Designation: B76 – 90 (Reapproved 2013)

Standard Test Method for Accelerated Life of Nickel-Chromium and Nickel-Chromium-Iron Alloys for Electrical Heating[1]

This standard is issued under the fixed designation B76; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method[2] covers the determination of the resistance to oxidation of nickel-chromium and nickel-chromium-iron electrical heating alloys at elevated temperatures under intermittent heating. Procedures for a constant-temperature cycle are provided. This test method is used for internal comparative purposes only.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 This test method is used by producers of electrical heating alloys to measure the cyclic oxidation resistance of these alloys.

2.2 Because of the effect of the environment, design, and use, the life values obtained from this test method may not correlate with that of an appliance or industrial heating unit.

3. Test Panel

3.1 *Size and Location*—The dimensions of the test panel shall be similar to those shown in Fig. 1. The test panel shall be located in a position free from drafts of air.

NOTE 1—The enclosure shall fit tightly on the panel and the glass slide shall fit snugly to prevent leakage of air at this point during the operation of the test, as even a slight draft of air in contact with the specimen will cause excessive variation in length of life. A screen of 40 wire mesh, 0.010-in. (0.025-mm) wire diameter, market grade, may be used as a cover over the individual stations.

3.2 *Upper Terminal*—The upper terminal shall consist of a binding post attached to a rod passing through another binding post or through the upper bus bar. This provides for adjustment laterally and vertically, as shown in Fig. 1.

3.3 *Lower Terminal*—A 10-g weight shall be attached to the lower end of the specimen. A flexible silver foil (approximately 0.375 in. (9.52 mm) wide and 0.0015 in. (0.038 mm) thick) connected to the 10-g weight shall constitute the lower terminal.

NOTE 2—Experiments have shown that with high temperatures alloys of nickel-chromium and nickel-chromium-iron are subject to plastic flow when under relatively light load. The weight specified in 3.3 does not cause appreciable increase in length during the test.

4. Apparatus

4.1 The test apparatus shall be similar to the requirements specified in 4.2 to 4.8, inclusive, and shall be connected as shown in Fig. 2.

4.2 *Power Supply*—The transformer or motor generator set shall be capable of delivering a controlled voltage of from 10 to 20 V to the circuit. It shall have a continuous current capacity of at least 20 A/specimen.

4.3 *Voltage Control*—The automatic voltage control shall be capable of maintaining across the bus bars a constant voltage within ±0.5 %.

NOTE 3—It has been found impossible to make accurate tests without voltage control, as changes in line voltage were sufficient to cause considerable variation in the results obtained (see Annex A1).

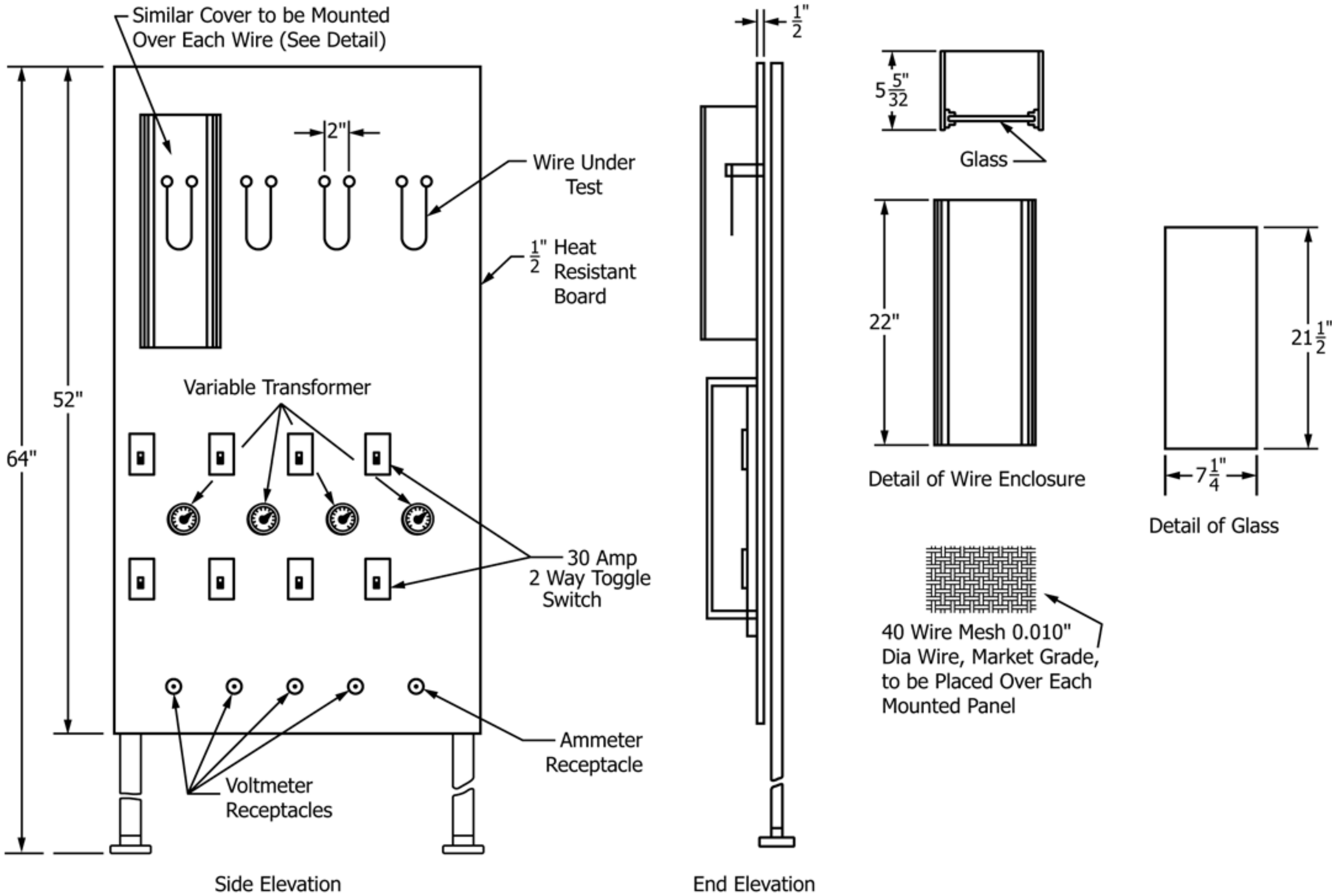
4.4 *Variable Transformer*—The transformer shall be capable of adjusting the voltage across the specimen so that current is controlled to approximately 0.25 % of desired value, and shall have a continuous current rating of approximately 25 A.

4.5 *Ammeter and Voltmeter*—The ammeter and voltmeter shall have an accuracy of 1 % of normal test deflection (approximately 15 A and 15 V, respectively). For alternating current the range used shall be such as to give a reading above

[1] This test method is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.10 on Thermostat Metals and Electrical Resistance Heating Materials.

Current edition approved May 1, 2013. Published May 2013. Originally approved in 1929. Last previous edition approved in 2007 as B76 – 90 (2007). DOI: 10.1520/B0076-90R13.

[2] Further information on this test method is given in a paper by F. E. Bash and J. W. Harsch, "Life Tests on Metallic Resistor Materials for Electrical Heating," *Proceedings*, ASTEA, American Society for Testing and Materials. Vol 29, Part II, 1929, p. 506.



Metric Equivalents

in.	½	5⁵⁄₃₂	7¼	21½	52	64
mm	12.7	131.0	184.2	546.1	1321	1626

FIG. 1 Test Panel for Accelerated Life Test

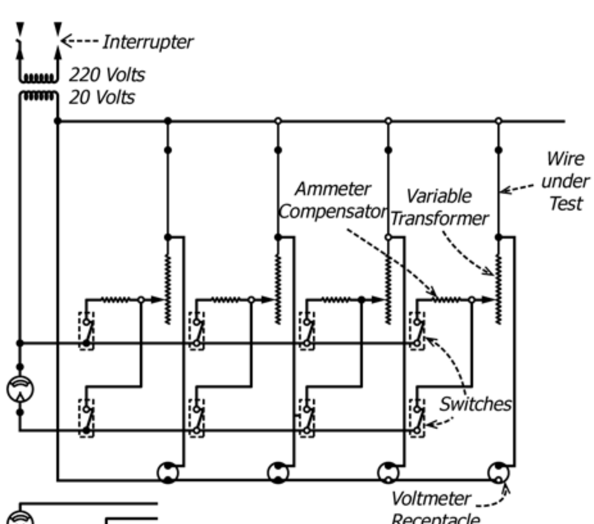


FIG. 2 Electrical Circuit Diagram for Accelerated Life Test

the lower fifth of the scale range. The ammeter has appreciable resistance. A compensating resistance shall be cut into the circuit to replace the resistance of the ammeter so that the overall resistance of the circuit is not changed. This resistance shall be inserted in series with the blade of the upper switch shown in Fig. 2.

4.6 *Optical Pyrometer or Infrared Thermometer*—The optical system shall be such as to provide a magnification of at least four diameters. This may be accomplished by the use of a special lens or combination of two standard lenses in the objective to provide a short focal length and the desired magnification. (See Annex A1.) These instruments must have an accuracy of ±10°F and NIST traceability.

NOTE 4—It is highly important that the temperature of the test specimen be adjusted as accurately as possible, as small variations in temperature result in considerable variation in length of life. An optical pyrometer or infrared thermometer makes it possible to determine the temperature at any particular point on the wire and with the arrangement described the temperature of a comparatively small wire may be taken quite readily.

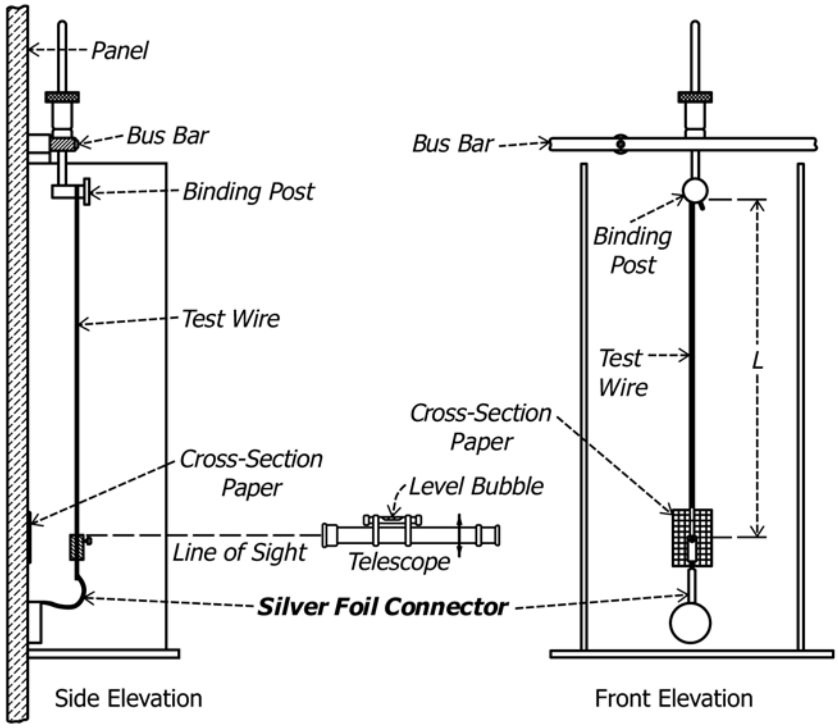


FIG. 3 Apparatus for Measuring Length Changes During Life Test

4.7 *Interrupter*—Some form of apparatus shall be used as an interrupter to open and close the circuit.

4.8 *Apparatus for Recording Time of Burnout*—If no apparatus is available for recording the time of burnout, arrangements shall be made for hourly observations for burnouts. Some form of electric-clock mechanism which can be connected into the circuit may be used.

4.9 *Apparatus for Measuring Length Changes*—Any form of optical apparatus such as a traveling microscope, an optical projection system, a projection microscope, or a contact microscope may be used for determining changes in length of the test specimen. A type of apparatus that has been found satisfactory consists of a telescope with a horizontal cross hair and leveling bubble. The apparatus may be mounted on a frame so that it can be readily moved from one position to another for examining specimens in the life test. The telescope mount should be adjustable in the vertical plane on guides by means of a threaded member. A movement of 2.5 in. (64 mm) is desirable. A piece of cross-section paper, 4 in. (102 mm) in length by 3 in. (76 mm) in width, calibrated 20 lines to 1 in. (25.4 mm) should be mounted on the test panel so that the lower edge is below a horizontal line drawn across the top of the lowest possible position of the weight attached to the lower end of the wire under test. A satisfactory arrangement is shown in Fig. 3. A steel scale 18 in. (457 mm) in length, calibrated to 0.01 in. (0.25 mm), may be used for length measurements.

5. Test Specimen

5.1 The test specimen shall be No. 22 Awg, 0.0253 in. (0.64 mm). The length of wire selected for test shall be such as to permit the use of a 12-in. (305-mm) test length between the two terminals.

5.2 The test specimen shall be representative, as regards surface, of the average of the coil or spool of wire which has been selected for test. Particular care shall be taken to see that the specimen selected is free from kinks. This is necessary, as a kink, even though later removed, may cause burnout at that point.

NOTE 5—It is also very desirable to select and keep as a reference standard for comparison a spool or coil of wire which is uniform in cross section from one end to the other. Tests may then be made at any time on the reference standard, and if conditions have changed they will be noted by the length of life on the standard. Comparisons between tests made at different times between the standards and other wires may be correlated in this manner (see Annex A1).

6. Mounting of Specimens

6.1 The test specimens shall be mounted on the test panel in a vertical position, as shown in Fig. 1, and shall have the following typical spacing:

Distance between test panel and specimens	2 in. (50.8 mm)
Distance between specimens	6 in. (152.4 mm)
Distance between specimen and shield	2 in. (50.8 mm)
Distance between upper bus bar and silver foil contact ... approximately	20 in. (508 mm)

NOTE 6—This recommendation is based on a series of tests run in four laboratories to determine the best position for the specimen in which horizontal mounting, catenary mounting, and vertical mounting were compared. The results of the tests indicated that the vertical mounting gave the best results and was most convenient. It might be expected that the vertical wire would be a great deal hotter near the top than near the bottom. This does not appear to be the case due to the fact that convection currents are greater near the top, and therefore largely compensate for variations that otherwise would occur.

6.2 In mounting a test specimen, one end of the specimen shall be inserted in the upper terminal and the weight attached to the other end. The upper terminal shall then be adjusted to give a test length of the wire of approximately 12 in. (305 mm) between the two terminals. Care shall be taken to see that the weight will be able to move freely after the specimen has expanded upon heating.

6.3 *Number of Test Specimens:*

6.3.1 The life value shall be the average of three simultaneous determinations on wire specimens of the material being tested.

7. Ballast Resistance

7.1 The voltage between the bus bars shall be adjusted so that it will not be necessary to make the ballast resistance in series with the specimen greater than 20 % of the resistance of the specimen.

8. Temperature of Test

8.1 In the test method all temperatures are true temperatures.[3]

8.2 For alloys of nominal composition 80 % nickel and 20 % chromium, the temperature of test shall be 2200°F (1204°C); for alloys of nominal composition 60 % nickel, 15 % chromium and 25 % iron, the temperature of test shall be 2200°F (1204°C); for alloys of nominal composition 35 % nickel, 20 % chromium, and 45 % iron, the temperature of test shall be 2050°F (1121°C).

9. Procedure

9.1 Carry out the procedure as described in 9.1.1 to 9.1.13, inclusive.

9.1.1 Support the temperature measuring instrument so that it can be quickly adjusted and read.

9.1.2 Set the series variable transformer at minimum voltage resistance.

9.1.3 Close the switch in series with the specimen.

9.1.4 Adjust the variable transformer until the specimen is at a low red heat.

9.1.5 Grasp the weight to apply a slight tension, sufficient to straighten the wire.

9.1.6 If change of length measurements are to be made as specified in 9.1.15, open the switch in series with the specimen and make the initial length measurement of the unheated specimen. Then again close the switch to reheat the specimen.

9.1.7 Adjust the temperature of the specimen to 200°F lower than the test temperature.

NOTE 7—The interrupter shall not be in operation while the temperature is being adjusted.

9.1.8 Allow the specimen to operate under this condition until 2 h have elapsed in order to bring the emissivity nearer to a black body condition.

9.1.9 Adjust the temperature of the specimen to the test temperature. Maintain this balance until 1 min has elapsed.

9.1.10 After another 13 min readjust the temperature of the specimen to the test temperature. Final adjustment shall be completed within the next minute or a total of 15 min. The end of this 15-min period is the start of the test. It is important to maintain this time schedule.

9.1.11 Measure the voltage and the current and record the values together with the starting temperature and time of starting the test.

9.1.12 Start the interrupter, the timing device of which shall have been previously regulated so that the "on" period and the "off" period shall be equal and shall each have a duration of 2 min.

NOTE 8—Various cycles have been tried varying from 10 min on and 5 min off to 30 s on and 30 s off, when it was found that the 2 min on and 2 min off cycle gave the shortest life for a given temperature. It appears that sufficient cooling time has to be allowed to permit the specimen to reach a low enough temperature to cause any loosening or cracking of scale which will occur due to variations in coefficient of expansion of the scale and the metal. The heating and cooling operation is more injurious to wire than maintaining it at a definite temperature.

9.1.13 Adjust the temperature to the test temperature after 5 h and 24 h total elapsed time. Record the voltage and current after each resetting. Stop the interrupter before each resetting and start it again after making the observation.

9.1.14 After the first 24-h period, allow the test to run without readjustment for the next 24 h. At the end of this period and every 24 h thereafter until burnout, readjust the temperature so that it will be the same as the test temperature. After each adjustment of the temperature, observe and record the current and voltage measurements.

9.1.15 *Length Changes of Specimen*—Changes in length of the test specimen may be determined with an accuracy of 0.5 % by the following procedure: First measure with a steel scale the length between the point at which the specimen wire leaves the binding post and the top of the weight attached to the lower end of the specimen wire. This measurement should be accurate to ±0.02 in. (0.51 mm) (see 9.1.6). If the apparatus described in 4.9 is used, adjust the telescope in the vertical plane until the cross hair is directly lined up with the top of the weight attached to the wire (see 9.1.6). Estimate the readings on the cross section paper to the nearest 0.01 in. (0.25 mm). Other readings through the telescope may be taken in the same manner and noted. Calculate the changes in length of the specimen as the difference between the first reading made on the cross-section paper and the subsequent readings.

10. Record

10.1 Measurements and observations shall be recorded on a data sheet similar to that shown in Fig. 4 (see Annex A1 for reference to useful life).

11. Report

11.1 Report the following information:

11.1.1 Nominal analysis,

11.1.2 Identification of specimen,

11.1.3 Cross-sectional dimensions of the specimen,

11.1.4 Life of the specimen in hours (total elapsed time from the end of the first 15-min adjustment period to burnout), and

[3] The apparent temperature is lower than the true temperature by approximately 20°F (11.1°C) and 30°F (16.7°C) for the 80-20 type alloy and the 60-15-25 type alloy, respectively: reference, Roeser, W. F., "Spectral Emissivity (At 0.65 μ) of Some Alloys for Electrical Heating Elements," *Proceedings*, ASTEA, American Society for Testing and Materials, Vol 39, 1939, p. 780.

ACCELERATED LIFE TEST RECORD

Nominal Analysis ....

Laboratory Name .... Sample No. ....

Dimensions of Specimen	Test Temperature, °C	Bus Voltage	

Date	Time	Elapsed Time, h	Voltage Across Specimen After Adjustment, V	Current Through Specimen After Adjustment, A	Resistance of Specimen After Adjustment, Ω	Temperature After Adjustment, °F

Total Life of Specimen, h	Final Resistance, Percentage of Resistance at End of 15 min	Elapsed Time to 10 % Increase in Resistance Starting from End of First 15 min, h

REMARKS

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FIG. 4 Data Sheet for Accelerated Life Test Record

11.1.5 The elapsed time in hours to 10 % increase in resistance, starting after the end of the first 15-min adjustment period.

11.1.6 *Length Changes of Specimen*—The changes in length of the specimen during the course of the life test, when reported, shall be given as the percentage change in length per 100 h of elapsed time, including the 2-h emissivity adjustment period.

12. Reproducibility of Results

12.1 In the course of the development of this test method, it has been found that the major source of irregularity is in respect to temperature measurement. Therefore, no attempt shall be made to run standard accelerated-life tests until it has been definitely proved that the operator can obtain consistent results with specimens taken from the same sample coil or spool. Four or five specimens shall be tested at the same time to make sure that no variables, such as errors in temperature measurement, would affect one test and not another. Consecutive tests also shall be run. If the tests are properly made and controlled, the life of a number of specimens cut from the same spool should not vary more than ±10 % from the average.

13. Precision and Bias

13.1 The life test is an individual internal comparative test only. Too many variables exist to define a unit that would enable precision and bias to be defined. Insufficient need exists to alter the existing test method. Therefore, precision and bias are not defined.

14. Keywords

14.1 accelerated life test; alloys; electrical; heating alloys; life test; nickel-chromium; nickel-chromium-iron; oxidation resistance

ANNEX

(Mandatory Information)

A1. CONSIDERATIONS AND PRECAUTIONS FOR ACCELERATED LIFE TEST

A1.1 Scope

A1.1.1 This annex covers a few of the general considerations and precautions which should be kept in mind in the setting up and operation of the life test equipment and in the making of the accelerated life test.

A1.2 Temperature

A1.2.1 In general, it has been found desirable to use a temperature for any particular alloy which will result in a total life of approximately 100 h. Experience has indicated that this is a sufficient length of life to give a fair index of the quality of the material. A measure of the necessary length of time to get a good life test is shown by the consistency of the results; for example, if the test temperature is too high, the results are likely to be inconsistent since the excessive temperature causes aggravated hot-spot conditions.

A1.2.2 In addition to the temperature, care must be used in general applications of the test method to various types of alloys, particularly those of low creep strength. It will be noted in the test method that a weight is placed on the specimen in order to keep it straight; this weight has been calculated within the creep strength for the nickel-chromium alloy type material. For other types of material, with very low creep strengths, the test must be modified to eliminate any loading which would approach the creep value of the material at the temperature of test.

A1.2.3 Temperature is one of the most important variables in a life test. The probable life of a wire varies inversely with an exponential function of the temperature. This is readily understandable when it is considered that the life of the wire when operated at a temperature close to the melting point will be but a few hours, while at lower temperatures, as for example, about a red heat, it will endure for several thousand hours.

A1.2.4 To determine the temperature accurately, if a disappearing filament type optical pyrometer is used, the desired magnification can be obtained by substituting for the standard objective lens another lens having approximately one half its focal length. The temperature of the wire under test is very greatly affected by drafts. The enclosure, therefore, should be left in place at all times during the temperature observation and the pyrometer reading made directly through the glass front of the enclosure. In taking this reading through the glass front, it is necessary to allow for the reflection and absorption of the glass. Reflection at the surface of the glass is the principal cause of error. This effect is nearly independent of the kind and thickness of the glass. Reflection from external light sources shall be avoided. A correction of approximately 10°F (5.5°C) or a correction as determined by a specific test for the conditions involved shall be added to the temperature as observed. The glass slide shall be kept clean at all times to avoid increase in the absorption of light.

A1.3 Voltage Control

A1.3.1 In a number of cases, it has been attempted to make life tests, using the regular line voltage with no regulation, but this has never succeeded in producing uniform results. It is absolutely essential that voltage control be used.

A1.4 Reference Standard

A1.4.1 The method of tests suggests the desirability of comparing the specimen under test with a reference standard. This is of advantage, as the hours of life will vary somewhat with the different seasons of the year, due to varying humidity and other causes. Tests can be made upon the standard at the same time as the wires under test and the life can be reported as a percentage of the standard.

A1.5 Useful Life

A1.5.1 It is not practicable to give a general rule which will indicate the limit for the useful life of a heating element. In many cases, a limit of 10 % increase in resistance has been specified, which would cause a drop in wattage of 10 %. Sometimes a heating element is useful until it burns out, and in other cases the useful life may be considered as some other figure.