ANSI C50.32-1976 and
IEEE Std 117-1974
(reaffirmed 1984)
(Revision of IEEE Std 117-1956)

An American National Standard

IEEE Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery

Sponsor
Rotating Machinery Committee
of the
IEEE Power Engineering Society

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The Institute of Electrical and Electronics Engineers, Inc

345 East 47th Street, New York, NY 10017, USA

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Foreword

(This foreword is not part of IEEE Std 117-1974, Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.)

The Institute wishes to acknowledge its indebtedness to those who have so freely given of their time and knowledge, and have conducted experimental work on which many of the IEEE publications are based.

Early work with random-wound models of coil and slot assemblies (motorettes) indicated that a wide range of life expectancy with a given insulation system could be obtained. In 1958, as a result of an industry round robin, the Committee did not consider the data reported to be sufficiently consistent to warrant standards being based upon the figures. Accordingly a new test program using motorettes was initiated.

The Working Group delved deeply into each element of the 1956 version of this standard. The result was a specific written set of instructions regarding the preparation of the motorette, and the testing procedure itself. In the latter case, it was found that a special humidity environmental chamber had to be designed to reduce variation due to lack of humidity control. These features are discussed and referenced in the procedure itself.

The general conclusion of the second round robin was that test results indicated that the IEEE Std 117-1974 Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery must be rigidly adhered to in all testing details, if uniform results between different testing locations are to be achieved.

This Test Procedure has been prepared by a Working Group of the Insulation Subcommittee of the Rotating Machinery Committee of the IEEE Power Engineering Society. Members who participated in the prepersontion of this Test Procedure are as follows:

G.H. Bowers, *Chair*
L.M. Johnson, *Vice Chair*
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CLAUSE PAGE

An American National Standard

IEEE Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery

1. Introduction

1.1 Purpose

The chief purpose of this test procedure is to classify insulation systems in accordance with their temperature limits by test, rather than by chemical composition. The intention is, first to classify according to the recognized thermal classification A, B, F, H, and above H categories as referenced in the Appendix. The motorette procedure is intended to be used as an Industry Standard for insulation systems in that data obtained in accordance with this standard can be correlated between testing laboratories.

A wide variety of synthetic electrical insulation materials is available for application in electric machinery and apparatus. As there is a growing tendency either to rely solely on these materials as electrical insulation, or to employ them with the old familiar materials in novel combinations, there is a corresponding increase in the problems associated with the selection and evaluation of insulations. Consequently a complete insulation system must be evaluated rather than testing only individual insulating materials.

Many of the specifications regulating the use of insulation materials were written before the advent of the newer synthetics and were based upon experience gained with the old materials over a long period of time. Difficulties arise, therefore, when an effort is made to classify these new materials or combinations for insulation purposes under IEEE Std 1-1969 General Principles for Temperature Limits in the Rating of Electric Machinery and supplementary documents IEEE Std 98-1972, Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indices of Solid Electric Insulating Materials, and IEEE Std 99-1970. Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment.

A wide range of properties is available in current synthetic materials, so that it is not feasible to classify them on the basis of their chemical composition alone. Secondly, it is not desirable to wait and acquire the knowledge required to classify them solely on the basis of experience. In the third place, composite systems of insulation, in which materials of different temperature classes are used in different parts of the structure, may give satisfactory service at temperatures higher than normally permitted for the lowest temperature component; and, conversely, compatibility or other problems may arise whereby the highest temperature component is rendered unsuitable for use at its classified temperature.

This test procedure has been prepared to outline useful methods for the evaluation of systems of insulation for random-wound stators of rotating electric machines. It is expected that the several insulating materials, or components, making up any insulation system to be tested will first be screened in accordance with specific test procedures for each type of material. Normally materials that have given acceptable performance in these separate screening tests would be included in the system evaluation tests outlined in this procedure.

This procedure is intended to evaluate insulation systems for use in "usual service conditions" with air cooling. It has also been a useful tool for evaluating systems for special requirements where machines are enclosed in gas atmospheres, subjected to strong chemicals, to metal dusts, or submersion in liquids. However, these special requirements are beyond the scope of this test procedure.

1.2 Methods of Evaluation

The test procedure includes two principal sections.

1) Section 2. describes motorettes (models suitable for use in insulation evaluation tests) and recommends a series of exposures to heat, vibration, and moisture to which the motorettes may be subjected to represent cumulative effects of long service, under accelerated conditions. Procedures for applying periodic voltage checks, to establish the end point of insulation life, are also given
2) Section 3. describes similar procedures when actual motors are used as the test specimens

It is recommended that for each particular system to be evaluated, a suitable type of a specimen, namely a motorette or a complete motor be selected; and then an adequate number of these be subjected to repeated cycles of heat, vibration, moisture, and electrical stress as outlined in Sections 2. and 3. of this procedure.

An adequate number of samples to obtain a good statistical average, in no case less than ten motorettes or five motors, should be carried through the test procedure until failure occurs, for each chosen temperature of heat exposure. It is recommended that the tests be carried through on the indicated number of specimens for at least three different test temperatures, for each insulation system to be evaluated. To promote uniformity in the results there are given six possible ranges of exposure requiring from 1 day to 32 days per given temperature, that are appropriate for making these tests.

The number of cycles and the total number of hours of heat aging, to the end of life for the average of each group of samples and for each of the test temperatures, are then reported as the final results of the tests. The extrapolated regression line obtained for a new insulation system is determined from these data according to the procedure in IEEE Std 101-1972, Guide for Statistical Analysis of Thermal Life Test Data. (The motorette or motor life from an *accepted standard* must be used as the criterion to determine the new insulation systems thermal rating from the plot. A control set of test units using an established insulation system should be used so that a comparison of the new system to the old system can be made.) As indicated in Section 2. the combined effects of the heat, vibration, moisture, and electrical stresses imposed on the insulation during these tests are intentionally made more severe than those normally found in service at the same temperature. Therefore, the life of any given insulation system in these tests will be shorter than that to be expected in actual service at a comparable temperature.

At present this procedure will permit approximate comparisons only and cannot be relied upon to determine completely the merits of any particular insulation. Such information can only be obtained from extended service experience. In the course of time, however, it is expected that enough data may be obtained from tests of this kind to establish a normal number of hours of heat aging before failure that will be representative of each of the standard temperature classes of insulation.

2. Motorettes

2.1 Insulation Test Specimens

2.1.1 Scope

This section suggests appropriate test specimens for evaluating insulating systems, which may be usefully subjected to the exposures outlined in Section 2.2, to simulate their behavior in service. It is considered that one type of motorette, as defined in the following, will adequately represent random-wound machines, both fractional and integral, of 600 V rating or less. Other types of specimens will be required to represent machines with more than 600 V and with other than random-wound insulation systems. Procedures for evaluating such other types of insulation not covered elsewhere [21, 22] are under study, and will be included in future revisions of this procedure.

2.1.2 Motorettes

The model shall be made to embody all of the elements and should be as nearly as possible representative of a complete winding insulation system.

Specifically, it is recommended that for the purposes of testing random-wound motor insulation, a motorette be employed, as shown in Figs 1, 2, and 3. At least ten motorettes shall be subjected to each of a series of test exposures, as outlined in the following:

Fig 1 shows typical components of a motorette before final assembly. Each of these components should be subjected to separate screening tests, to establish uniformity and normality before they are assembled. For example, a number of representative samples of the wire, slot cells, phase insulation, and so forth, may be broken down by 60 Hz high-potential tests, or other means. It should be recognized that the number of tests required to establish the acceptable temperature limit in service will increase greatly, if the performance of individual components varies over a wide range. Therefore, everything possible should be done to assure that the individual components are uniform and representative of the materials used in actual service.

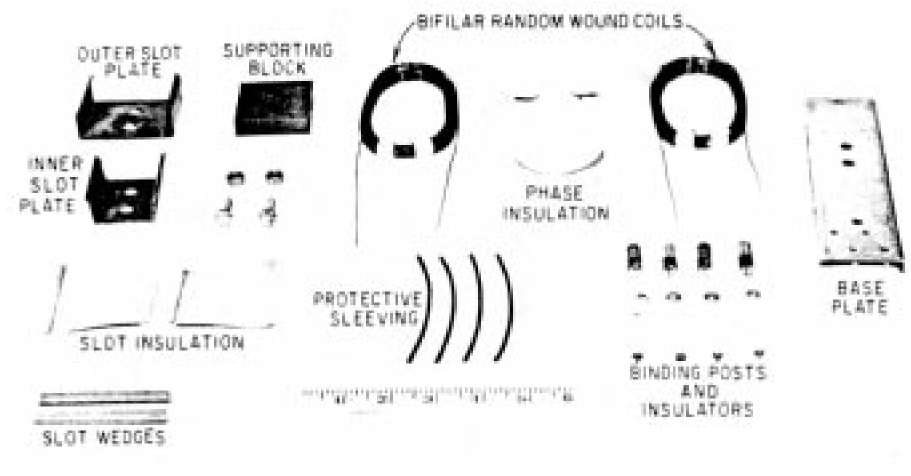


Figure 1—Components of Motorette Before Final Assembly

The finished motorette consists of a rigid supporting metal stand with four suitable stand-off porcelain insulators bolted to one end and with a slot portion, made from an inner and outer plate, bolted to the other end. The supporting stand has holes for mounting the fixture during vibration testing. The slot sections are fabricated from U S Standard no 16 gauge (0.060 in [1.52 mm]) steel sheets such as AISI 1010 cold rolled steel. The assembled slot portion contains two coils insulated from ground by slot cells, insulated from each other by phase insulation and held in place with slot wedges. These components are typical parts used in actual motors. The coils are each wound with two parallel wires so that conductor-to-conductor electrical tests may be made. They can be machine wound on pins or forms, as in ordinary shop practice. In special cases the construction and processing procedures may be modified to simulate the intended use.

2.1.3 Preparation of Motorettes

The following is a detailed description of the preparation of the motorettes for the industry wide round robin and is presented as a guide to those who have need to build them. As noted above, modifications may be made to simulate more clearly the intended use.

2.1.3.1

Components used:

1) Wire—AWG no 18 magnet wire. heavy film coated
2) Slot Liner—10 rail (0.25 mm) sheet insulation slit into rolls of 2 3/4 in (70 mm) width. The material was cuffed [frac18] in (3.2 mm) on each side making a final width of 2 1/2 in (64 mm). This allowed 3/16 in (4.8 mm) to project from each end of the slot
3) Phase Insulation—10 rail (0.25 mm) sheet insulation cut into pieces, two pieces for each motorette, 1/2 in (13 mm) by 3 in (76 mm) strips and one circular piece 2 1/2 in (64 mm) diameter with a hole 1 1/2 in (38 mm) in diameter in center. This allowed 1/4 in (6.4 mm) overlap on the rectangular pieces. The circular pieces were cut in half and the two halves placed in the end turns
4) Slot Wedges—the wedges were cut from preformed U-shaped stock. The wedges were 3/8 in (9.5 mm) wide at the base and 3 in (76 mm) long. One end of the wedge is rounded to insure easy passage through the slot

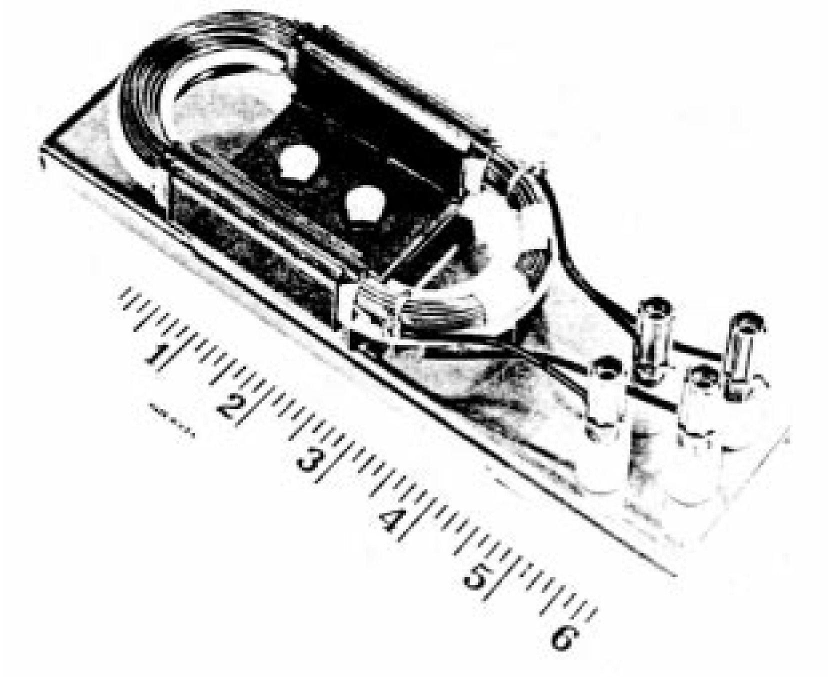


Figure 2—Completely Assembled and Varnished Motorette

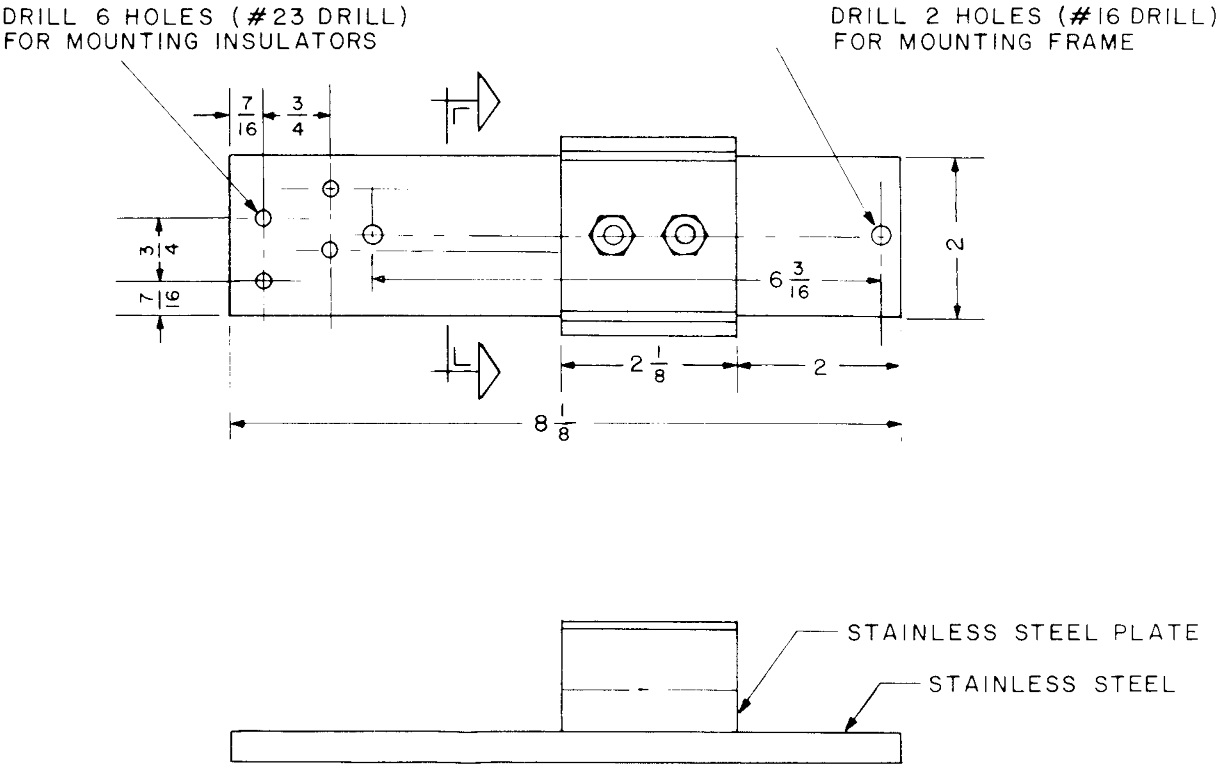
5) Tubing—insulated tubing of sufficient size to go over lead and sufficient length to cover lead from the center of slot portion of coil to terminal
6) Tie Cord—this was of sufficient length to tie coil and leads together

7) Binding Tape— 1/2 in (13 mm) electrical tape
8) Insulating Varnish—electrical grade

2.1.3.2

The motorette assembly was as follows:

1) Winding Coils—Coils were wound with two parallel wires on forms as in ordinary shop practice. Each coil was composed of 20 turns of wire wound 2 in hand or 40 wires. Since there were two coils in each slot, this means each slot had 80 wires. The coils were tightly wound in the form of an oval with parallel sides extending the length of the slot portion approximately 2 1/2 in (64 mm). The parallel sides were separated by 1 3/4 in (44 mm). The round end of the oval was a 1 3/4 in (44 mm) diameter semicircle. The dead ends of each coil were brought out and separated by 3/16 in (4.8 mm). The active ends of the coil were separated and taped with one layer of binding tape brought above and below each lead. The leads left the coil in the center of one of the semicircles
2) Before assembly each metal component of the motorette was immersed in a solvent composed of equal parts of toluol and denatured alcohol for at least 30 minutes. Each part was removed from the solvent, rinsed with fresh solvent, and wiped with a lint-free cloth. The motorette metal parts were carefully assembled insuring that the slot portions were equal in width and the sides parallel. A simple device for this is to cut two wooden blocks equal in width to the slot portion and center the slot by placing the blocks in the slot portion prior to tightening slot hold down bolts
3) The slot insulation was cut from the strip in the form of a 2 1/2 in (64 mm) square and bent to fit the slot. This allowed the sheet insulation to be folded under the wedge and it projected 3/16; in (4.8 mm) from each end of the slot. The slot insulation was inserted in the slot portion with extreme care so that equal amounts extended beyond each end of the slot



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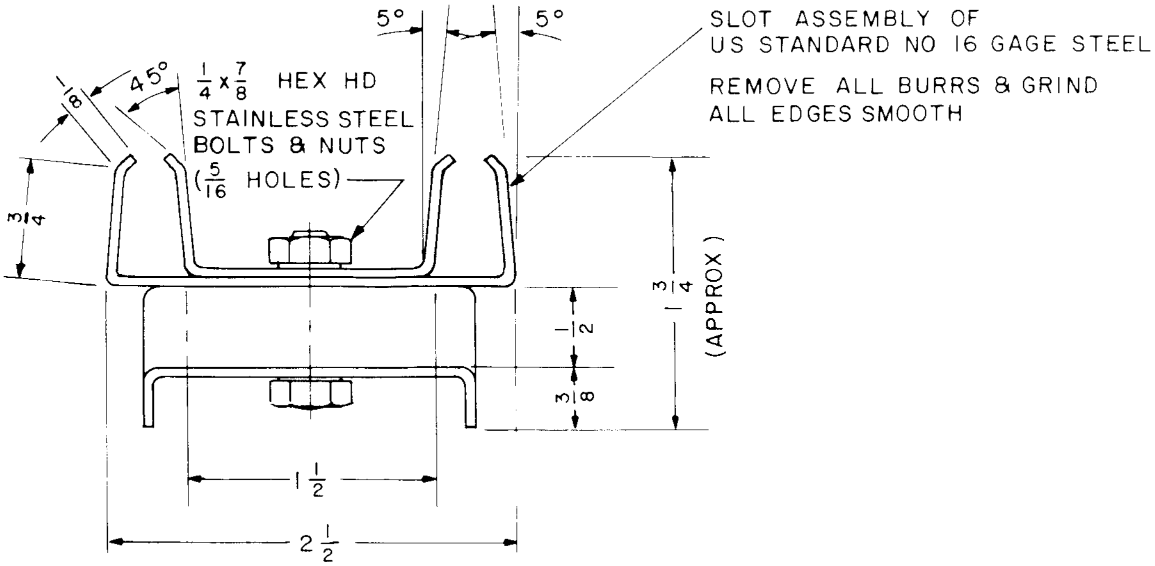

SECTION
SCALE: FULL

ALL DIMENSIONS ARE GIVEN IN INCHES

Figure 3—Working Drawing of Motorette Frame

4) The slot insulation was folded back at the top of the slot to act as a feeder to insure that the magnet wire was not abraided when it was placed in the slot. The bottom coil was inserted in the slot with the dead coil ends down and the lead extensions at the top of the coil. After the bottom coil was in place, the phase insulation was inserted, and care was taken to insure that the sides of the phase insulation within the slot completely covered the bottom coil. If the phase insulation within the slot was too large, the edges were folded upward toward the top of the slot. The phase insulation was adjusted to provide an equal border over the bottom coil. The bottom coil ends were not bent since the edges of the slot insulation would be ruptured. The top coil was inserted in the same manner as the bottom coil, but with the dead coil end up and lead extension down. The top coil was adjusted to maintain the same border as the bottom coil, insuring that the wires of the top coil did not slip around the phase insulation
5) The leads were carefully measured to terminate at the insulators. The last 1/2 in (13 mm) of the lead was stripped of enamel and tinned at the end with solder before connection to the insulated terminals. The leads of the bottom coils were connected to the inside insulators and the top coils to the outside insulators. The slot insulation was cut even with the top of the slot. The ends of the slot insulation were lapped over the coil and the wedge was inserted on the top of the slot insulation
6) The coils were checked for insulation resistance as desired and given a voltage check as recommended under Section 2.1.3.4. If found to pass this test, the motorette was then treated with electrical insulating varnish

2.1.3.3

The treating cycle was as follows:

1) The units were preheated to anneal the wire enamel and remove moisture
2) The viscosity of the varnish was measured and the varnish adjusted to give the viscosity recommended by the manufacturer. The unit was placed in varnish with the slot section in a vertical position with the connections up. It was allowed to remain submerged for 15 minutes. The varnish was brought into the laboratory at least three hours before use and adjusted to a temperature of 73°F, ± 2°F (23°C ± 1.1°X)
3) The units were removed from the varnish by mechanical means at the rate of 4 in (102 mm) per minute to assure an even coating
4) The units were allowed to drain with the slot section in a vertical position, connections up, and away from the dip tank so as to prevent washing by solvent fumes. The unit was drained for 15 minutes or longer
5) The motorettes were placed in an oven with the slot section in a vertical position and connections up, and the varnish cured as in the manufacturer's recommendation
6) The motorettes were removed from the oven and allowed to cool
7) This was repeated as above for the required number of dips and bakes

2.1.3.4

Electrical check. After assembly and after varnish curing, a screening test was performed on the motorettes using a 400 V conductor-to-conductor ac potential with a 50 mA circuit breaker to denote failure. In addition, a 2000 V phase and ground screening test was used.

2.1.3.5

The motorette mounting was as follows: Ten motorettes were bolted to a rack (1/2 in [13 mm] thick rigid aluminum proved quite successful). This rack had metal removed between motorettes so that air circulation was not impeded. The rack was sized to fit the ovens and condensation chamber drawers and was capable of being bolted to the vibration table.

2.2 Test Exposures

2.2.1 Scope

It is the purpose of this section of the test procedure to specify appropriate exposures to heat, mechanical stress, moisture, and electrical stress, concurrently, or in repeated cycles, which will represent the cumulative deteriorating effects of service, on insulation materials and systems, on an accelerated basis.

Extensive experience with other tests of this general nature has indicated that most of the deteriorating effects of service can be reasonably approximated by such a sequence of exposures to high temperature, mechanical stresses, moisture, and voltage, as outlined in this section.

The best results are obtained when the sample is first thermally aged, then exposed to mechanical stress, and finally exposed to moisture followed by voltage (thus applying electrical stress over the weakened insulation). An overnight room temperature drying period is recommended before the next thermal aging cycle.

It is recognized that ovens provide the most convenient means of obtaining high temperatures. This method of aging subjects all the parts of the insulation system to the full temperature, while in actual service a large proportion of the insulation may operate at considerably lower temperatures than the hottest spot temperature. For this reason, the life in oven aging at a given hot-spot temperature should be expected to be shorter than in actual service.

It is recognized that failures resulting from abnormally high mechanical stresses or voltages are generally of a different character from those failures which are produced in long service. For this reason, the mechanical and electrical exposures recommended are only moderately above those normally met with in service. The temperature and moisture exposures are intentionally made more severe than usually met with in service, in order to shorten the required time for testing.

2.2.2 Temperature Exposure

Table 1 lists the suggested temperatures and corresponding times of exposure in each cycle for insulating systems for the different estimated values of the limiting hottest spot temperature. For example, the recognized A, B, F, and H classes of insulation would normally be tested at the times and temperatures shown in columns A, B, F, H, and above H of the table, respectively. To permit use of available ovens in different laboratories, a range of exposure temperatures are given in the table. Either the time or the temperature or both may be adjusted to make the best use of facilities.

The oven used for motorette tests shall be of the forced air baffle type with ventilation to obtain uniform temperatures.

The selected temperature should be controlled to ±2°C up to 180°C and ±3°C from 180°C to 300°C after heat up for the aging portion cycle.

Table 1*—Temperature and Exposure Time Guide‡ (Estimated Hottest Spot Temperature Range)

Exposure Temperature (°C)	Class A (days)	Class B (days)	Class F (days)	Class H (days)	Class Above H (days)
300					1
290					2
280					4
270					8
260					16
250				1	32
240				2	
230				4	
220			1	8	
210			2	16	
200		1	4	32	
190		2	8		
180	1	4	16		
170	2	8	32		
160	4	16			
150	8	32			
140	16				
130	32				

*The above schedule is based upon an approximate "ten degree rule" for insulation deterioration which states that the life of the insulation is reduced one-half for each ten degrees Celsius rise in temperature.

‡In order to obtain an average number of heat cycles between 8—20 test cycles: (1) If no samples fail by the end of the 8th cycle, the heat aging period of the test cycle is doubled; (2) If 3 or more samples fail by the end of the 4th cycle, the heat aging period of the test cycle is halved.

‡‡The temperature measurements are taken in the immediate neighborhood of each specimen, as the temperature is rarely uniform over the entire oven space.

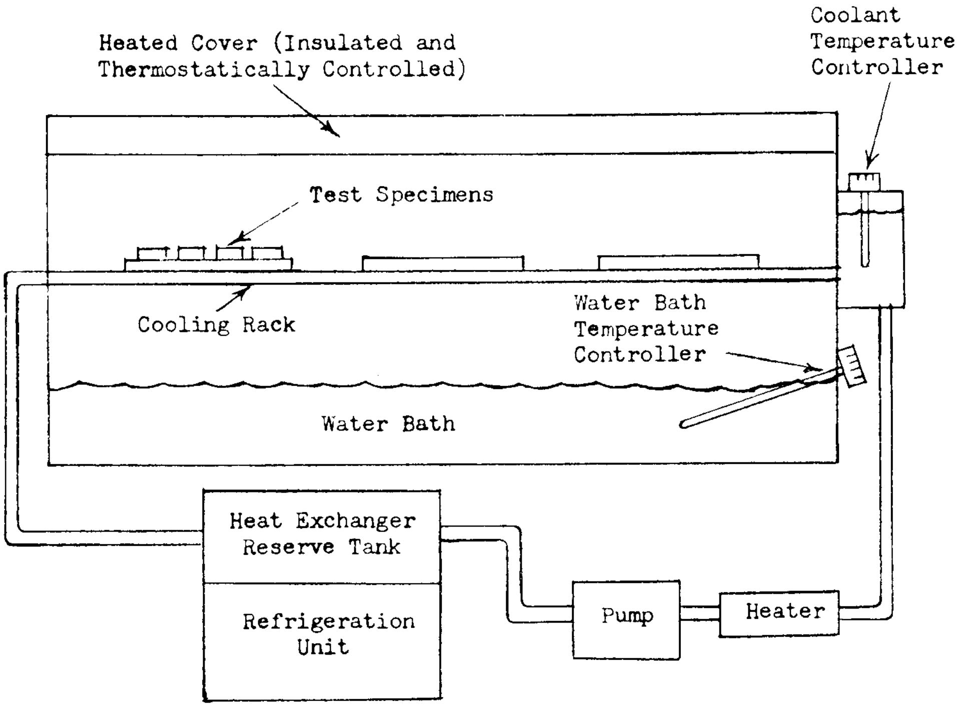

Figure 4—Block Diagram Illustrating Basic Principle of Condensation Chamber

Motorettes are subjected to the nearest temperature corresponding to the 32 day exposure period that is necessary to provide a minimum 5000 hour mean life and to at least two of the other temperatures. At least ten samples are carried through successive cycles of exposure at each of the test temperatures until failure occurs.

It is intended that these temperature exposures be obtained by placing the specimen in enclosed ovens, with just sufficient ventilation or forced convection to maintain temperatures uniform over the specimens. The cold specimens are placed directly in preheated ovens, so as to subject them to a uniform degree of thermal shock in each cycle. Likewise, the hot specimens are removed from the ovens directly into room air, so as to subject them to uniform thermal shock on cooling as well as on heating.

In certain cases materials age more rapidly when the products of decomposition remain in contact with the insulation surface, whereas other materials age more rapidly when the decomposition products are continually removed. It is, therefore, desirable that the conditions of ventilation and temperature be precisely maintained for tests on other specimens with which the test materials are to be compared. If the insulation in actual service is so arranged that the products of decomposition remain in contact with it, the test specimens should then be designed in the same way; so that the oven ventilation will not remove these decomposition products.

2.2.3 Mechanical Stress Exposure

Following each cycle of temperature exposure, after cooling to room temperature each specimen shall be subjected for a period of one hour to mechanical stress.

The following is the preferred method of applying mechanical stress to motorettes: after each cycle of high temperature exposure each motorette is mounted on a shake table and operated for a period of one hour with a 60 Hz oscillating motion, with a double amplitude (peak to peak) of approximately 8 mils (0.20 mm).

The motorettes are so mounted that the motion occurs at right angles to the plane of the coils, so that the coil ends will be free to vibrate as they would under radial end winding forces in an actual motor. This vibration test is made at room temperature and without any applied voltage.

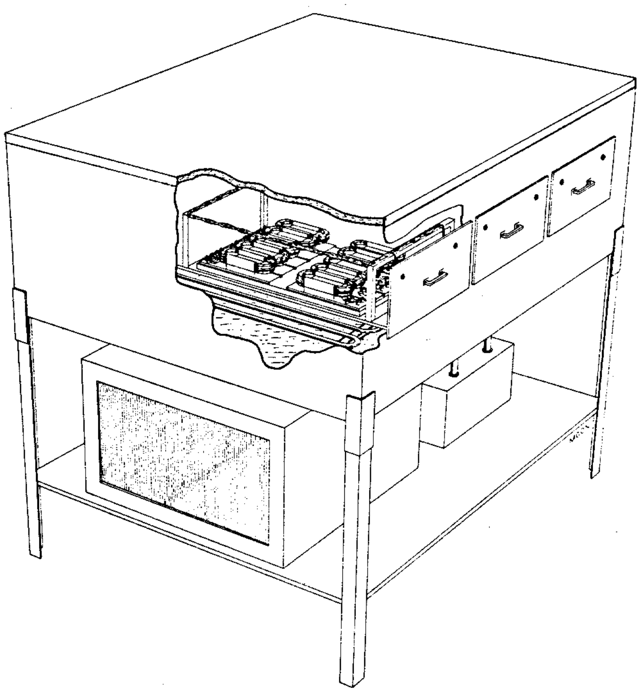

Figure 5—Artist's Cut-Away View of Condensation Chamber

2.2.4 Moisture Exposure

After each cycle of mechanical stress exposure, each specimen is exposed for at least 48 hours to an atmosphere of 100 percent relative humidity with uniform and visible condensation on the winding. No voltage is applied to the specimen during this period.

The following test chamber[1] [17] or equivalent is recommended for moisture exposure.

Fig 4 is a schematic block diagram illustrating the basic principle employed. The specimen rack in its drawer as shown in Fig 5 is refrigerated by means of a circulating coolant (water) which is thermostatically controlled to maintain a specified temperature differential between the specimens and the surrounding chamber air. This differential is independent of normal room ambient variations. Since both the heated water bath and the coolant are thermostatically controlled, this independence is limited only by the capacity of the system. Temperature control is not lost in the event of the room ambient should rise to a temperature above that of the water bath. The heat lost to the refrigerated rack keeps the water within the control of the heater, thus allowing the balance of temperatures to be maintained. In case the room temperature should fall below that of the cooling rack, again the control is preserved by the heat supply of the water bath heater. In contrast to a conventional plus-dew chamber, this balancing effect between the heating and cooling systems eliminates the necessity for the chamber to be in a temperature-controlled room. The interior of the chamber should be so designed that all motorette specimens would be located in the same position with respect to the distance above the water bath and below the roof of the chamber. This is done so that each specimen is equally influenced by such factors as radiating surfaces, air temperature, and degree of relative humidity.

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[1] A suitable chamber may be obtained from U.S. Testing Company, Hoboken, NJ.

Fig 5 shows the rack of ten motorette specimens placed in the drawer of the condensation chamber. After the desired moisture exposure, the specimens are connected to a test stand by cables which lead to the receptacles on the face of the chamber drawers.

When the test chamber is maintained at the following temperatures uniform condensation will occur:

Water Bath Temperature	30.0°C
Motorette Coil Temperature	24.0°C
Chamber Air Temperature	
(1 inch above motorettes)	25.0°C
Center. Underside Chamber Roof	28°C–29°C

2.3 Voltage checks

2.3.1 Recommended Check Voltages

Each motorette is carried through repeated cycles of the thermal aging, mechanical stress, and moisture exposure in sequence until failure occurs. In order to check the condition of the samples and determine when the end of their useful life has been reached, a current of frequency 60 Hz is applied after each successive exposure to moisture as follows:

Expected Line-to-Line Voltage in Service rms Volts	**Check Voltage for Testing (rms Volts at 60 Hz)**		
	To Ground	**Between Winding**	**Between Conductors**
110–550	600	600	120

The voltage between conductors is chosen to be well above the maximum service voltage across a single turn of the winding and to be adequate to break down the air space between wires in the presence of moisture.

Following each exposure to moisture, the voltages are applied for a period of ten minutes while the specimens are still in the condensation chamber and are wet from exposure, at approximately room temperature. The applied voltage is held successively for ten minutes using the circuit arrangement shown in Fig 6; first between the parallel- wound conductors, then from phase to phase, and finally from all coils to ground, or all of these voltages may be applied simultaneously, by the circuit arrangement shown in Fig 7. However, if these voltages are applied simultaneously the voltages from winding to winding, and winding to ground may not be exactly equal. Therefore care should be taken to adjust the voltages to make the lowest one equal to the required test value. It is suggested that surge protectors be included in the test circuit to eliminate high-voltage spikes.

Experience has shown that this prolonged time of voltage application in the wet condition is necessary to detect failures. Many of the failures are found along wet surfaces, with gradual building up of the leakage current, which could not occur in the usual one-minute test.

Any such failure in any component of the insulation system constitutes failure of the entire sample and fixes the end point of the life.

It is recognized that by applying the voltages as above recommended, which are fixed by the intended voltages in actual service, markedly different periods of life may be obtained for the same insulating materials, depending on the insulation barriers and lengths of the creepage paths employed.

As this indicates, the test procedures recommended are adapted to prove the reliability of the insulation proposed for a given temperature, for high humidity, and for a given voltage.

Other tests,[2] besides the test where a current of frequency 60 Hz is applied, may be employed to check deterioration of the specimens. These may be provided for in future revisions of this test procedure. They are not considered sufficiently positive or uniform in their indications to warrant their inclusion at this time.

It is desirable to take periodic (relatively nondestructive) measurements of insulation quality during the course of the tests on a part of the samples, such as insulation resistance, power factor, or corona intensity or all three at some overvoltage. By noting changes in such qualities and correlating them with the time before final failure occurs much can be learned about the nature and the rate of deterioration of the insulation, and greater confidence in the reliability of the final results can be established.

One of the most significant factors in the experience of testing motorettes is that of the behavior variations of the circuit breakers used to detect failure. It is strongly recommended that failure be determined by precalibrated electromechanical overcurrent breakers[3] set at 0.5 and 0.75 A rather than neon light protectors.

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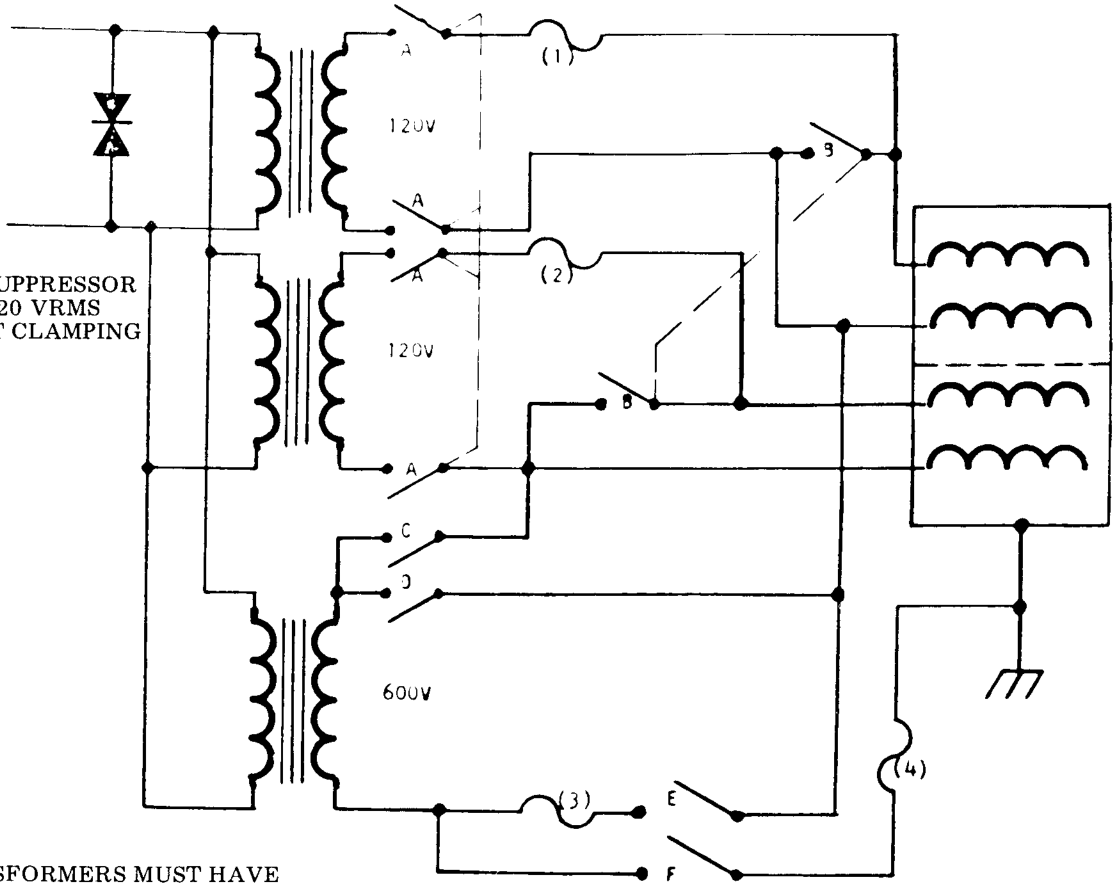
[2] These include alternative methods and procedures for applying various types of voltages to detect changes in the test specimens.

[3] A suitable breaker is manufactured by Heinemann.



SURGE SUPPRESSOR
RATED 220 VRMS
600 VOLT CLAMPING

ALL TRANSFORMERS MUST HAVE
VOLTAGE REGULATION
WITHIN FIVE PERCENT AT THE
LOAD IMPOSED BY THE NUMBER
OF MOTORETTES THEY ENERGIZE

CIRCUIT BREAKERS

TRIP TIME 2—3 SECONDS

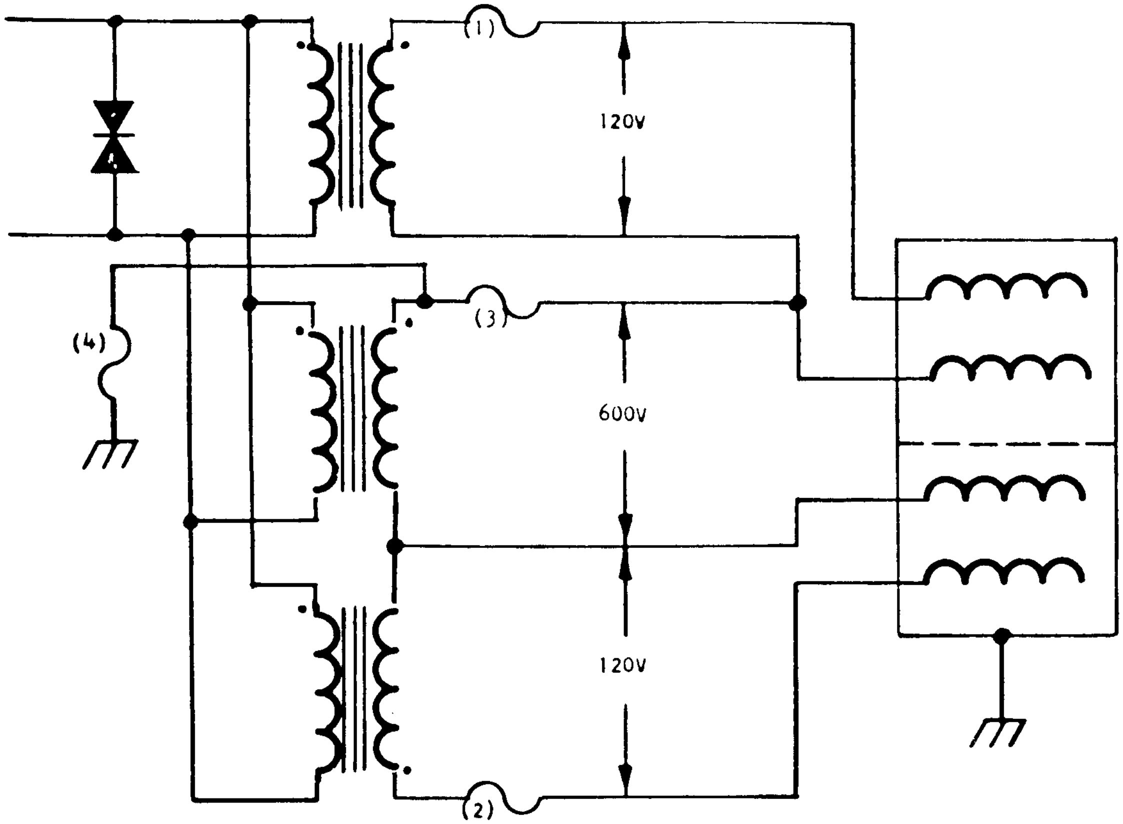
(1) WIRE TO WIRE	— 0.75 A
(2) WIRE TO WIRE	— 0.75 A
(3) PHASE TO PHASE	— 0.5 A
(4) GROUND	— 0.5 A

OPERATION

WIRE TO WIRE		PHASE TO PHASE		GROUND	
SWITCH OPEN	SWITCH CLOSED	SWITCH OPEN	SWITCH CLOSED	SWITCH OPEN	SWITCH CLOSED
B	A	A	B	A	B
C		D	C	E	C
D		F	E		D
E					F
F					

Figure 6—Test Circuit for Successive Proof Testing

SURGE SUPPRESSOR
RATED 220 VRMS
600 VOLT CLAMPING



ALL TRANSFORMERS MUST HAVE VOLTAGE REGULATION WITHIN FIVE PERCENT AT THE LOAD IMPOSED BY THE NUMBER OR MOTORETTES THEY ENERGIZE

CIRCUIT BREAKERS

TRIP TIME 2—3 SECONDS
(1) WIRE TO WIRE — 0.75 A
(2) WIRE TO WIRE — 0.75 A
(3) PHASE TO PHASE — 0.5 A
(4) GROUND — 0.5 A

Figure 7—Test Circuit for Simultaneous Proof Testing

3. Motors

3.1 Scope

This Section lists the procedure for testing of insulation of complete motors. It utilizes the analysis of IEEE Std 101-1972, in order to arrive at a rating of the insulation system into the Classes A, B, F, and H as defined in the Appendix.

3.1.1 General

The insulation systems tested under this Section 3. procedure consist of complete systems assembled in actual motors. The motorette tests in accordance with Section 2. involve such a simple and highly standardized winding that the effects of normal manufacturing processes do not constitute a variable in the tests. On the tests of Section 3. the dimensions of components and the manufacturing processes of winding and shaping do affect the test results. When comparing systems of various materials the variations in manufacturing processes should be reduced to an absolute minimum when manufacturing the two systems to be compared. These tests are also of value to a manufacturer in the development of his design processing methods.

Due to a wider variation in manufacturing processes and methods of testing motors, it is exceedingly difficult to compare motor tests of one facility to those of another. It is the intent of this procedure to compare motor insulating systems within one manufacturing and testing facility.

3.2 Models

The models will consist of complete motors. A motor may be modified to increase its mechanical life, restrict ventilation, or increase its temperature rise provided no changes are made in the insulation system and its immediate environment.

3.2.1 Number of Samples

At least five motors are carried through each test as a group for each temperature being tested.

3.2.2 Screening Tests

To eliminate defective units, the motors shall be screened, first by visual inspection and then by subjecting them to a high potential test (NEMA Motors and Generators 1-12.03) and a repetitive surge test (Surge Comparison Test).

Any of the following tests may be used as additional screening tests:

1) Corona starting voltage
2) Dissipation factor and capacitance measurements
3) Insulation resistance measurements
4) Phase balance
5) Current leakage to ground

The voltage in the above tests are applied in such manner as not to reduce the insulation life of the acceptable motors. If, in any one of these tests the values obtained for individual motors varies widely from the mean, the reason for the variation should be investigated to be sure that the motors are adequately uniform.

3.3 Test Exposures

This section specifies appropriate exposures to heat, mechanical stress, moisture, and electrical stress concurrently or in repeated cycles which will represent the cumulative deteriorating effects of service on insulation materials and systems on an accelerated basis.

The most meaningful results are obtained when the sample is thermally aged, exposed to mechanical stress, and finally exposed to moisture followed by voltage (thus applying electrical stress over weakened insulation).

It must be realized that greater mechanical stress and higher concentration of the products of decomposition occur during tests at higher than normal temperature. Also, it is recognized that failures from abnormally high mechanical stress or voltages are generally of a different character from those failures which are produced in long service.

Furthermore, the temperature and moisture exposures are intentionally made more severe than usually met with in service. Hence, the life predicted at the system temperature rating (see Section 1.5, IEEE Std 1-1969) will be much lower than for normal operation at that rating. Also, because of variations in control of these extraneous factors, comparison between laboratories is difficult.

3.3.1 Thermal Aging

Table 1 lists the suggested temperatures and corresponding times of exposure in each cycle for insulating systems of different classes. This table is based on a constant number of cycles to failure regardless of test temperatures.[4] Either the time or the temperature or both may be adjusted to make the best use of facilities. Test temperatures shall be measured by the resistance method. Thermocouples may be installed for purposes of control. Temperature should be controlled to ±2°C up to 180°C and ±3°C from 180°C to 300°C after heat up for the heat-aging portion cycle. If the average temperature of any one motor deviates from the group being run at a common temperature by more than 2°C, it should be so recorded and analyzed.

The mode of heat generation is dictated by the type of motor being used and the laboratory equipment available. Higher-than-normal winding temperatures may be obtained by increasing motor losses such as larger than normal air gaps, superimposing a dc current on the ac current, starting and reversing each motor, restricting ventilation, or increasing temperature of air surrounding the motor. During the heat-aging portion of the cycle the motors are run continuously at normal voltage and frequency with an electrical control which automatically starts and stops or reverses the rotation of the motors at intervals as outlined in Section 3.3.2. Other acceptable means of temperature control include automatic voltage variation, adjustment of the surrounding air temperature, superimposition of a dc current on a normal ac current, or combinations thereof. The heating-up time is to be considered as part of the thermal aging period while the cooling-down time is not.

For any system being evaluated, tests are made for at least three different temperatures. The lowest test temperature should be no more than 25°C above the system temperature rating. The highest temperature test should be at least 40°C above lowest temperature test, and temperature points should be selected to give approximately equal temperature intervals. The average life at the highest temperature shall be no less than 100 hours.

3.3.2 Mechanical Stress

Mechanical stress is obtained in Section 3. tests by the normal vibration of the motor running with additional starts or reversals or both. There is a mechanical shock from starting or reversing; vibration at twice line frequency is increased by reducing the rotor diameter; and large forces are present in the windings as a result of the high currents during starting and reversing of the motors. These mechanical forces occur during the test at elevated temperatures.

The test motors should either be solidly mounted or mounted on shock pads that will give a uniform amount of shock to all motors. The mounting method shall be reported and comparison of systems should be made only on a constant method of mounting. Single phase motors shall have at least 250 start-stop operations each day of the heat aging portion of the cycle.[5] Polyphase motors shall have at least 1000 starts or reversals each day of the heat-aging portion of the cycle.[6]

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[4] Since experience has shown that the life of a system may be affected by the number of aging cycles, the average number of cycles should not be less than 8 nor more than 20. To assure that this average falls within this range, the procedure explained in the footnote of Table 1 is followed. However, when only five or six motors are tested at one temperature, the cycle length is halved if two (in place of three) samples fail by the end of the fourth cycle.

[5] The starting winding of a single-phase motor normally operates at a much higher current density than the main winding during starting. At each start it may reach a temperature of 10°C to 30°C higher than the main winding, and the magnet wire which is normally smaller than the main winding wire is subjected to high currents. In order to insure that the correct emphasis is placed on the main winding portion of the insulation system, excessive numbers of starts should not be employed.

[6] Often the electrical loss during reversal is used to maintain the elevated temperatures, in which case the number of reversals may greatly exceed 1000 per day. At the highest temperature test the total time of exposure is relatively short which results in a low number of reversals during the life of the test. At the lowest temperature, the time of exposure may be 16 to 20 times as long as that of the highest level. This wide variation in total number of starts may affect the slope of the time-temperature curve. It is recommended that the number of reversals at the low temperature be no greater than twice those at the high temperature. Other means as listed in Section 3.3.4 may be used to supplement the heating caused by reversal.

3.3.3 Moisture

Moisture is used to make dielectric tests more discerning of physical and thermal damage to electrical insulation systems. The presence of condensed moisture on windings results in an easy electrical path by filling cracks and porosities in the insulation with water. The resultant current flow then causes the breaker to trip, indicating failure. Resistance to ground may be plotted against time in humidity to determine length of time until moisture is effective. In place of such a plot, a humidification of 48 hours shall be used.

A visible condensation must be present on the winding during the humidification portion of the cycle. In order to insure visible condensation, the insulation system must be at a lower temperature than the dew point of the surrounding moisture-laden atmosphere at all times. The preferable method of meeting this requirement is by use of a condensation chamber described in Section 3.2.4 of this procedure.

However, larger motors may be difficult to move and difficult to support in a condensation chamber or the chamber may not be available. Other methods of applying moisture are to apply an enclosing hood around the motor, or by using a conventional humidity cabinet. One method of obtaining an atmosphere of 100 percent relative humidity with condensation is by covering the floor under the hood or in the chamber with a shallow layer of water heated five to ten degrees above the chamber temperature. The base of the motor should be mounted to a body that is colder than its surrounding atmosphere to insure the insulation system is at a lower temperature than the dew point of the atmosphere. The roof of the hood or chamber should be sloped so as to drain any condensed water to the back or sides of the cabinet to prevent drip on the test samples. For totally enclosed motors, end bells should be removed or openings provided in the enclosure. No voltage is applied during the exposure.

3.3.4 Electrical Stresses and Tests

The test motors are to be run during the heat exposure periods at their highest rated name-plate voltage. A grounded power source should be used and the motor frame should be grounded so that normal voltage stresses are present during the entire heat aging portion of the cycle. Start up should be made within fifteen minutes after the moisture portion of the cycle to insure that voltage is applied with moisture present. During the heat-aging portion of the cycle, motors are subjected to line surges such as normally obtained in service by starts and reversals. The motors may be given a voltage test prior to starting each thermal-aging cycle by applying a repeated surge impulse test to each winding or phase of the motor in turn. The test voltage, if used, measured from crest to ground shall be no greater than 22 times the line voltage.

3.3.5 Failure Criteria

The end point of the motor life in these tests is fixed by its electrical failure under rated applied voltage. Excessive currents during any portion of the heat cycle constitute a failure. Indiscriminate starting in either direction of rotation of a single phase motor may indicate failure of the starting winding. Nondestructive tests, such as measurements of insulation resistance, and dissipation factor may be employed to check deterioration of insulation quality of the specimen or approaching failure.

3.4 Operating Cycle Sequence

A preliminary estimate is made of the total life expectancy of the insulation at the chosen test temperature and the period of heat exposure is then chosen to be about 0.1 of this time as indicated in Table 1. After completion of each cycle of heat exposure, the motor is subjected to 48 hours of moisture. Impulse-surge voltage tests and other tests may be made immediately following the moisture portion of the cycle.

Line voltage of the heat-aging portion of the cycle should be applied in less than fifteen minutes after the moisture portion of the cycle. If this is impractical, then voltage checks of Section 3.3.4 should be applied immediately on completion of humidity portion of the cycle and heating portion of the cycle started as soon as practical. If valid comparisons are to be made with data from previous tests, drying-out time must be kept the same.

3.4.1 Heat Aging

Place the motor on reversals or start-stop sequence to heat to the aging temperature. This heat-up time is considered as part of the heat-aging time. Both the power supply and the motor housing should be grounded. After four hours of operation at this time, it is permissible to stop the motor for standardization measurements if desired. This may be done on the initial heat-aging run only. All subsequent measurements are then taken at the conclusion of the above steps.

3.4.2 Moisture

Humidification of each motor shall be for 48 hours unless a variation is permitted as a result of an investigation as in Section 3.3.3

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Annex

(Informative)

(This appendix is not part of IEEE Std 117-1974, Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery.)

The following are definitions for various recognized temperature classifications of insulation systems for electrical and electronic equipment:

Class A insulation system. A Class A insulation system is a system utilizing materials having a preferred temperature index[7] of 105 and operating at such temperature rises above stated ambient temperature as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized system test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class A insulation system is 105°C.

Class B insulation system. A Class B insulation system is a system utilizing materials having a preferred temperature index of 130 and operating at such temperature rises above stated ambient temperature as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized system test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class B insulation system is 130°C.

Class F insulation system. A Class F insulation system is a system utilizing materials having a preferred temperature index of 155 and operating at such temperature rises above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class F insulation system is 155°C.

Class H insulation system. A Class H insulation system is a system utilizing materials having a preferred temperature index of 180 and operating at such temperature rises above stated ambient temperature as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class H insulation system is 180°C.

Class N insulation system. A Class N insulation system is a system utilizing materials having a preferred temperature index of 200 and operating at such temperature rises above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class N insulation system is 200°C.

Class R insulation system. A Class R insulation system is a system utilizing materials have a preferred temperature index of 220 and operating at such temperatures above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class R insulation system is 220°C.

Class S insulation system. A Class S insulation system is a system utilizing materials having a preferred temperature index of 240 and operating at such temperatures abovestated ambient temperatures as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that

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[7] Temperature Index of materials as defined and explained in Section 1.21 of IEEE Std 1-1969 , is: “Temperature index is related to the temperature at which the material will provide a specified life as determined by test or as estimated from service experience.”

experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class S insulation system is 240°C.

Class C insulation system. A Class C insulation system is a system utilizing materials having a preferred temperature index of over 240 and operating at such temperatures above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. This system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy. The preferred temperature classification for a Class C insulation system is over 240°C.