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AC Overload Test for
Film Insulated Magnet Wire

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FOREWORD

This standards publication was prepared by the NEMA Magnet Wire Technical Committee and reflects the input of various industries that use magnet wire. All information in this publication is Authorized Engineering Information.

NEMA magnet wire publications are periodically reviewed by the NEMA Magnet Wire Section for revisions considered necessary to keep them current with technological changes. Proposed revisions should be submitted to:

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This standards publication was developed by the Magnet Wire Section. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Magnet Wire Section was composed of the following members:

American Wire Corporation—Sandy Hook, CT
AXA Cables—Monterrey, NL Mexico
The Bridgeport Insulated Wire Company—Bridgeport, CT
Elektrisola, Inc.—Boscawen, NH
Essex Group, Inc.—Fort Wayne, IN
Femco Magnet Wire Corporation—Franklin, IN
Magnetek Lighting Products—Gallman, MS
Nexans Magnet Wire, Inc.—Markham, ON Canada
PD Wire and Cable—Fort Wayne, IN
Rea Magnet Wire Company, Inc.—Fort Wayne, IN
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INTRODUCTION

When voltage is applied to magnet wire in a finished motor, transformer, coil, etc., current flows through the conductor. Mechanical or electrical overload of products using magnet wire can result in excessive current flow. If this condition is not relieved, the excess energy will be released as heat and failure will ultimately occur. Overload is directly related to the thermal degradation of the polymer film insulation on the magnet wire. This is known as overload failure. With all other factors remain constant, the time for overload failure is directly related to the chemistry and thermal stability of the film insulation.

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HISTORY

Various techniques have been used to measure overload characteristics of magnet wire insulations. Locked rotor, coilette, and twisted pair overload testing are among the most common methods. Note: The term "burnout" has historically been used incorrectly. It has been used interchangeably with the term "overload," where "overload" is a condition, and "burnout" or "overload failure" is the result of overload. The concept of twisted pair overload testing was first introduced during the 1960 National Conference on the Application of Electrical Insulation. Variations of this approach were expanded on over the next few years. By 1967 three different overload test methods were being considered by NEMA. The Magnet Wire Technical Committee had discontinued evaluation of the constant current and continuously rising current methods by 1969 and was concentrating on developing the stepwise advancing current procedure. After years of controversy surrounding the reliability of the test instrument and lack of repeatability of test results, the overload test procedure was finally dropped from NEMA MW 1000 Magnet Wire in 1983 as a periodic conformance test. It was agreed at that time that if a reliable test instrument could be designed, the procedure would become a document classified by NEMA as Authorized Engineering Information. The NEMA Magnet Wire Equipment Subcommittee was then assigned this task.

The Equipment Subcommittee and the manufacturer of the original standardized overload test equipment worked together to improve the equipment, leading to the introduction of a third model. Various round robin studies have been conducted, evaluating different magnet wire insulations and different sample preparation and testing procedures. It was determined that there were still considerable differences observed between pieces of testing equipment, but that the test was valuable as a relative test in ranking the overload capabilities of different insulation types.

In order that comparison can be made between overload data resulting from several types of tests, a "common denominator" is necessary. This most properly should be the watts delivered to the twisted pair of I^2R. However, due to the variation of resistance and the unknown heat loss to the surroundings, it was decided to use time as a replacement for R, as in I^2t. The overload figure of merit is the integrated sum of the I^2t values over the entire test with a suitable constant included to produce an overload figure of merit in the range of 0 to 20. The overload figure of merit or OFM can be expressed by the following equation:

$$OFM = \sum(I^2 t / 10^5)$$

Where:

I = the applied current in all phases of the test
t = time in seconds

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Section 1
GENERAL

1.1 SCOPE

This document describes a method and the equipment that may be used for determining the current overload due to resistance heating of 18 AWG heavy build film-insulated round copper wire.

1.2 REFERENCES

American Society for Testing Materials
100 Barr Harbor Drive
West Conshohoken, PA 19103

ASTM D 1676 *Standard Methods for Testing Film-Insulated Magnet Wire*

National Electrical Manufacturers Association
1300 N. 17th Street, Suite 1847
Rosslyn, Virginia 22209

MW 1000 *Magnet Wire*

1.3 DEFINITIONS

AC overload test: A test to determine the time before a step-wise increase in alternating current flow through a magnet wire conductor results in a temperature sufficient to cause dielectric failure.

Overload failure: The condition when the insulation is degraded sufficiently as to not maintain the electrical barrier between the conductors in the twisted pair. This is often used interchangeably with overload.

Overload figure of merit (OFM): The integrated sum of the I^2t values over the entire test with a suitable constant included to produce a value in the range of 0 to 20.

$$OFM = \sum(I^2 t / 10^5)$$

Where:
I = the applied current in all phases of the test
t = time in seconds.

1.4 EQUIPMENT DESCRIPTION

The test equipment should be designed to operate at conventional input voltage levels as required by the user. The test specimen should be completely enclosed by a cover, and an interlock safety switch should be supplied to prevent equipment operation when the cover is open.

The equipment should be designed with a 130 $\pm$ 10 VAC detection circuit across the twisted pair test specimen. The tester operation is interrupted when a 50 milliamp current flow is detected between the legs of the twisted pair sample. A timer, in 1-second increments, will provide the elapsed time from start until circuit interruption.

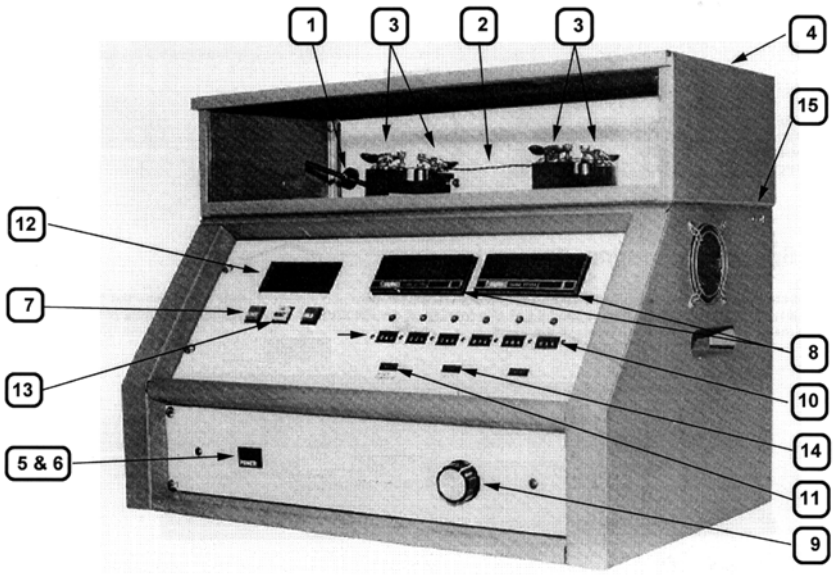
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The current supply is capable of maintaining a steady state AC current of between 30 and 50 amps through both strands of the specimen for a period of not less than 900 seconds. The tester should be capable of automatically increasing the currents in a step wise fashion every 180 seconds.

A minimum of five amperage steps should be provided with a means of setting, balancing, maintaining, and monitoring the currents being applied to the sample.

A method should also be provided so that a tension of 300 grams is consistently applied to the test specimen. Figure 1 is a drawing of such an instrument.

A dielectric twist fabricator is required to prepare the magnet wire specimens to be tested. Figures 2 and 3 show typical dielectric twist fabricators.



1. Load weight adjustment
2. Twisted pair specimen
3. Connector clamps
4. Apparatus lid
5. Power switch
6. Power light
7. Start button
8. Amp meter readout
9. Current balance adjustment
10. Amp meter readout
11. Reset light
12. Elapse time in seconds
13. Reset button
14. Overload fault light
15. Safety switch

Figure 1
TYPICAL AC CURRENT OVERLOAD TESTERS

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The laboratory equipment in Figure 2 is designed to quickly and simply fabricate twist samples for dielectric testing of wire sizes 16-44 AWG when used in accordance with NEMA standards publication MW 1000.

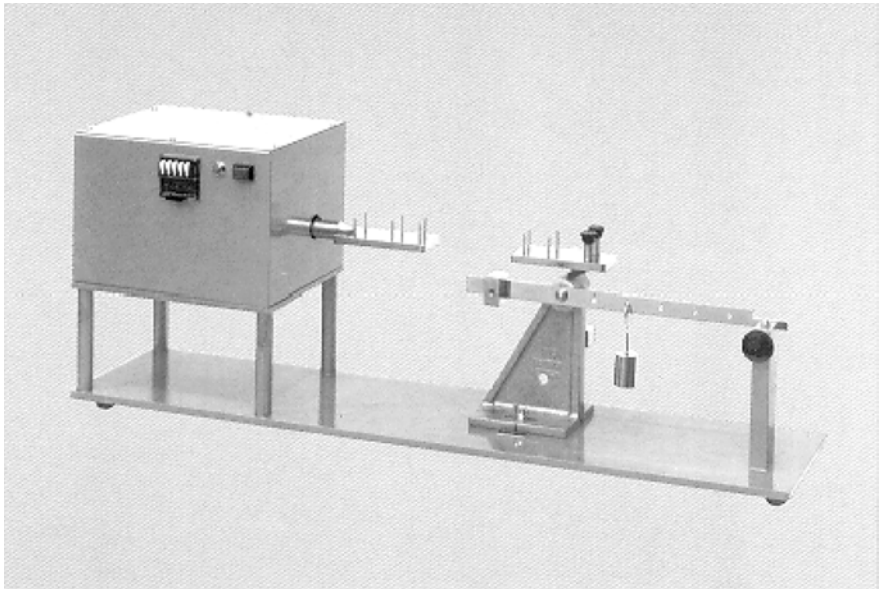


Figure 2
TYPICAL AUTOMATIC DIELECTRIC TWIST FABRICATOR

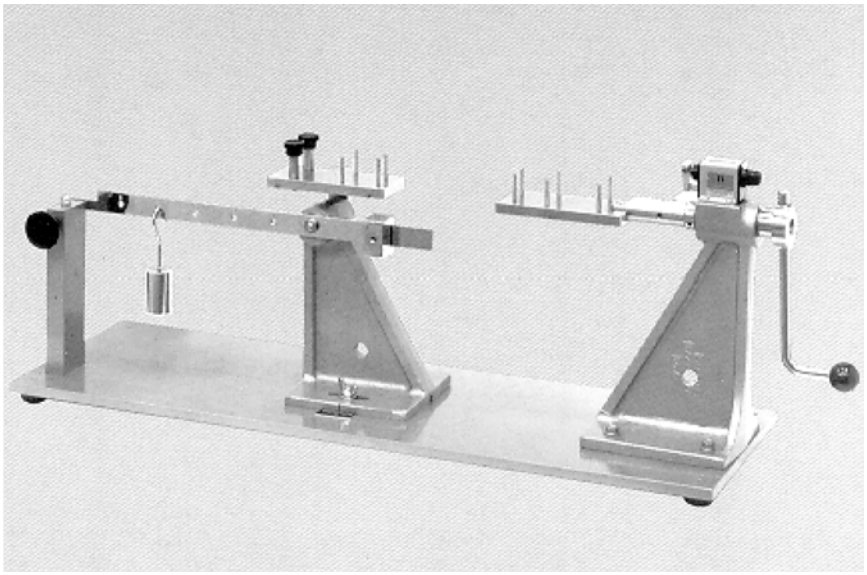


Figure 3
TYPICAL HAND OPERATED DIELECTRIC TWIST FABRICATOR

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To operate, determine the proper tension, place the sample on the twist mechanism, set the counter on the number of twists required, and press the start button. When the twist is completed, it is ready for testing on the dielectric breakdown tester. It will provide for additional specimens of the same specification.

The hand-operated unit in Figure 3 performs exactly the same function as the automatic unit, except that it can handle wire sizes 10-44 AWG and is manual.

1.5 DISCUSSION

AC overload varies greatly with the level of supplied current and chemistry of the wire insulation. Wire gauge and conductor metal may have an effect on the overload results. The tester described is only capable of evaluating a very limited range of wire diameters, 16-22 AWG copper conductors.

Table 1 lists some typical overload failure times for a variety of wire insulation types. Test Method 1 has been used to give maximum product differentiation for various magnet wire insulations. Test Method 2 was developed as an alternative procedure and adopted in ASTM D-1676.

Table 1
TYPICAL AC OVERLOAD TEST RESULTS
(AWG 18 COPPER HEAVY BUILD MAGNET WIRE)

Products ↓	**Condition 1**	**Condition 2**
Number of twists	8 twists	16 twists
A1–A5 Amp Steps	36/38/40/42/44	34/36/39/43/48
MW 16		
Mean Seconds	845	648
Std. Dev.	25.8	26.6
MW 35		
Mean Seconds	441	426
Std. Dev.	43.6	5.5
MW 30		
Mean Seconds	391	410
Std. Dev.	18.3	22.8
MW 24		
Mean Seconds	275	356
Std. Dev.	21.1	44.4
MW 15		
Mean Seconds	226	351
Std. Dev.	61.6	52.7
MW 26		
Mean Seconds	201	374
Std. Dev.	9.9	36.9
MW 75		
Mean Seconds	80	156
Std. Dev.	3.5	33.5

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Section 2
TEST METHOD
MAGNET WIRE OVERLOAD TESTER

2.1 SUMMARY OF METHOD

A controlled current (I) should be passed through both strands of a magnet wire twisted pair. The resistance heating of this specimen due to the current will result in a rapid rise in temperature and eventual thermal degradation of the polymer insulation. When the level of degradation is sufficient for 50 mA of leakage current at 130 $\pm$ 10 VAC to pass through the film, overload will be detected and the timer stopped at the elapse time (T) of the test.

2.2 SIGNIFICANCE

The magnet wire current overload tester is designed to rate the performance of various wire insulations under higher than normal operating temperatures brought about by current overloads. The time (T) in seconds should relate to the performance of these polymer insulating films under overload conditions in actual field operations. Test results should allow magnet wire producers and users to evaluate the relative performance of various magnet wire products.

2.3 SAFETY STATEMENTS

WARNING: *Mechanical Hazard*—This test uses mechanical equipment, the twist fabricator, which may expose the worker to mechanical hazards. Care should be exercised to protect the eyes, fingers, hands, and other body parts from injury.

WARNING: *Electrical Hazard*—This test uses equipment with high voltage and high amperage. It is important that the equipment be designed to comply with good engineering practices, with safety being an integral part of the design. There must be a safety switch on the lid, which prevents the energizing of the sample if the lid is open. To avoid shock, necessary precautions should be taken and the equipment manufacturers' recommendations should be followed.

WARNING: *Thermal Hazard*—After exposure to the high currents, the twisted pair specimens will be hot. Precautions should be taken in handling these specimens to avoid skin burns.

WARNING: *Chemical Hazard*—Volatile components evolved during the heat degradation of the polymer insulation should be vented to prevent exposure of the operator to these fumes. Information and instructions contained in the Material Safety Data Sheet (MSDS) for magnet wire products should be followed.

2.4 PREPARATION OF THE TEST SPECIMEN

Load the dielectric twist fabricator with an approximately 30 inch long sample of 18 AWG copper magnet wire to be tested. Apply three pounds of tension and set the counter for the desired number of twists. Make the twisted pair sample either automatically by pressing the button or manually depending on the twist fabricator being used. After the twist is made, there should not be any sharp bends in the specimen or physical damage to the insulation. Remove the specimen from the twist fabricator and cut the legs of the twisted pair to the proper length of the overload equipment. Remove the insulation by a mechanical stripping device to expose the bare wire so proper electrical connections can be made to the sample.

2.5 TEST PROCEDURE

Turn on the main power switch (5) to the overload test equipment, and warm up the unit if it is required. See the manufacturer's manual for this specific procedure.

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Reset the timer and current settings on the overload test equipment by pushing the reset button (13). Open the lid (4), and secure the specimen in place making electrical connections with the clamps (3).

Adjust the current step controls (10) (A-1 through A-5) to the desired amperage setting while also observing the associated time intervals listed in Table 2.

Close the lid and push the start button (7) to begin the test. After the current flow to the two wires has stabilized at the first amperage setting as indicated by amperage meters (8) and (10), adjust the current balance (9) until both meters are equal.

Upon completion of the test as indicated by the fault light (14), record the elapse time which is captured in seconds on the timer display (12). Push the reset button and wait until the reset is complete.

Have ventilation available to remove the fumes trapped inside of the lid of the overload tester. Open the hood and carefully remove the test specimen with needle nose pliers. Caution: The twisted pair sample remains hot for some time after the test is completed.

2.6 TEST REPORT

Repeat this procedure, as a minimum of three specimens of each wire insulation being evaluated should be tested. The test report should include: wire identification, test conditions used, time to failure for each individual specimen, the mean time in seconds, and calculated OFM.

Table 2
STEPWISE INCREASES IN CURRENT AND CORRESPONDING TIME INTERVALS

Current Step	Time, Seconds	Test Condition 1 Current, amperes	Test Condition 2 Current, amperes
A-1	0–180	36	34
A-2	181–360	38	36
A-3	361–540	40	39
A-4	541–720	42	43
A-5	721–900	44	48

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