used.

X1.7.2 If the instrument is adjusted so that the 100 point of the scale represents 100 % reflectance and if the black glass is then placed on the search unit, the reading will be one or two division lines. However, only a part of this reading is due to specular reflection, the other part being due to the stray light effect referred to in X1.6.

X1.7.3 Evaluate the gloss effect as the difference between the black glass reading and the black body cavity reading. This difference is less than one division for a properly focused lamp. If gloss is higher, return the search unit to the manufacturer for inspection.

X1.8 Position of Search Unit

X1.8.1 If the apparatus is calibrated with the search unit upright, then measurements must be made in the upright direction, or vice-versa. Therefore, ensure that the specimen opening is always at the top for testing asbestos pellet specimens.

X1.9 Service Notes

X1.9.1 The optical system of the search unit should be cleaned from time to time. It is accessible on one side through the sample opening, while the other side can be reached after the crackle-finished tubular sleeve of the search unit has been removed from the other part.

X1.9.2 Dust or dirt on the lens or the lamp will have the effect that the sensitivity control knobs have to be turned farther clockwise and, in extreme cases, may make it impossible to reach the rated reflectance values of the working standard.

X2. PROCEDURE FOR USE OF THE PHOTOVOLT REFLECTION METER[10] MODEL NO. 670

X2.1 Preliminary Steps

X2.1.1 Check the bottom panel and make sure the voltage selector switch is in the appropriate position (110 or 220 V). Then connect the 3-prong plug to a grounded outlet. If no such outlet is available, use the adapter provided, but be sure to connect the pigtail to some convenient ground such as the outlet box.

X2.1.2 Observe the meter and make sure the pointer indicates zero. If it does not, adjust it to zero with the small screw located at the needle axis (*X* in Fig. X2.1). Turn on the instrument by means of switch *A* in Fig. X2.1.

X2.1.3 With the zero suppressor off (extreme left knob *D* turned fully clockwise until it clicks) and the sensitivity controls *F* and *G* fully clockwise, adjust the amplifier zero control *C* to make the meter read zero.

NOTE X2.1—The amplifier zero should be rechecked from time to time, certainly no more than once a day. For a quick recheck, it is not necessary to disconnect the search unit. However, care must be taken to prevent any light from reaching the photocell by covering the opening, and lamp switch *B must* be off.

X2.1.4 Plug the search unit into the socket on the rear apron.

X2.1.5 Turn on the search unit by means of switch *B* and allow it to warm up for about 1.8 ks (30 min). Place the search unit with the specimen opening upward for calibration and for measurements.

X2.2 Procedure

X2.2.1 Insert the appropriate tristimulus color filter into the search unit.

X2.2.2 Proceed as in 10.5-10.8 of the test method.

X2.3 Lamp Replacement

X2.3.1 Proceed as in X1.4.

X2.4 Lamp Adjustment

X2.4.1 Proceed as in X1.5.

X2.5 Internal Stray Light Effect

X2.5.1 Refer to X1.6.

X2.6 Effect of Specular Gloss

X2.6.1 Refer to X1.7.

X2.7 Service Notes

X2.7.1 In cold, dry weather, a static charge may form on the meter window. This will be evidenced by erratic movement or sticking of the pointer. This charge may be removed by wiping the window with a damp cloth, but a more permanent cure may be effected by applying anti-static spray, which is available in most electronic supply houses.

X2.7.2 Refer to X1.3 and X1.9 for additional notes.

X2.8 Operation with a Digital Galvanometer

X2.8.1 The output terminals on the rear apron may be used to connect a digital readout accessory (Catalog No. 6500). The fine adjustment for this outlet is provided by the output terminal control which adjusts the voltage to 1000 ± 100 mV.

X2.8.2 Insert the metal end of the connecting cable into the receptacle on the right sidewall of the digital galvanometer, and tighten the thumb screw. Plug in the pigtail of the cable into *either* of the pinjacks. Then plug the bayonet end of the cable

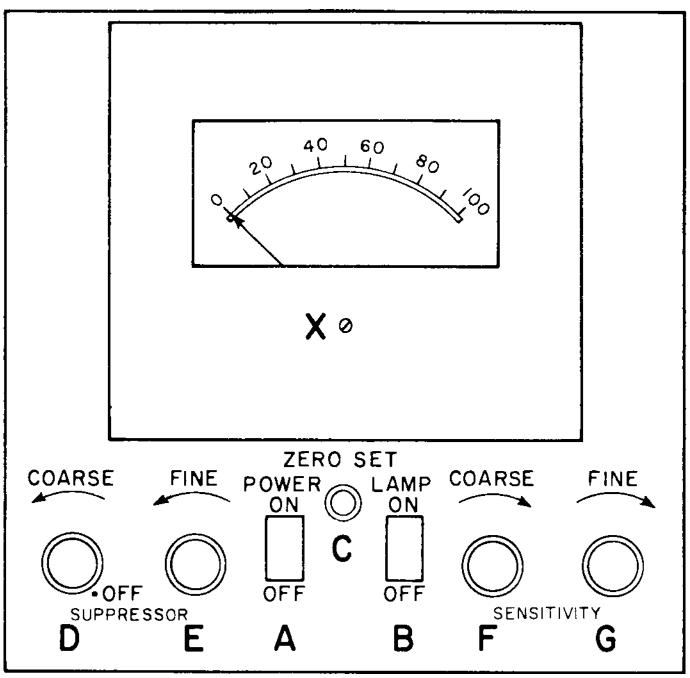

FIG. X2.1 Photovolt Model No. 670 Instrument Panel into the outlet marked "Recorder" on the back of the meter. The side marked "GND" should be in the black jack. (If the "GND" cable is connected to the red jack, the digital readout will run backwards. This indicates that the cable should be reversed.)

X2.8.3 With the reflection meter set on zero, turn the main switch of the digital galvanometer to "ZERO SET" and adjust the left-hand "ZERO-SET" knob until the digital display shows 000.0.

X2.8.4 Place the calibration standard on the search unit and adjust the reflection meter so that the needle galvanometer will correspond to the value of the standard (see Note X2.2). Switch the digital galvanometer to "READ" and set the digital display to the exact value of the calibration standard using the "CALIBRATE" knob.

NOTE X2.2—The meter display need not be in exact coincidence with the digital display.

X2.8.5 After standardization, switch to "STANDBY" and place the test specimen on the search unit. Switch to "READ" to take the required measurement.