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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Developing Accelerated Tests to Aid Prediction of the Service Life of Building Components and Materials[1]

This standard is issued under the fixed designation E 632; 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 practice covers steps that should be followed in developing accelerated tests for predicting the service life of building components and materials. Although mathematical analyses needed for prediction of service life are not described in detail, either deterministic or probabilistic analysis may be used.

NOTE 1—Comparative testing is an alternative to the steps identified in this practice; it involves qualitative comparison of the results of a test component or material with the results of a similar control component or material when exposed to identical conditions.

1.2 This practice outlines a systematic approach to service life prediction, including the identification of needed information, the development of accelerated tests, the interpretation of data, and the reporting of results.

2. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *aging test*—a test in which building components or materials are subjected or exposed to factors believed to cause degradation.

2.1.2 *accelerated aging test*—an aging test in which the degradation of building components or materials is intentionally accelerated over that expected in service.

2.1.3 *biological degradation factor*—any of the group of degradation factors that are directly associated with living organisms, including microorganisms, fungi, and bacteria.

2.1.4 *building component*—an identifiable part of a building that may include a combination of building materials, such as a wall or a roof.

2.1.5 *building material*—an identifiable material that may be used in a building component, such as brick, concrete, metal, or lumber.

2.1.6 *critical performance characteristic(s)*—a property, or group of properties, of a building component or material that must be maintained above a certain minimum level if the component or material is not to lose its ability to perform its intended functions.

2.1.7 *degradation mechanism*—the sequence of chemical or physical changes, or both, that leads to detrimental changes in one or more properties of a building component or material when exposed to one or more degradation factors.

2.1.8 *degradation factor*—any of the group of external factors that adversely affect the performance of building components and materials, including weathering, biological, stress, incompatibility, and use factors.

2.1.9 *durability*—the capability of maintaining the serviceability of a product, component, assembly, or construction over a specified time.

2.1.10 *incompatibility factor*—any of the group of degradation factors that result from detrimental chemical and physical interactions between building components or materials.

2.1.11 *in-service test*—a test in which building components or materials are exposed to degradation factors under in-service conditions.

2.1.12 *performance criterion*—a quantitative statement of a level of performance for a selected performance characteristic of a component or material needed to ensure compliance with a performance requirement.

2.1.13 *performance requirement*—a qualitative statement of the performance required from a building component or material.

2.1.14 *predictive service life test*—a test, consisting of both a property measurement test and an aging test, that is used to predict the service life (or compare the relative durabilities) of building components or materials in a time period much less than the expected service life.

2.1.15 *property measurement test*—a test for measuring one or more properties of building components or materials.

2.1.16 *serviceability*—the capability of a building product, component, assembly, or construction to perform the function(s) for which it is designed and constructed.

2.1.17 *service life (of a building component or material)*—the period of time after installation during which all properties exceed the minimum acceptable values when routinely maintained.

2.1.18 *stress factor*—any of the group of degradation factors that result from externally applied sustained or periodic loads.

2.1.19 *use factor*—any of the group of degradation factors that result from the design of the system, installation and maintenance procedures, normal wear and tear, and user abuse.

[1] This practice is under the jurisdiction of ASTM Committee G-3 on Durability of Nonmetallic Materials and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Environmental Tests.

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2.1.20 *weathering factor*—any of the group of degradation factors associated with the natural environment, including radiation, temperature, rain and other forms of water, freezing and thawing, normal air constituents, air contaminants, and wind.

3. Significance and Use

3.1 It is difficult to develop accelerated aging tests for use in predicting long-term in-service performance for the following reasons:

3.1.1 The degradation mechanisms of building materials are complex and seldom well understood,

3.1.2 The external factors that affect performance are numerous and difficult to quantify, so that many existing accelerated procedures do not include all factors of importance and those included seldom relate quantitatively to in-service exposure, and

3.1.3 The materials are often tested in configurations different from those used in-service.

3.2 Despite their shortcomings, these tests are used to provide needed durability or service life data. This practice should be useful to standards-setting groups and others who develop predictive service life tests that include accelerated aging tests.

4. Procedures

4.1 The recommended procedures for developing predictive service life tests that utilize accelerated aging are outlined in Fig. 1.

I—PROBLEM DEFINITION

5. Scope

5.1 The problem definition step covers what the test should do and the degradation factors that should be included in the aging test.

6. Definition of In-Service Performance Requirements and Criteria

6.1 The expected in-service performance requirements and criteria define the minimum acceptable levels of performance, or the degradation from the initial performance level. The performance levels should be based upon the functions the component or material shall perform under expected service conditions.

7. Characterization of the Component or Material and Identification of Degradation Mechanisms

7.1 Characterize the component or material to be evaluated as thoroughly as possible in terms of structure and composition, critical performance characteristics, properties that can serve as degradation indicators, the range and type of degradation factors to which it will be exposed, and all possible mechanisms by which the degradation factors induce changes in the properties.

7.1.1 *Identification of Critical Performance Characteristics and Properties*:

7.1.1.1 Properties to be used as indicators of degradation may be the same as the properties critical to performance. Fig. 2 is an example of a matrix that may be useful in identifying properties that can indicate degradation. Similar matrices can be developed for all building components and materials.

7.1.1.2 The vertical axis of the matrix includes an alphabetical letter for each element or material in the component. For example, a wall component may include an exterior coating (A), an exterior substrate (B), a structural member (C), insulation (D), an interior substrate (E), and an interior coating (F). The interfaces between each pair of materials can then be designated, for example, A-B, B-C, A-C, etc.

7.1.1.3 Consider the characteristics of each material and interface in the evaluation. The horizontal axis of Fig. 2 is labeled "Observable Changes.'' It lists changes in properties that may be useful as measures of degradation, such as observable changes in an exterior coating (chalking, crazing, cracking, checking, flaking, scaling, blistering, changes in color [Δ color], changes in gloss [Δ gloss], etc.).

7.1.2 *Identification of Type and Range of Degradation Factors*:

7.1.2.1 Identify the type and range of degradation factors to which the component or material will be exposed in service. A list of some degradation factors is presented in Table 1. This list is not exhaustive and other possible important factors should be sought in each specific case. The listed factors include weathering, biological, stress, incompatibility, and use factors.

7.1.2.2 Weathering factors include radiation, temperature (elevated, depressed, and cycles), water (solid, liquid, and vapor), normal air constituents, air contaminants (gases, mists, and particulates), freeze-thaw, and wind. Some quantitative information on weathering factors is available from published weather and climatological data. These data will usually be sufficient to indicate the ranges of intensities to which the component or material will be exposed in service.

7.1.2.3 Biological factors include microorganisms, fungi, and bacteria.

7.1.2.4 Stress factors consist of sustained stress, such as those developed by the weight of a building, and periodic stress, such as wind loads. The intensities of stress factors can be estimated from engineering calculations.

7.1.2.5 Chemical and physical incompatibility between dissimilar materials include corrosion caused by contact between dissimilar metals or stress caused by the different thermal expansion coefficients of rigidly connected dissimilar materials.

7.1.2.6 Use factors include the design of the system, installation and maintenance procedures, normal wear and tear and abuse.

7.1.2.7 It is difficult to quantify the in-service intensity of biological, incompatibility, and use factors, but upper limits within the normal range can usually be established by conservative judgment. Consider each of the degradation factors that may affect the performance of a building system component or material in designing predictive service life tests.

7.1.3 *Identification of Possible Degradation Mechanisms*—The final step of the characterization procedure is to identify all reasonably possible mechanisms by which the identified degradation factors induce changes in the properties of the

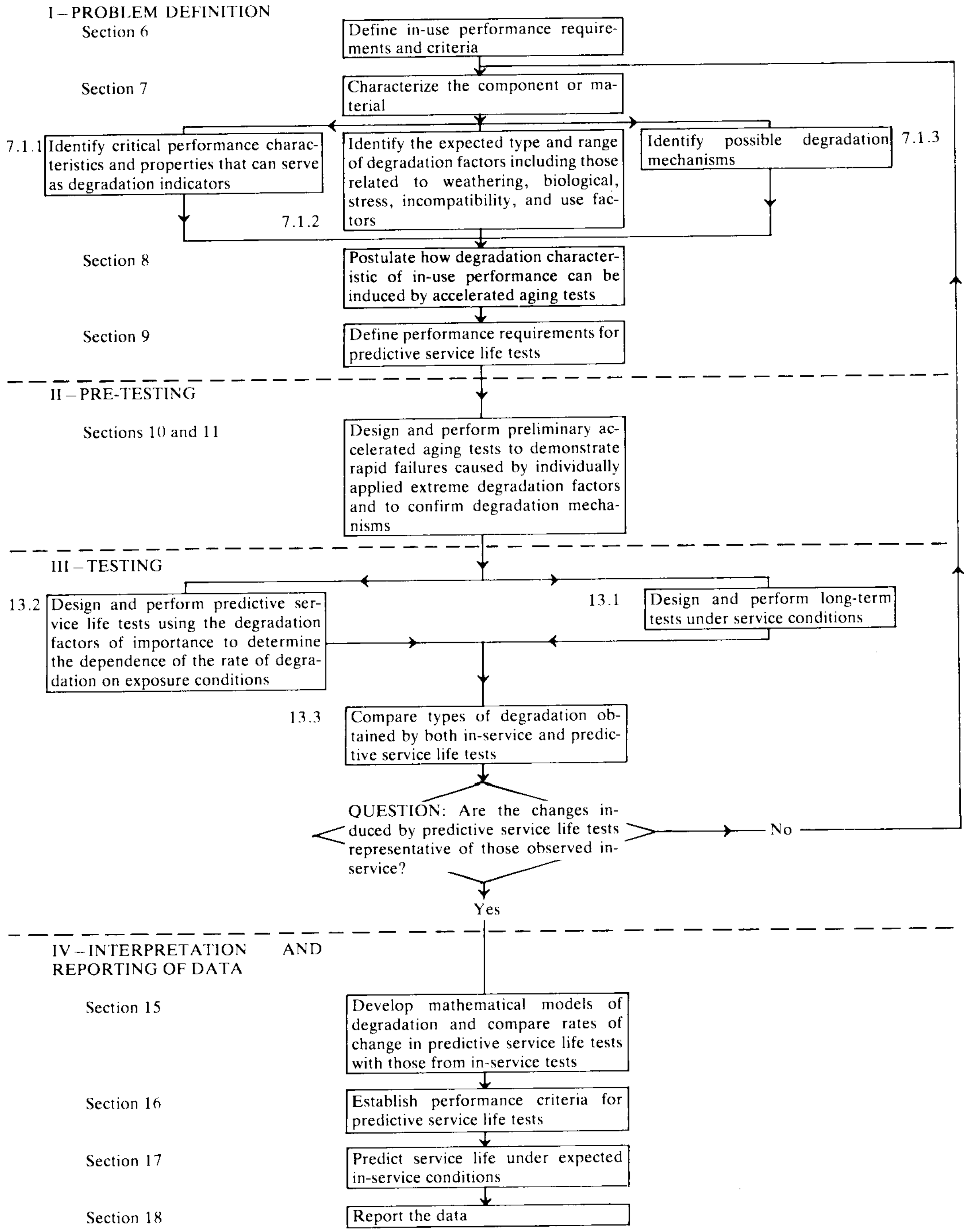

FIG. 1 Recommended Procedures for Developing Predictive Service Life Tests

component or material. The mechanisms can be defined at various levels. If much is known about the chemistry of the material(s), it may be possible to identify mechanisms based upon specific chemical reactions, such as hydrolysis and photo-oxidation. On the other hand, if little is known about the chemical reactions of the material, mechanisms may be defined in more general terms, for example, thermal decomposition, volatilization of constituents, constituent diffusion, corrosion, shrinking/swelling, etc. Limitations on the knowledge available will always exist. However, it is important to identify as many degradation mechanisms as possible. This reduces the possibility for error and improves the basis for establishing that mechanisms induced by the accelerated aging tests are representative of those that occur in service.

8. Postulations Regarding Accelerated Aging Tests

8.1 Once the information from Sections 6 and 7 has been obtained, postulations can be made regarding specific procedures for accelerating the identified mechanisms of degradation using the identified degradation factors. For example, if thermal degradation is identified as a possible degradation mechanism, then it may be postulated that this type of degradation can be accelerated by exposure to temperatures higher than those expected in service. Take care to ensure that extreme

Observable Change	Visual Inspection											Measured Change																												
Building Element	Micro-organisms growth	General appearance	Chalking	Crazing	Cracking	Checking	Flaking	Scaling	Blistering	Efflorescence	Rupture	Color	Gloss	Reflectance	Haze	Texture	Transparency	Abrasion resistance	Hardness	Washability	Surface wettability	Water absorption	Vapor permeance	Dimensions	Thermal properties	Electrical properties	Creep rupture	Creep deformation	Peel strength	Flexural strength	Tear strength	Impact resistance	Fatigue strength	Tensile strength	Compressive strength	Shear strength	Tensile modulus	Compressive modulus	Shear modulus	Adhesion
A																																								
A-B																																								
B																																								
B-C																																								
C																																								
⋮																																								

NOTE 1—Let A represent either the exterior-most or interior-most element; let A-B, B-C, etc., represent interfaces between elements.

FIG. 2 Example of a Matrix for Identifying Observable Changes of Building Components and Materials

TABLE 1 Degradation Factors Affecting the Service Life of Building Components and Materials

- Weathering Factors
  - Radiation
    - Solar
    - Nuclear
    - Thermal
  - Temperature
    - Elevated
    - Depressed
    - Cycles
  - Water
    - Solid (such as, snow, ice)
    - Liquid (such as, rain, condensation, standing water)
    - Vapor (such as, high relative humidity)
  - Normal Air Constituents
    - Oxygen and ozone
    - Carbon dioxide
  - Air Contaminants
    - Gases (such as, oxides of nitrogen and sulfur)
    - Mists (such as, aerosols, salt, acids, and alkalies dissolved in water)
    - Particulates (such as, sand, dust, dirt)
  - Freeze-thaw
  - Wind
- Biological Factors
  - Microorganisms
  - Fungi
  - Bacteria
- Stress Factors
  - Stress, sustained
  - Stress, periodic
    - Physical action of water, as rain, hail, sleet, and snow
    - Physical action of wind
    - Combination of physical action of water and wind
    - Movement due to other factors, such as settlement or vehicles
- Incompatibility Factors
  - Chemical
  - Physical
- Use Factors
  - Design of system
  - Installation and maintenance procedures
  - Normal wear and tear
  - Abuse by the user

levels of degradation factors do not result in degradation mechanisms that would not be experienced in service. The postulates that are made in this step lay the groundwork for designing preliminary accelerated aging tests.

9. Definition of Performance Requirements for Predictive Service Life Tests

9.1 Define performance requirements for the predictive service life tests. The performance statements should be qualitative summaries of the information obtained in Sections 7 and 8 that describe what the test shall do.

II—PRE-TESTING

10. Scope

10.1 The pre-testing demonstrates that rapid changes in the properties of the component or material can, in fact, be induced by exposure to extreme levels of the degradation factors. These changes, if observed, support (or rule out) the previously identified mechanisms by which property changes occur. They may also contribute to a better understanding of the primary degradation factors leading to property changes and indicate properties that are likely to be useful as measures of the extent of degradation. Information obtained from pre-testing includes indications of (*1*) property changes that are likely to be useful as degradation indicators, (*2*) the order of importance of the degradation factors, (*3*) mechanisms by which properties change, and (*4*) the intensities of degradation factors needed to induce rapid property changes.

11. Design of Pre-Tests

11.1 Pre-tests should be based upon the information obtained in Sections 7, 8, and 9. The tests should provide for various properties to be measured before and after accelerated aging to determine which properties can best be used as degradation indicators. Also, evaluate the degradation factors identified in Section 7, to which the component or material will be exposed in service, to determine which factors are the most important.

11.2 The intensity of weathering and stress factors used in pre-tests can be used in the quantitative ranges identified in Section 7. Weather and climatological data for the most extreme climates in which the component or material will be used can form the basis for the intensities of these factors in the pre-tests. Calculations of sustained stress due to the weight of a building and periodic stress due to wind and impact can be used.

11.3 Biological and incompatibility factors may not be important unless combined with extreme values of weathering factors. For example, fungi and bacteria are most active in warm, moist locations; chemical incompatibility may only be important as long as liquid water is present between the joined materials; physical incompatibility may not be important unless there are large temperature changes. The effects of incompatibility factors can, therefore, usually be evaluated along with tests to determine the effect of weathering factors.

11.4 Use factors are not often included in predictive service life tests. Installation and maintenance practices are assumed to be provided as recommended by the manufacturer, and abuse is usually considered to be beyond the scope of test methods. Although use factors are not often included in accelerated aging tests, they can affect the service life of building components and materials and should be evaluated if deemed critical.

III—TESTING

12. Scope

12.1 The purposes of this procedure are to design and perform new or improved predictive service life tests to determine the relationships between the rates of degradation and the exposure conditions; to design and perform tests under in-service conditions to confirm that degradation mechanisms induced by accelerated aging tests are similar to those observed in service; and to measure the rates at which properties change in service.

13. Design of Tests

13.1 *Long-Term In-Service Tests*—Long-term in-service tests shall emphasize the degradation factors of importance for the component or material. These tests may be actual in-service tests of the complete system or exposure of selected materials at outdoor weathering sites. It is essential to design the tests so that all factors of importance are considered. Where possible the tests should permit the most important degradation mechanisms to be identified in a relatively short period of time. However, information obtained during larger exposures is also needed to aid in relating the rates of change in the predictive tests to those in the in-service tests. The intensity or magnitude of the degradation factors should be measured during the tests.

13.2 *Predictive Service Life Tests*:

13.2.1 The goal of predictive service life tests is to provide a relatively rapid means of measuring the rate of property changes typical of those that occur in long-term in-service tests. Predictive tests should normally be designed from information obtained in pre-tests. In general, the intensity of factors in these tests will be less than in the pre-tests to reduce the likelihood of causing degradation by mechanisms that are not important in service. The properties measured before and after aging should be those that have been identified as most useful or most important for indicating degradation. All important degradation factors should be included in the exposure conditions.

13.2.2 The possibility of synergism should always be born in mind in the development of accelerated aging tests. For example, the combined effects of weathering factors, such as solar radiation, temperature cycles, and moisture, may be greater than the sum of the effects of the individual factors. The intensity or magnitude of the degradation factors in the accelerated aging test should be measured to aid in determining the effects of increased intensity and in relating the rates of change in the in-service and predictive tests.

13.3 *Comparison of Types of Degradation*—Compare the types of degradation obtained in the accelerated aging tests and in the in-service tests. If the initial accelerated aging tests do not induce mechanisms representative of in-service degradation, alter the aging tests after reassessing the information obtained in Parts I and II (see loop in Fig. 1).

IV— INTERPRETATION OF DATA AND REPORTING OF CONCLUSIONS

14. Scope

14.1 This procedure covers the purpose of the interpretation and reporting of data so as to assess the data obtained in testing, and either predict the service life of the component or material based upon the results of the predictive service life tests or compare the relative durabilities of components and materials.

15. Development of Mathematical Models for Comparing Rates of Changes

15.1 After establishing that the mechanisms induced by the accelerated aging tests are the same as those observed in service, compare the rates of change of properties in the two tests. For the simplest case, where degradation proceeds at a constant rate, determine the acceleration factor, *K*, as follows:

$$K = \frac{R_{AT}}{R_{LT}} \tag{1}$$

where:

R_{AT} = rate of change obtained from the accelerated aging test, and

R_{LT} = rate of change obtained from the long-term in-service test.

15.1.1 However, the relationship between the results of the two types of tests is seldom so simple. For nonlinear relationships, mathematical modeling of the observed degradation in terms of the known or assumed degradation mechanisms or data analysis using the principles of reliability analysis may be necessary to establish a satisfactory relationship between the rates of change. Such models must be able to process quantitative data about the degradation factors in calculations of the rates of change during the test period.

16. Definition of Performance Criteria for Predictive Service Life Tests

16.1 Establish performance criteria that define quantitative minimum acceptable levels of performance.

17. Prediction of Service Life or Comparison of Relative Durabilities

17.1 The expected service life of the component or material can be predicted based upon the results of the predictive service life tests. Obtain the predicted service life by using the information in Section 15 to compare the rates of change in the predictive service life tests and the in-service tests. An alternative to actually predicting service life is to compare the relative durabilities of a number of components or materials that have been tested in a similar manner. Such comparisons are often made to rank components or materials in terms of expected long-term performance.

18. Report of Data

18.1 A report summarizing the findings of the analysis in Parts I, II, III, and IV should be prepared. The report is particularly important to others who attempt to use the tests or understand the rationale for procedures or assumptions. For this reason, state assumptions made and give reference to works that have directly affected decisions. It is suggested that the report include the elements described in Parts I, II, III, and IV.

19. Precision and Bias

19.1 No quantitative statement can be made on the precision or the bias of this practice because the general guidelines provided herein on the specimens, instrumentation, and procedures are not sufficient to make possible statistical analysis.

19.2 The precision and bias of any service life prediction will depend on many factors including the variability of the specimens, differences between the expected and actual service conditions, the correctness of the assumptions that underlie the predictions, and the precision and bias of the tests used. Because the errors may be very large, the report of the data and the predictions must contain a clear statement about the possible sources of error and an assessment of the precision and bias of the service life predictions.