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Materiel Test Procedure 5-2-599
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

CREEP TEST PROCEDURES

1. OBJECTIVE

The objective of this MTP is to instruct personnel in the techniques for conducting creep tests on ~~various materials~~ and the evaluation of the data from these tests.

2. BACKGROUND

The deterioration of materials may assume many forms that arise from various causes. Thus, the physical properties of materials may change due to changes in structure, such as those caused by overaging. Progressive deformation of materials may occur due to fatigue from the repeated application of cyclic stresses. Further, materials may creep objectionably from exposure to relatively high temperatures when under stress, and they may deteriorate progressively, when under load, due to the propagation of defects that were present originally. Creep is the name given to the phenomenon of slow deformation of solid materials, over an extended period of time, while being subjected to a load.

Data from creep tests is of considerable importance in predicting the strength of materials for resisting loads continuously applied for long periods of time and in predicting dimensional changes which may occur as a result of long continued constant loads, particularly at elevated temperatures.

3. REQUIRED EQUIPMENT

a. Loading device(s), as required
b. Heating device(s), as required
c. Temperature controller(s), as required
d. Thermal instrumentation, as required
e. Extensometer(s), as required
f. Extensometer calibration equipment, as required
g. Timing device(s), as required
h. Recording equipment, as required
i. Humidity controller(s), as required
j. Machine shop facilities, as required

4. REFERENCES

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T. American Society for Testing Materials, Philadelphia, Pa. The following standard or tentative specifications:

1) ASTM D 621-64 Tests for Deformation of Plastics Under Load

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2) ASTM D 638-64T Tests for Tensile Properties of Plastics.
3) ASTM D 648-56 Test for Deflection Temperature of Plastics Under Load
4) ASTM D 674-56 Testing Long Time Creep and Stress Relaxation of Plastics Under Tension or Compression Loads at Various Temperatures
5) ASTM D 695-63T Test for Compressive Properties of Rigid Plastics
6) ASTM D 759-48 Tests for Tensile and Compressive Properties of Plastics at Subnormal and Supernormal Temperatures.
7) ASTM D 1042-51 Measuring Change in Linear Dimensions of Plastics
8) ASTM E 21-66T Short-Time Elevated Temperature Tests of Materials
9) ASTM E 83-64T Verification and Classification of Extensometers
10) ASTM E 139-66T Conducting Creep and Time-for-Rupture Tension Tests of Materials
11) ASTM E 150-64 Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times
12) ASTM E 151-64 Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates
13) ASTM E 209-65 Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates

U. Federal Test Method Standard No. 406 Plastics: Methods of Testing, October 5, 1961: The Following Test Methods.

1) Method 1011 Tensile Properties of Plastics
2) Method 1021 Compressive Properties of Rigid Plastics
3) Method 1063 Tensile Time Fracture and Creep
4) Method 2011 Deflection Temperature Under Load

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5. SCOPE

5.1 SUMMARY

This MTP outlines the various tests which can be performed to determine creep data for metallic and plastic materials. A general discussion of the creep behavior of materials is given in Appendix A while the criteria for selecting a test method are outlined in Appendix B. The test procedures for evaluating the creep behavior of materials are included in the two main test categories. Additional information concerning creep tests for metals and plastics is given in Appendix C and Appendix D, respectively.

A brief review of testing equipment and test parameters for metal and plastic material is included as Appendix E.

The list of references is the key to the sources of specific information concerning the various test procedures.

5.2 LIMITATIONS

None

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Select the method of testing using the criteria described in Appendix B.

b. Perform the following as required for the individual test to be run.

1) Prepare the test specimens
2) Prepare the testing, control and monitoring equipment
3) Instrument the test specimens
4) Calibrate the control and measurement instrumentation

6.2 TEST CONDUCT

6.2.1 Tests for Metals and Metallic Alloys

6.2.1.1 Tension Creep Tests

Conduct tension creep tests as required by the applicable sections of ASTM E 21-66T and/or ASTM E 151-64.

6.2.1.2 Creep and Time-for-Rupture Tension Tests

Conduct creep and time-for-rupture tension tests as required by the applicable sections of ASTM E 139-66T and/or ASTM E 150-64.

6.2.1.3 Stress Relaxation Tests

Conduct the stress relaxation tests as required by the Bar-Bardgett Tests described in reference 4V.

6.2.1.4 Compression Creep Tests

Conduct the compression creep tests as required by the applicable sections of ASTM E 209-65.

6.2.1.5 Short-Time Tension Creep Tests

Conduct short-time tension creep tests as required by one of the following:

a. Hadfield Time vs Yield Test

b. DVM (German Standard) Test
c. British Standard 1271
d. Rohn Test

NOTE: The testing methods and creep specifications are listed in Appendix C.

6.2.2 Test for Plastic Materials

6.2.2.1 Tension, Time-Fracture and Creep Tests

Conduct tension, time-fracture and creep tests as required by the applicable sections of ASTM D 674-56 and Federal Standard Method No. 1063.

6.2.2.2 Deformation Under Load Tests

Conduct deformation under load tests as required by the applicable section of ASTM D 621-64, Method A and Federal Standard Method No. 1101.

6.2.2.3 Compression Tests

Conduct compression tests as required by the applicable sections of ASTM D 695-63T and Federal Standard Method No. 1021.

6.2.2.4 Deflection Temperature Under Load Tests

Conduct deflection temperature under load tests as required by the applicable sections of ASTM D 648-56 and Federal Standard Method No. 2011.

6.2.2.5 Long-Time Creep and Stress Relaxation Tests

Conduct long-time creep and stress relaxation tests as required by the applicable sections of ASTM D 674-56.

6.3 TEST DATA

6.3.1 Tests for Metals and Metallic Alloys

6.3.1.1 Tension Creep Tests

Record data as collected under the applicable sections of ASTM E 21-66T and/or ASTM E 151-64.

6.3.1.2 Creep and Time-for-Rupture Tension Tests

Record data as collected under the applicable sections of ASTM E 139-66T and/or ASTM E 150-64.

6.3.1.3 Stress Relaxation Tests

Record data as collected in the conduct of the Bar-Bardgett Tests.

6.3.1.4 Compression Creep Tests

Record data as collected under the applicable sections of ASTM E 209-65.

6.3.1.5 Short-Time Tension Creep Tests

Record data as collected under the following, as applicable:

a. Hadfield Time vs Yield Test
b. DVM (German Standard) Test
c. British Standard 1271
d. Rohn Test

6.3.2 Tests for Plastic Materials

6.3.2.1 Tension, Time-Fracture and Creep Tests

Record data as collected under the applicable sections of ASTM D 674-56 and Federal Standard Method No. 1063.

6.3.2.2 Deformation Under Load Tests

Record data as collected under the applicable sections of ASTM D 621-64 Method A and Federal Standard Method No. 1101.

6.3.2.3 Compression Tests

Record data as collected under the applicable sections of ASTM D 695-63T and Federal Standard Method No. 1021.

6.3.2.4 Deflection Temperature Under Load Tests

Record data as collected under the applicable sections of ASTM D 648-56 and Federal Standard Method No. 2011.

6.3.2.5 Long-time Creek and Stress Relaxation Tests

Record data as collected under the applicable sections of ASTM D 674-56.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 General

Creep test data shall be presented as plots of strain vs times or stress vs time-to-rupture. Because of the length of time required to conduct these tests, few creep tests are rerun and often the tests are not conducted over long enough periods of time. These two situations often give rise to the need for extrapolating which may not be valid if the data being extrapolated have been obtained from a test of too short duration or if the data are from the secondary stage of a creep curve that may be approaching the inflection point prior to entering third stage creep.

The methods of data presentation for creep tests of plastics are the same as those for metals. The times to rupture for plastics, however, are much shorter than those for metals and complete creep histories for plastics are easier to achieve. Because of this, extrapolation of creep test data for plastics is seldom necessary.

In past years, work has been carried on to derive formulae to fit creep data curves and aid in extrapolating data. It should be realized that these formulae, at best, are empirical methods and are to be used prudently. A brief discussion of these formulae for various creep data extrapolation is being presented in paragraphs 6.4.2 and 6.4.3. Extrapolation of creep data is discussed in greater detail in the various references listed in this MTP. Individual tests also specify the data presentation.

6.4.2 Constant Stress Data

The following equation may be used to extrapolate creep for times greater than those shown by a creep data curve, if the following conditions exist:

a. The values of V_o must be reliable.

b. The time interval for E (strain) must be less than that which would induce third stage creep.

c. The material must show idealized creep, as displayed in Figure A-1. The equation:

$$E = E_o \quad V_o t$$

Where:

E = required strain

E_o = initial creep (Refer to Figure A-1)

V_o = slope of strain versus time curve during secondary stage

t = time

Another expression which may be used to extrapolate creep data where steady state creep constitutes most of the strain and elastic strains are neglected is:

$$E = B\sigma^n$$

Where:

E = the strain rate

B and n = constants obtained from creep test data

σ = the stress applied

This equation is presently the most commonly used in literature for the calculation of creep.

6.4.3 Stress vs Rupture Data

The most straightforward method for extrapolating stress vs rupture is to compile data for as long a time period as possible then boldly extrapolate. Since this is difficult due to unpredictable changes which the curves could have shown had longer time periods been used, an attempt has been made to correlate the effects of temperature (T) and time-to-rupture (tr). Various parameters involving T and tr have been formulated and extrapolated and are based upon a plot of the (T, tr) parameter as a function of stress. The more useful of these parameters is the Larson-Miller parameter, that is:

$$T(C - \log E_c)$$

Where:

T = temperature in degrees Rankine
E_c = creep rate
C = a constant obtained by plotting $\frac{1}{T}$ vs tr at constant stress where tr is expressed in hours

APPENDIX A

CREEP BEHAVIOR OF MATERIALS

The creep behavior of materials has been studied for many years from both the theoretical and applied viewpoints. In general, these studies have been directed toward understanding the effects of material variables, such as composition, grain size, fabrication, and the effects of service variables (such as stress and temperature). The theory of creep is incomplete. Creep is the changing of shape of materials (plastic flow) while a continuously applied force is acting on the material. At low temperatures creep rate is usually low and strain is often found to vary as the logarithm of time. The effect of creep increases rather rapidly with an increase in temperature.

The physical process is comparatively slow, but continuously increasing strain may cause failure in structures due to the breaking of a member or due to structural distortions which exceed design tolerances. Although creep in metals is generally associated with high temperatures, large structures or those structures having close tolerances may be seriously distorted at room temperature by even small nonelastic strains. The nature of creep is a complex phenomenon which, in metals, generally advances in three stages as shown in Figure A-1. If a rod-shaped specimen is placed under a dead load in tension at room temperature at a stress lower than the proportional limit, the strain OA will occur and will remain constant as designated by OAB. If, however, the same stress is applied at an elevated temperature, the strain OC occurs. This strain may be elastic or plastic depending upon the material of the specimen, the temperature, and the stress, but is greater than OA due partly to a lower modulus of elasticity at the higher temperature. The strain continues to increase nonlinearly with time through the primary stage (from C to D) until the second stage is reached. The second stage (from D to E) is characterized by an almost constant increase in strain with time. This is caused by changes in grain structure due to strain hardening. The third stage (from E to F) is characterized by an abrupt change of slope for the strain versus time curve, and strain increases rapidly to the failure of the specimen. During the test, if the stress is removed from the specimen, some of the strain recovers as indicated by the dotted line EH.

The majority of creep tests are conducted with stress and temperature limits selected so that creep does not progress into the third stage. The failure of metals at low temperatures is characterized by fracture through the crystal boundaries. The temperature at which transition from intracrystalline to intercrystalline fracture occurs is referred to as the equicohesive temperature. This temperature varies with each metal and metallic alloy, but as a general rule, the use of a metal or an alloy is limited to a temperature of approximately one-half of its melting point. At temperatures below the equicohesive temperature, strain in metals occurs more as a quasiviscous intercrystalline movement. At or below the equicohesive temperature, strain hardening will occur and creep will not continue unless the applied stress is of such magnitude to overcome strain hardening resistance. At temperatures above the equicohesive temperature, yielding will exceed strain hardening and creep will progress under even low applied stresses.

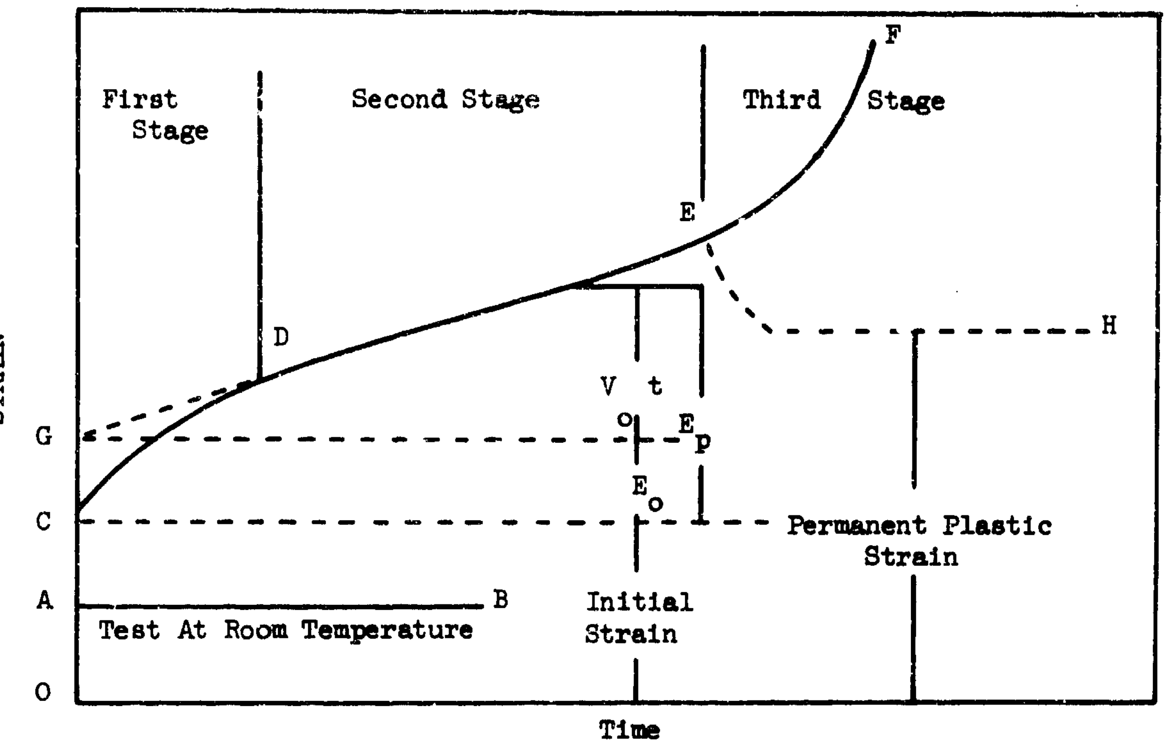

Figure A-1 Strain Vs Time

Where:

V_o = creep rate during second stage
t^o = total time to second stage
E_o = elementary creep by extending ED to G
P_p = E + V t = total creep

APPENDIX B

CRITERIA FOR TEST METHOD SELECTION

The selection of the method for measuring creep in materials is, generally, not a difficult one. The desired results usually are set forth in a test directive and determines to a large extent which method of testing shall be used. However some choice exists, especially where more than one test method can be utilized to generate the necessary data.

Factors which affect the choice of the method are:

a. Test Material

The type of material to be tested can be:

1) Ferrous metal
2) Ferrous alloy
3) Non-ferrous metal
4) Non-ferrous alloy
5) Plastic

Immediately, the test material can be assigned to one of the two major categories of testing outlined in this MTP.

b. Material Properties

The mechanical properties of a material must be considered in order to determine the test parameters. Sources of information on material properties include:

1) Experimental data
2) Theoretical studies
3) Manufacturer technical literature
4) In-service measurements

c. Operational Environments

The expected operational environments determine the selection of material as well as the test parameters. The magnitude of operating temperatures and, therefore, the magnitude of stresses to which the material will be subjected can be predicted and thus the choice of test methods narrowed considerably.

d. Time Requirements

Since creep tests are classed as both short-time and long-time tests the time requirement becomes important. Generally, short-time tests, if reliably carried out, are less costly and provide data for differentiating between materials. Long-term testing is considered as a source of more reliable data, but if time is a factor, then predications from short-time tests must be utilized.

e. Required Data

Finally the nature of the required data will often determine the ultimate test method. For example, if time-to-fracture must be found for a material, then the choice of tests is further narrowed and combined with other considerations allowing the decision on the test method to be made.

APPENDIX C

CREEP TESTING FOR METALS AND METALLIC ALLOYS

1. INTRODUCTION

Satisfactory tests to determine the metal properties at high temperatures are creep tests at those temperatures to which the metals are expected to be subjected. Creep testing is not a definitive process and there is much to be learned. There are, however, sufficient data available to provide several criteria applicable to creep testing. Creep tests of metals are lengthy tests, but generally are much shorter in duration than the service life of the actual structures on which the test is being conducted. Therefore, judicious extrapolation of creep test data is required by the test engineer. For example, if data are extrapolated from creep tests which have not been carried beyond the first stage, there will be excessively high values of predicted creep. Extrapolation of data from tests carried well into the second stage cannot guarantee that the metal will not enter third-stage creep under service conditions. The length of creep test time depends upon a reasonable expectation of the service life of the material being investigated.

2. TYPES OF TESTS

2.1 TENSION CREEP TESTS

These tests provide procedures for the determination of the amount of deformation of a test specimen as a function of time. During tension tests the test specimens are subjected to a constant tension loading at a constant temperature and the creep strain is recorded with respect to time.

The procedures and test requirements for tension creep tests are given in the following tentative practices recommended by the American Society for Testing Materials:

a. ASTM E 21-66T Short Time Elevated - Temperature Tension Tests of Materials.
b. ASTM E 151-64 Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates.

The essential equipment requirements and the test conditions are set forth by these procedures. It is noted that the ASTM E 21-66T tests are applicable to metals which are highly resistant to creep and which are to be used at moderately high temperatures but which are lower than the equicohesive temperatures for those metals and, yet, where strength characteristics as well as creep characteristics, are important.

2.2 CREEP AND TIME-FOR-RUPTURE TENSION TESTS

These are tension tests wherein a specimen is loaded and its time-to-rupture is recorded. Many specimens are tested at varying stresses and a plot of stress versus time to rupture is made. The tests have proven to be useful because it is possible to correlate the time-for-rupture of metals with minimum creep rate data. They are simpler to perform than regular tension creep tests due to the elimination of the task of measuring strain.

Rupture tests, properly interpreted provide a measure of the ultimate loading ability of a material as a function of time. Creep tests measure the load-carrying ability for limited deformations. Hence,the two tests supplement each other.

Pending the availability of creep data from prolonged tests, the rupture tests provide useful information regarding the validity of the usual extrapolation of creep data from tests of 1000 to 2000 hours duration for prolonged service with limited permissible deformation.

Procedures for conducting creep and time-for-rupture tension tests are outlined in ASTM E 139-66T and ASTM E 150-64 with provision for testing at various temperatures and durations.

2.3 STRESS RELAXATION TESTS

In the relaxation tests, the decrease of stress with time is measured while the total strain (elastic + plastic) is maintained constant. These tests have direct application to the loosening of turbine bolts and to similar problems, however, they do not provide insight into factors influencing fracture.

The Bar-Bardgett test is a relaxation test wherein the stress after 48 hours following the release of the load is measured on many specimens which were loaded at different initial stresses. Stress is applied to the specimens by means of a screw and is measured by the elastic extension of a calibrated weigh bar.

If the stress applied to the specimen is sufficiently high creep will occur. This results in a decrease in the stress in the weigh bar and in the specimens. Creep will occur at a progressively decreasing rate until the stress in the coupled test specimens and the weigh bar is such that no further significant amount of creep occurs within the duration of the test. Further information concerning this test can be found in reference 4V.

2.4 COMPRESSION CREEP TESTS

During these tests, the specimens are loaded in compression instead of tension. The problems in aligning the load to ensure uniaxial loading and to prevent buckling during the test make this type of test extremely difficult to conduct. Presently, there is little agreement on specific procedures for conducting this type of test and the wide divergence in available data leaves this test in an unsettled state. This same lack of available data and accepted test procedure is also true for torsion, bending, and pressure creep tests.

Procedures, equipment and test specimens are described by ASTM E 209-65

Compression Tests of Metallic Materials at Elevated Temperatures with Conventional or Rapid Heating Rates and Strain Rates.

2.5 SHORT TIME TENSION CREEP TESTS

These tests have been used to obtain rapid evaluation of different materials, but are not considered the best methods for obtaining reliable data for making material selections. Four of the more common short time tension creep tests are:

a. Hadfield Time vs. Yield Test - This test is used to determine the stress which will produce an average creep rate of 10^{-6} per hour between the 24th to 72nd hour of a creep test. The total extension should not exceed 0.5 percent. Two thirds of this stress is taken as the safe working stress.

b. DVM (German Standard) Test - This test defines the creep limit as the stress which will produce an average creep rate of 10^{-5} per hour between the 25th and 35th hour of the test. When a material is subjected to the test as an acceptance test, the permanent deformation after 45 hours is limited to 0.2 percent.

c. British Standard 1271 - This test, adopted in 1945, is an acceptance test for boiler plate normalized from 875 to 925°C. In a test at 450°C, 843°F, and eight tons per square inch the average creep rate between the 24th and 48th hour must not exceed 5×10^{-5} per hour.

d. Rohn Test - This test is somewhat reversed from normal creep tests in that a constant stress is applied and the temperature is decreased until the creep rate vanishes. This is really more of a test to determine a limiting temperature than it is to determine the creep.

NOTE: None of the short time creep tests discussed in this paragraph are considered adequate for the prediction of long time strength in metals.

APPENDIX D

CREEP TESTING FOR PLASTICS

1. GENERAL

The term plastics as used in this MTP refers to those materials which are generally organic compounds, which display noncrystalline structures, and which derive their mechanical properties from bonding forces and/or network entanglements between molecules rather than inter-intracrystalline bonding as in metals.

Because these materials are noncrystalline, they are more nearly isotropic, though heterogeneous, structures than metals provided they are not fiber impregnated. The flow mechanism in these compounds, which is molecular in nature, depends on the bonding forces and network entanglements. In some ways, these conditions make the mechanical behavior of these materials simpler than the mechanical behavior of crystalline materials. This means that relatively large strains are required to cause anisole response.

There are certain physical property measurements associated with creep tests of plastics which are the same as those associated with creep tests of metals. These are creep, creep rate, recover, and time-to-rupture Measurements pertinent to creep tests of plastics, but not necessarily pertinent to creep tests of metals are instantaneous creep and instantaneous recovery. Instantaneous creep is the creep measured as close to the time of load application as possible. Instantaneous recovery is the recovery measured as close to the time of load release as possible.

The tests discussed in paragraphs 2.1 through 2.4 are adapted from Federal Test Method Standard No. 406, "Plastics: Methods of Testing", and ASTM Standards. The test discussed in paragraph 2.5 is adapted from ASTM Standards. All dimension measurements shall follow the criteria of ASTM D-1042-51 (1961).

2. TYPES OF TESTS

2.1 TENSION, TIME-FRACTURE AND CREEP TESTS

These tests are conducted to determine the ability of rigid plastics to withstand creep and fracture as a result of sustained loads. The tests shall be carried to 1000 hours duration using test specimens as prescribed in the Federal Test Method Standard No. 406, Plastics: Method of Testing, Method 1011, paragraph 2. Elevated temperatures are not a test requirement but the test temperature shall be 73.5 ± 2°F at a relative humidity of 50 ± 2 percent.

The test requirements are outlined in Federal Standard Method No. 1063 and the applicable sections of ASTM D 694-56 (1961).

2.2 DEFORMATION UNDER LOAD TESTS

These tests are conducted to determine the deformation under compression of rigid molded plastic materials. The data obtained by these tests indicate the ability of rigid plastics in assemblies of conductors, insulators etc., that are held together by bolts or other fastening devices, to withstand compression without yielding and loosening the assembly with time.

Temperature requirements for this test shall be as follows:

a. Preconditioning of the test specimens at 150 ± 5°F for 4 hours
b. Conditioning of the test specimens at 95 ± 2°F for 68 hours at a relative humidity of 90 ± 2 percent
c. Maintenance of the test chamber temperature (during test) at 90 ± 0.9°F

The applied constant load shall be 1000 ± 10 pounds for 24 hours. The method of testing shall comply with the procedures outlined in Federal Standard Method No. 1101 and in ASTM D621-64 Method A.

2.3 COMPRESSION TESTS

These tests are designed to determine the mechanical properties of rigid organic plastics when loaded in compression at relatively low uniform rates of straining or loading. Test specimens of standard shape are employed. The rate of head travel shall be 0.05 inch per minute, in the loading machine with the test temperature maintained at 73.5 ± 2°F at a relative humidity of 50 ± 2 percent.

The test methods are outlined in Federal Standard Method No. 1021 and in ASTM D695-63T.

2.4 DEFLECTION TEMPERATURE UNDER LOAD TESTS

This test is designed to determine the temperature at which an arbitrary deformation occurs when the specimen is subjected to arbitrarily predetermined test conditions. The data resulting from this test may be used to predict the behavior of plastics at elevated temperatures when time, temperature, loading methods, and stress of the plastic parts in question are similar to those specified in the test. The test specimen is immersed in a liquid heat transfer medium and supported as a simply supported beam with a load applied at midspan. The liquid heat transfer medium must not affect the chemical properties of the specimen in any manner. The temperature increase rate is 3.6 ± 0.36°F per minute until the desired temperature is obtained. The special loading device and heat transfer tank used for this test are fully described along with the test procedures in Federal Standard Method No. 2011, and in ASTM D648-56 (1961).

2.5 LONG-TIME CREEP AND STRESS RELAXATION TESTS

These tests utilize procedures for the determination of the time dependence of the deformation and strength of plastic specimens resisting long-duration constant tension or compression loads, under conditions of constant temperature and humidity, and with negligible vibration. Also determined are the time-dependence of stress (stress-relaxation) of plastics resisting long-duration constant tension or compression strains at conditions of constant temperature and relative humidity and negligible vibration. The extremely time-consuming nature of these procedures make them generally unsuitable for routine testing.

Temperature shall be controlled throughout the test period as follows:

a. ± 1°F for temperatures of -50 to 300°F
b. ± 2°F for temperatures of 300 to 800°F
c. ± 3°F for temperatures of 800 to 1200°F

Relative humidity shall be regulated to ± 1 percent of the specified humidity.

Test procedure details are outlined in ASTM D674-56 (1961).

APPENDIX E

CREEP TEST EQUIPMENT AND PARAMETERS

1. TESTS OF METALLIC MATERIALS

The equipment required for conducting creep tests on metal and metallic alloys consists primarily of:

a. A loading device
b. An electric furnace equipped with a sensitive temperature regulating mechanism
c. An accurate extensometer
d. A time measuring device

Most of the loading devices in use today are those which apply a dead load to the specimen through a series of levers. Although this type of loading device does not have the capacity for compensating the load for changes in cross sectional area of the specimen, it is satisfactory for long time creep testing and for creep testing where total deformation prior to rupture is small. For short time creep tests or for constant stress creep tests, a loading machine with a variable load capacity is required. The applied load should be measured to an accuracy of one percent. The most stringent requirement in loading is that the load on the specimen should be as nearly uniaxial as possible to prevent torsion or bending stresses. Some eccentricity can be avoided by using rods or wire cables of greatest possible length to attach the specimen gripping shackles to the heads of the loading machine.

Perhaps the most important item of equipment used in creep testing is the electric furnace and its temperature regulating device. The furnace generally consists of nickel chromium wire wound around a fused silica or alundum tube and cemented into place. The windings are spaced closer together at the ends of the furnace to supply enough heat to the pull-rod ends so that temperature gradients along the specimen can be reduced. An insulating cover is placed around the furnace to conserve energy and prevent temperature fluctuations. Temperature is regulated by thermocouples which control the power input to the furnace. The power supply voltage to the heater should be controlled to less than one percent variation. The necessity for accurate temperature control cannot be over emphasized.

The specifications for temperature control are given in the applicable ASTM's.

For temperature control on creep tests where creep rates of less than 10^{-6} per hour are being measured, it is necessary to employ a thermostat within a thermostat. The outer thermostat should control temperature from 0.45 to 0.95°F.

The ends of a furnace should be closed to prevent undesirable temperature fluctuation. It is further necessary that the furnace ends be closed to prevent the escape of an inert gas, when such a gas in introduced into the furnace to preclude oxidation of the test specimen surface.

Precise strain measurements are not as difficult to obtain as is proper temperature control, although for high quality work, measurements of 10^{-5} or 10^{-6} inches are usually mandatory. More precise work may require even closer measurements.

Three types of extensometers for creep tests are: mechanical, optical, and electrical. Mechanical extensometers consist of two chrome and nickel alloy rods. One end of each rod, at the gauge length extremities, is clamped to the test specimen and the other end of each rod is attached to a dial indicator. To ensure accuracy and aid in the detection of proper specimen alignment, an extensometer should be used on opposite sides of the specimen. The ease and rapidity with which readings may be taken permit quick determination of initial elastic strain without the introduction of errors caused by early plastic strains. This type of extensometer permits the determination of clearly defined plastic and elastic strains.

Optical extensometers consist of two telescopes which are sighted through windows in the side of the furnace and aligned with the gauge marks on the specimen. The extension of the specimen is measured by a filar micrometer attached to one of the telescopes. This type of extensometer requires considerable time for setting and reading the micrometer and thus prevents rapid determination of elastic strains or first stage creep strains. This deficiency may lead to giving a high value of initial strain and a low creep value which will compromise the creep test data. However, the primary advantage of the optical extensometer is that extremely small strains may be detected.

Electrical extensometers consist of electrical resistance strain gauges attached to the specimen and connected to a recording device which can produce a continuous record of the strain. This type of extensometer is elaborate and accurate, but is limited to use in temperatures below 900°F.

Procedures for the verification and classification of extensometers are described in ASTM E-83-64T.

2. <u>TESTS OF PLASTIC MATERIALS</u>

The equipment used for creep testing plastics is generally the same as that used for creep testing metals and metallic alloys as discussed in paragraph 1, except for the equipment used in the deflection temperature under load test. The apparatus used in the deflection temperature under load test is discussed in Federal Test Method Standard 406. The extensometers used for creep tests of plastics are similar to those used in creep tests of metal; however, some minor modifications may be required to account for the greater degree of creep in plastics.

There are, however, several important criteria which are of greater concern in creep testing plastics than in creep tests of metals and metallic alloys. These are humidity control, chemical environmental control, and isolation of the test specimen from vibration during testing. Slight changes in humidity or the chemical environment may drastically change the physical properties of a plastic. Vibrations may cause severe changes in applied stresses and, thus, compromise the creep test results.