This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: B567 – 98 (Reapproved 2021)

Standard Test Method for Measurement of Coating Thickness by the Beta Backscatter Method[1]

This standard is issued under the fixed designation B567; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the beta backscatter gages for the nondestructive measurement of metallic and nonmetallic coatings on both metallic and nonmetallic substrate materials.

1.2 The test method measures the mass of coating per unit area, which can also be expressed in linear thickness units provided that the density of the coating is known.

1.3 The test method is applicable only if the atomic numbers or equivalent atomic numbers of the coating and substrate differ by an appropriate amount (see 6.2).

1.4 Beta backscatter instruments employ a number of different radioactive isotopes. Although the activities of these isotopes are normally very low, they can present a hazard if handled incorrectly. This standard does not purport to address the safety issues and the proper handling of radioactive materials. It is the responsibility of the user to comply with applicable State and Federal regulations concerning the handling and use of radioactive material. Some States require licensing and registration of the radioactive isotopes.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *activity*—the nuclei of all radioisotopes are unstable and tend to change into a stable condition by spontaneously emitting energy or particles, or both. This process is known as radioactive decay. The total number of disintegrations during a suitably small interval of time divided by that interval of time is called "activity." Therefore, in beta backscatter measurements, a higher activity corresponds to a greater emission of beta particles. The activity of a radioactive element used in beta backscatter gages is generally expressed in microcuries (1 μCi = 3.7×10^4 disintegrations per second).

2.1.2 *aperture*—the opening of the mask abutting the test specimen. It determines the size of the area on which the coating thickness is measured. This mask is also referred to as a platen, an aperture plate, a specimen support, or a specimen mask.

2.1.3 *backscatter*—when beta particles pass through matter, they collide with atoms. Among other things, this interaction will change their direction and reduce their speed. If the deflections are such that the beta particle leaves the body of matter from the same surface at which it entered, the beta particle is said to be backscattered.

2.1.4 *backscatter coefficient*—the backscatter coefficient of a body, R, is the ratio of the number of beta particles backscattered to that entering the body. R is independent of the activity of the isotope and of the measuring time.

2.1.5 *backscatter count:*

2.1.5.1 *absolute backscatter count*—the absolute backscatter count, X, is the number of beta particles that are backscattered during a finite interval of time and displayed by the instrument. X will, therefore, depend on the activity of the source, the measuring time, the geometric configuration of the measuring system, and the properties of the detector, as well as the coating thickness and the atomic numbers of the coating and substrate materials. X_0 is the count produced by the uncoated substrate, and Xs, that of the coating material. To obtain these values, it is necessary that both these materials are available with a thickness greater than the saturation thickness (see 2.1.12).

[1] This test method is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.10 on Test Methods.

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2.1.5.2 *normalized backscatter*—the normalized backscatter, x_n, is a quantity that is independent of the activity of the source, the measuring time, and the properties of the detector. The normalized backscatter is defined by the equation:

$$x_n = \frac{X - X_0}{X_s - X_0}$$

where:

X_0 = count from the substrate,
X_s = count from the coating material, and
X = count from the coated specimen, and each count is for the same interval of time.

Because X is always $\geq X_0$ and $\leq X_s$, x_n can only take values between 0 and 1. (For reasons of simplicity, it is often advantageous to express the normalized count as a percentage by multiplying x_n by 100.)

2.1.5.3 *normalized backscatter curve*—the curve obtained by plotting the coating thickness as a function of x_n.

2.1.6 *beta particles*—beta particles or beta rays are high-speed electrons that are emitted from the nuclei of materials undergoing a nuclear transformation. These materials are called beta-emitting isotopes, beta-emitting sources, or beta emitters.

2.1.7 *coating thickness*—in this test method, coating thickness refers to mass per unit area as well as geometrical thickness.

2.1.8 *dead time or resolving time*—Geiger-Müller tubes used for counting beta particles have characteristic recovery times that depend on their construction and the count rate. After reading a pulse, the counter is unresponsive to successive pulses until a time interval equal to or greater than its dead time has elapsed.

2.1.9 *energy*—it is possible to classify beta emitters by the maximum energy of the particles that they release during their disintegration. This energy is generally given in mega-electronvolts, MeV.

2.1.10 *equivalent (or apparent) atomic number*— the equivalent atomic number of an alloy or compound is the atomic number of an element that has the same backscatter coefficient as the material.

2.1.11 *half-life, radioactive*—for a single radioactive decay process, the time required for the activity to decrease by half.

2.1.12 *saturation thickness*—the minimum thickness of a material that produces a backscatter that is not changed when the thickness is increased. (See also Appendix X1.)

2.1.13 *sealed source or isotope*—a radioactive source sealed in a container or having a bonded cover, the container or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

2.1.14 *source geometry*—the spatial arrangement of the source, the aperture, and the detector with respect to each other.

3. Summary of Test Method

3.1 When beta particles impinge upon a material, a certain portion of them is backscattered. This backscatter is essentially a function of the atomic number of the material.

3.2 If the body has a surface coating and if the atomic numbers of the substrate and of the coating material are sufficiently different, the intensity of the backscatter will be between two limits: the backscatter intensity of the substrate and that of the coating. Thus, with proper instrumentation and if suitably displayed, the intensity of the backscatter can be used for the measurement of mass per unit area of the coating, which, if the density remains the same, is directly proportional to the thickness.

3.3 The curve expressing coating thickness (mass per unit area) versus beta backscatter intensity is continuous and can be subdivided into three distinct regions, as shown in Fig. 1. The normalized count rate, x_n, is plotted on the X-axis, and the logarithm of the coating thickness, on the Y-axis. In the range $0 \leq x_n \leq 0.35$, the relationship is essentially linear. In the range $0.35 \leq x_n \leq 0.85$, the curve is nearly logarithmic; this means that, when drawn on semilogarithmic graph paper, as in Fig. 1, the curve approximates a straight line. In the range $0.85 \leq x_n \leq 1$, the relationship is nearly hyperbolic.

3.4 Radiation other than the beta rays are emitted or backscattered by the coating or substrate, and may be included in the backscatter measurements. Whenever the term backscatter is used in this method, it is to be assumed that reference is made to the total radiation measured.

4. Significance and Use

4.1 The thickness or mass per unit area of a coating is often critical to its performance.

4.2 For some coating-substrate combinations, the beta backscatter method is a reliable method for measuring the coating nondestructively.

4.3 The test method is suitable for thickness specification acceptance if the mass per unit area is specified. It is not suitable for specification acceptance if the coating thickness is specified and the density of the coating material can vary or is not known.

5. Instrumentation

5.1 In general, a beta backscatter instrument will comprise: (*1*) a radiation source (isotope) emitting primarily beta particles having energies appropriate to the coating thickness to be measured (see Appendix X2), (*2*) a probe or measuring system with a range of apertures that limit the beta particles to the area of the test specimen on which the coating thickness is to be measured, and containing a detector capable of counting the number of backscattered particles (for example, a Geiger-Müller counter (or tube)), and (*3*) a readout instrument where the intensity of the backscatter is displayed. The display, in the form of a meter reading or a digital readout can be: (*a*) proportional to the count, (*b*) the normalized count, or (*c*) the coating thickness expressed either in thickness or mass per unit area units.

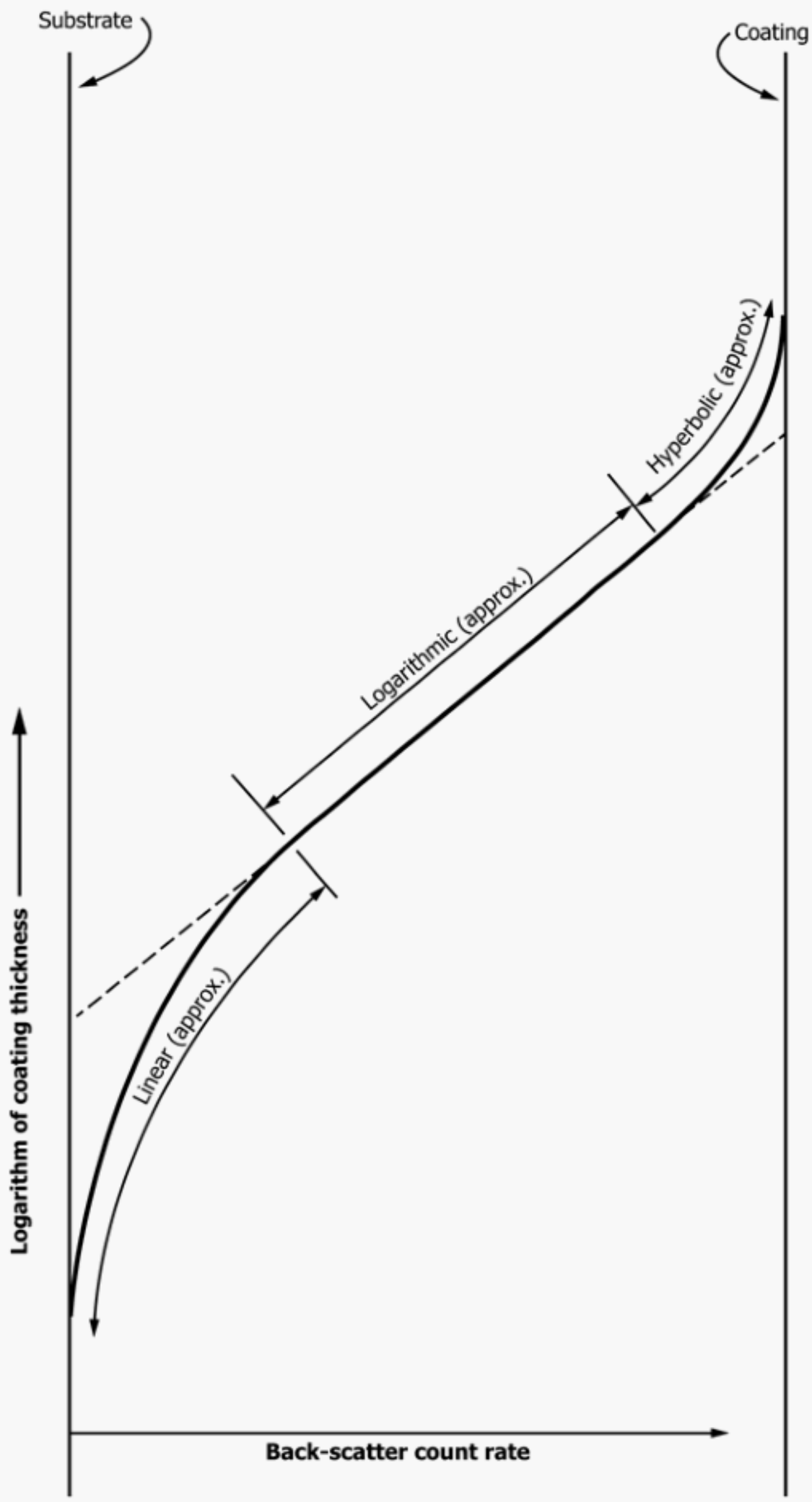

FIG. 1 Normalized Backscatter

6. Factors Affecting the Measuring Accuracy

6.1 *Counting Statistics:*

6.1.1 Radioactive disintegration takes place randomly. Thus, during a fixed time interval, the number of beta particles backscattered will not always be the same. This gives rise to statistical errors inherent to radiation counting. In consequence, an estimate of the counting rate based on a short counting interval (for example, 5 s) may be appreciably different from an estimate based on a longer counting interval, particularly if the counting rate is low. To reduce the statistical error to an acceptable level, it is necessary to use a counting interval long enough to accumulate a sufficient number of counts.

6.1.2 At large total counts, the standard deviation (σ) will closely approximate the square root of the total count, that is $\sigma = \sqrt{X}$; in 95 % of all cases, the true count will be within $X \pm 2\sigma$. To judge the significance of the precision, it is often helpful to express the standard deviation as a percentage of the count, that is, $100\sqrt{X}/X$, or $100/\sqrt{X}$. Thus, a count of 100 000 will give a value ten times more precise than that obtained with a count of 1000. Whenever possible, a counting interval should be chosen that will provide a total count of at least 10 000, which corresponds to a statistical error of 1 % for the count rate. It should be noted, however, that a 1 % error in the count rate can correspond to a much larger percentage error in the thickness measurement, the relative error depending on the atomic number spread or ratio between coating and substrate materials.

6.1.3 Direct-reading instruments are also subject to these statistical random errors. However, if these instruments do not permit the display of the actual counting rate or the standard deviation, the only way to determine the measuring precision is to make a large number of measurements at the same coated location on the same coated specimen, and calculate the standard deviation by conventional means.

NOTE 1—The accuracy of a thickness measurement by beta backscatter is generally poorer than the precision described in 5.1, inasmuch as it also depends on other factors that are described below. Methods to determine the random errors of thickness measurements before an actual measurement are available from some manufacturers.

6.2 *Coating and Substrate Materials*—Because the backscatter intensity depends on the atomic numbers of the substrate and the coating, the repeatability of the measurement will depend to a large degree on the difference between these atomic numbers; thus, with the same measuring parameters, the greater this difference, the more precise the measurement will be. As a rule of thumb, for most applications, the difference in atomic numbers should be at least 5. For materials with atomic numbers below 20, the difference may be reduced to 25 % of the higher atomic number; for materials with atomic numbers above 50, the difference should be at least 10 % of the higher atomic number. Most plastics and related organic materials (for example, photoresists) may be assumed to have an equivalent atomic number close to 6. (Appendix X3 gives atomic numbers of commonly used coating and substrate materials.)

6.3 *Aperture:*

6.3.1 Despite the collimated nature of the sources used in commercial backscatter instruments, the backscatter recorded by the detector is, nearly always, the sum of the backscatter produced by the test specimen exposed through the aperture and that of the aperture plate(n). It is, therefore, desirable to use a material with a low atomic number for the construction of the platen and to select the largest aperture possible. Measuring errors will be increased if the edges of the aperture opening are worn or damaged, or if the test specimen does not properly contact these edges.

6.3.2 Because the measuring area on the test specimen has to be constant to prevent the introduction of another variable, namely the geometrical dimensions of the test specimen, it is essential that the aperture be smaller than the coated area of the surface on which the measurement is made.

6.4 *Coating Thickness:*

6.4.1 In the logarithmic range, the *relative measuring error* is nearly constant and has its smallest value.

6.4.2 In the linear range, the *absolute measuring error*, expressed in mass per unit area or thickness, is nearly constant, which means that as the coating thickness decreases, the relative measuring error increases. At or near $x_n = 0.35$, the relative errors of the linear and logarithmic ranges are about the same. Thus, the relative error at this point may, for most practical purposes, be used to calculate the absolute error over the linear range.

6.4.3 In the hyperbolic range, the measuring error is always large because a small variation in the intensity of the beta backscatter will produce a large variation in the measured coating thickness.

6.4.4 For instruments that indicate only backscatter count rate and not thickness directly, the count rate is normally converted to a thickness by means of an appropriate graph. Such graphs are generally valid only within a specific range of coating thicknesses so that extrapolation of a linear range calibration curve (straight line on rectangular coordinates) into the logarithmic thickness range will result in measurement errors. Similarly, extrapolation of a logarithmic range calibration into the linear thickness range will also produce significant errors. Many instruments that indicate coating thickness directly are limited to the combined linear and logarithmic coating thickness ranges but will be in error if measurements are attempted in the hyperbolic thickness range. The instrument manufacturer's instructions must be followed relative to the limiting coating thicknesses beyond which the particular instrument being used may give substantial errors.

6.5 *Resolving Time of the Detector*—Because of the dead time of Geiger-Müller tubes (see 2.1.8), the number of pulses displayed by the readout instrument is always less than the actual number of backscattered beta particles. Normally, this does not diminish the measuring accuracy significantly unless the count rate is so high as to saturate the detector.

6.6 *Source Geometry*— The greatest measurement precision is obtained with the source placed in a particular position with respect to the test specimen. This position depends on the collimation of the beam of beta particles from the source and the location, form, and size of the aperture. If possible, most of the beta particles emitted by the source should be backscattered from the test specimen, and not from the aperture plate(n). The instructions furnished by the manufacturer of the instrument for mounting the source shall be followed exactly.

6.7 *Curvature*—This test method is sensitive to the curvature of the test specimen. However, the normalized backscatter curve remains nearly the same if the surface of the test specimen does not protrude into the aperture of the platen by more than about 50 µm. By the use of specially selected aperture platens or masks where the isotope is premounted in a fixed, optimum position, it is possible to obtain nearly identical readings on both flat and curved specimens. This permits the use of flat calibration standards for the measurement of curved specimens. The relationship between maximum aperture size and specimen surface curvature is peculiar, in most cases, to the individual instrument design. These details are therefore best obtained from the manufacturer's data.

6.8 *Substrate Thickness:*

6.8.1 *Test Specimens with Single-Layer Coatings:*

6.8.1.1 This test method is sensitive to the thickness of thin substrates, but for each isotope and material there is a critical thickness, called "saturation thickness," beyond which the measurement will no longer be affected by an increase of the substrate thickness. This thickness depends on the energy of the isotope and on the density of material. If the saturation thickness is not supplied by the manufacturer, it should be determined experimentally.

6.8.1.2 If the substrate thickness is less than the saturation thickness, effective saturation thickness can sometimes be obtained by backing up the substrate with more of the same material, but only if the substrate is not coated on both sides. If the substrate is of constant thickness, the instrument may be calibrated for that thickness of substrate. However, if the substrate thickness is less than the saturation thickness and also varies in thickness, this method will not yield a single value for the coating thickness, but a range of values with an upper and lower limit.

6.8.2 *Test Specimens with Multiple-Layer Coatings:*

6.8.2.1 If the intermediate layer adjacent to the coating is thicker than the saturation thickness, this test method will not be affected by any variations in the substrate thickness as long as the instrument is calibrated with standards having the intermediate coating material as the basis material.

6.8.2.2 If the thickness of the intermediate layer is less than saturation thickness, but constant in thickness, the instrument may be calibrated for that particular combination of materials. However, if the thickness of this intermediate layer is less than saturation thickness and varies in thickness, this method will not yield a single value for the coating thickness, but a range of values with an upper and lower limit.

6.9 *Surface Cleanliness*—Foreign material, such as dirt, grease, and corrosion products, will produce erroneous readings. Natural oxide coatings, which form on some metal coatings, also tend to produce low readings, especially if the measurement requires the use of an isotope having an energy of less than 0.25 MeV.

6.10 *Substrate Material*—To obtain accurate thickness readings, it is necessary that the backscatter produced by the substrate materials of the test specimen and that of the calibration standard be the same. If they are different, other calibration standards will have to be used, or appropriate corrections made. Beta backscatter instruments are available that can automatically make these corrections.

6.11 *Density of Coating Material*—The beta backscatter method is basically a method of comparing the mass per unit area of the coating of the test specimen to that of the calibration standard. If the instrument readout is in units of mass per unit area, the linear thickness is obtained by dividing by the coating density:

$$T = \frac{M \times 10}{D}$$

If the instrument readout is in linear units and if there is a difference between the coating densities of the calibration

standards and of the test specimens, a density correction must be applied:

$$T = \frac{T^* \times D^*}{D}$$

where:

T = linear thickness of coating of test specimen, µm,
T^* = linear thickness readout of instrument, µm,
D = density of coating of test specimen, g/cm^3,
D^* = density of coating of calibration standard, g/cm^3, and
M = mass per unit area of coating of test specimen, mg/cm^2.

In addition to porosity, voids, and inclusions, codeposited materials can influence the density of the coating. For most metallic elements the effects are usually considered negligible for deposits obtained under normal conditions from properly maintained electroplating baths free of contamination. The only documented exception is gold, the density of which is dependent on the deposition process.

6.12 *Composition of Coating*—Because the composition of a coating affects the mass of coating per unit area, it will also affect the instrument response (amount of backscattered beta radiation). This effect may be negligible with alloying elements having densities close to each other, such as cobalt-nickel alloys. Very small quantities of alloying elements, such as those present in high gold alloy deposits, also have little effect.

6.13 *Energy of Beta Particles:*

6.13.1 Because the precision of the measurement is not constant over the entire range of measurement for a given isotope, but is the best in the logarithmic portion of the normalized beta backscatter curve (see Fig. 1), the isotope should, whenever possible, be selected in such a manner that the expected measurements fall into the range $0.35 \leq x_n \leq 0.85$ of the normalized curve. See Appendix X2 for a list of isotopes used with beta backscatter gages.

6.13.2 In general, instructions for selecting the proper isotope are furnished by the manufacturer.

6.14 *Measurement Time*—Too short a measurement time will yield a poor measurement precision. The selection of the measurement time will, therefore, depend on the measurement precision that is required. Each time the measurement time is increased by a factor of n, the counting measurement precision will improve by a factor of approximately $1/\sqrt{n}$.

6.15 *Activity of Radioactive Source*—The count rate is dependent on the activity of the source. An old source may have a low activity, requiring excessive time to make a good measurement (see 5.1). As a practical guide, the source should be replaced before its half-life has elapsed.

6.16 *Coating-Substrate Combination* —The measurement precision depends on the difference between the atomic numbers of the coating and substrate materials. The greater this difference, the better the precision (see also 6.2).

6.17 *Surface Roughness*—Measurement accuracy can be significantly influenced by the roughness of the coating surface, but the effect is minimized if the energy of the beta particles is high and the atomic number of the coating is low.

6.18 *Detector*—Errors can be introduced by erratic operation of the detector. If instability or drift is suspected, the user is advised to consult the manufacturer.

6.19 *Wear of Calibration Standards:*

6.19.1 Coating thickness standards used to calibrate beta backscatter instruments are subject to wear when used and thus to a decrease in thickness.

6.19.2 The thickness of a calibration standard should be checked from time to time by comparing it with another calibration standard or reference sample that has not been used since the last check.

7. Calibration of Instruments

7.1 Beta backscatter instruments shall be calibrated with standards before measurements are made and also each time the measuring conditions are changed. To obtain the best possible measurement precision, the largest possible aperture suitable for the area to be measured should be selected. Select the calibration measuring time, the number of calibration measurements to be made on each calibration standard, and the test piece measuring time in accordance with the manufacturer's instructions to obtain the required measurement precision (see 7.8) with the measuring time, aperture, isotope, and number of readings to be used for measuring the test piece. For certain types of measurement application, this may require unusually long measuring times (greater than 80 s).

NOTE 2—A measurement is that value obtained under the same conditions of time, aperture, isotope, and number of readings as used to measure the test piece. It may be a single reading or an average of two or more readings.

Before use, the calibration shall be checked as described in 7.8. During use, the calibration shall have been checked within the preceding 4 h as recommended by the instrument manufacturer. Attention shall be given to the factors listed in Section 6 and the procedures in Section 9.

7.2 In addition to the zero point, the complete calibration curve can be defined either by two points of the logarithmic range, or by a single point, if the slope in the logarithmic range is known. In the first case, two calibration standards are required, in the second, only one.

7.3 The instrument shall be calibrated with standards having a uniform coating thickness. Whenever possible, these standards shall have an accuracy of ±5 % at a 95 % confidence interval, or better. The coating and substrate materials of the standard should have the same or equivalent atomic numbers as the substrate and coating materials of the test specimen. Standards corresponding to the bare substrate material and the coating material are also considered to be "calibration" standards. Sometimes it is also possible to use foils of the coating material for calibration. These are placed on, and in contact with, the substrate. It is necessary that the foil be clean, smooth, and uniform in thickness, and that the contact between foil and substrate be intimate.

7.4 Before an instrument is calibrated, the condition of the calibration standards shall have been checked. Scratched, worn, or pitted standards shall not be used to calibrate the instrument.

7.5 If coating materials have the same or equivalent atomic numbers, but different densities, the normalized backscatter curves will be essentially parallel in the logarithmic region. Under these circumstances, thickness measurements must be corrected for the difference in densities (see also 6.11). If "equivalent" calibration standards are used for the calibration of the instrument, their suitability shall be established prior to the measurements.

7.6 The substrate thickness for the test specimen and the calibration standards should be the same, unless the saturation thickness as defined in 6.8.1 is exceeded. If they are different, appropriate corrections have to be made (see 6.10).

7.7 The curvature of the calibration standard and of the test specimen shall be the same, except if it can be demonstrated that the readings from a flat or curved specimen are essentially the same. If this is not possible, the readings will have to be corrected.

7.8 Before use, the calibration should be checked as follows. Take 5 measurements on each calibration standard, removing and replacing the standard after each reading, under the same conditions of time, aperture, isotope, and number of readings as the conditions to be used for measuring the test piece. The average of each set of five measurements shall be within 3 % of the stated thickness of the corresponding calibration standard. Failure to meet these requirements invalidates the calibration.

NOTE 3—Failure to meet these requirements may indicate faulty (worn) calibration standards, a worn aperture platen, improper standard positioning on the aperture platen, insufficient measuring time, or improper compensation for isotope decay.

8. Referee Test

8.1 If a referee test is required to resolve a disagreement, it shall be performed by using "suitable" Standard Reference Material (SRM) thickness standards from the National Institute of Standards and Technology (NIST), if such standards are available.

8.2 A "suitable" SRM standard is an SRM standard of the same substrate/coating combination for which the beta backscatter instrument was calibrated and the thickness of which is within the range of the calibration, preferably close to that of the test items being measured.

8.3 The SRM shall be measured five times, each measurement being made under the same conditions as used for the measurement of the test piece. If the average of the five measurements of the SRM differs from the certified mass per unit area or equivalent thickness by more than 10 %, the calibration is not valid.

NOTE 4—SRMs are issued by the NIST[2] and include "coating thickness" SRMs for some coating systems. The stated mass per unit area of each "coating thickness" SRM is certified to be within 5 % of the true mass per unit area.

[2] SRMs may be obtained from the Office of Standard Reference Materials, National Institute of Standard and Technology, Gaithersburg, MD 20899.

9. Procedure

9.1 Operate each instrument in accordance with the manufacturer's instructions, paying attention to the factors listed in Section 5. Calibrate the instrument in accordance with Section 7.

9.2 Check the calibration of the instrument at the test site each time the instrument is put into service and at frequent intervals during use in accordance with 7.1.

9.3 *Precautions*— Observe the following precautions:

9.3.1 *Substrate Thickness*—The substrate thickness shall exceed the saturation thickness or the calibration shall be made with a substrate having the same thickness and properties as the test specimen (see 6.8).

9.3.2 *Measuring Aperture*—The size of the measuring aperture depends on the size and shape of the test specimen. Follow the manufacturer's recommendations concerning the choice of a measuring aperture. The measuring aperture shall not be larger than the coated area available on the test specimen. The test specimen shall be seated firmly and securely against the measuring opening.

9.3.3 *Curved Specimens*— It shall be verified that the aperture used for the measurement is correct for the radius of curvature of the test specimen and, if the calibration has not been made with standards having the same curvature as the test specimen, that the calibration is applicable to the measurement.

9.3.4 *Substrate Material*—The backscatter produced by the substrate of the standard shall be the same as that produced by the test specimen. Verify this by actual tests. If the two differ, follow the manufacturer's instructions regarding corrections or use new standards that agree with the test specimen (see 6.10).

9.3.5 *Surface Cleanliness*—Remove all foreign materials, such as dirt, grease, lacquer, oxides, and conversion coatings, from the surface before the measurement by cleaning without removing any coating material. Avoid measuring specimen areas having visible defects, such as flux and acid spots.

9.3.6 *Measuring Time*—Use a sufficient measuring time to obtain a repeatability of readings that will yield the desired precision.

10. Report

10.1 The report shall include the following information:

10.1.1 Type of instrument used,

10.1.2 Size of aperture,

10.1.3 Measurement time,

10.1.4 Description of test specimen and measurement area,

10.1.5 If applicable a statement that a correction for density was made,

10.1.6 Type of calibration standards and the measurement mode used,

10.1.7 Thickness of coating as determined from the measurements,

10.1.8 Statistical measurement parameters of the measurement series as required,

10.1.9 Identification of testing facility and operator,

10.1.10 Date of measurements.

11. Precision and Bias

11.1 The equipment, its calibration, and its operation shall be such that the coating thickness can be determined with an uncertainty of less than 10 % at 95 % confidence level.

11.2 Instruments suitable for compliance with section 11.1 are available commercially.

11.3 The measurement bias is the discrepancy remaining between the measured thickness and the true thickness if all random errors are eliminated. It is, therefore, no greater than, and attributable to (*1*), the calibration error of the instrument and (*2*) the quality of the calibration standard used to calibrate the instrument.

12. Keywords

12.1 aperture, beta backscatter, coating thickness, isotope

APPENDIXES

(Nonmandatory Information)

X1. SATURATION THICKNESS AS A FUNCTION OF DENSITY FOR VARIOUS ISOTOPES

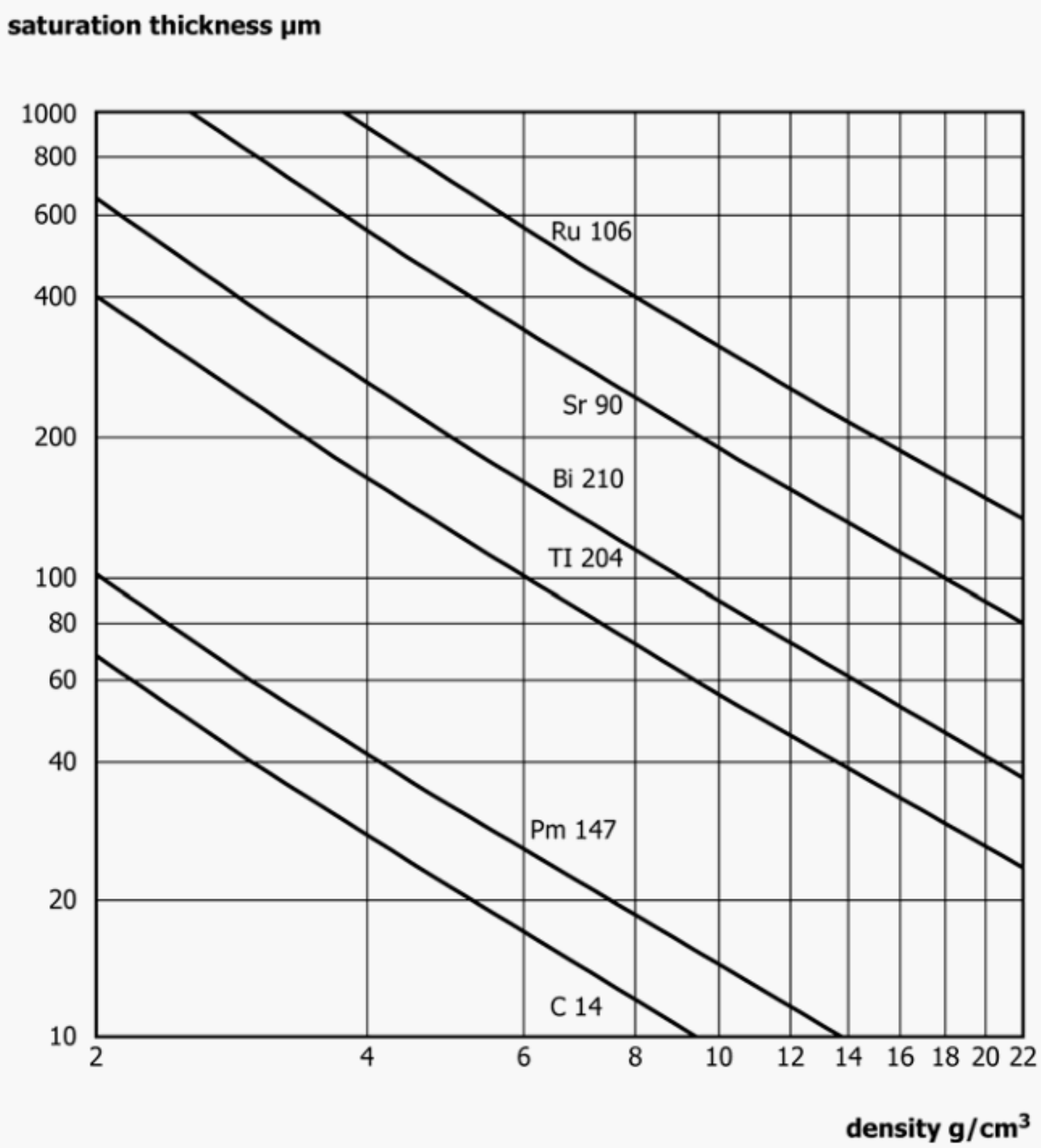

FIG. X1.1 Saturation Thickness

X2. ISOTOPES USED WITH BETA BACKSCATTER GAGES

Isotope or Source	Symbol	*E*max, MeV	Approximate Half-Life, years
Carbon	C-14	0.16	5750.7
Promethium	Pm-147	0.22	2.8
Thallium	T1-204	0.77	3
Lead-210 – bismuth-210	Pb-210 – Bi-210		
Radium D + E	Ra D + E	1.17	19.4
Strontium – yttrium	Sr-90 – Y-90	2.27	28
Ruthenium – rhodium	Ru-106 – Rh-106	3.54	1

X3. ATOMIC NUMBERS OF SOME COMMONLY USED COATINGS AND SUBSTRATES

Element	Atomic Number
Aluminum	13
Cadmium	48
Chromium	24
Cobalt	27
Copper	29
Gold	79
Iron	26
Lead	82
Magnesium	12
Nickel	28
Organic materials	~6
Platinum	78
Rhodium	45
Silver	47
Tin	50
Titanium	22
Zinc	30

X4. REPRODUCIBILITY OF MEASUREMENTS

X4.1 The following table summarizes the results of a round robin participated in by 46 laboratories and conducted by ASTM Committee B08.[3] Each laboratory measured two specimens of gold on nickel, 0.7 and 1.3 µm, using an 0.8-mm aperture with the promethium isotope. Measurement time was 30 s and calibration measurements were 240 s each. Each specimen was measured ten times after the instrument was calibrated. The calibration and set of ten measurements were repeated five times. Subsequent to the round robin, Section 7 on calibration was revised to incorporate tighter control of the calibration procedure in order to reduce the variations between laboratories.

Standard Deviations
(Square roots of components of variance for various sources of variability)

Thickness	0.7 µm	1.3 µm
repeatability of a single measurement	0.015 µm	0.025 µm
between calibrations	0.014	0.027
between laboratories	0.047	0.054

These data indicate the overall performance of the laboratories and not necessarily the adequacy of the test method even though the laboratories were instructed to follow this test method. Also similar measurements of other coating systems are likely to yield different results.

[3] "An Interlaboratory Comparison of Gold Thickness Measurements by Fielding Ogburn and John Mandel," *Plating and Surface Finishing* Vol 72 No. 9, 1985 p. 48.

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