NEMA Standards Publication

NEMA MW 750-2009 (R2014)

Standard for Dynamic Coefficient of Friction of Film-Insulated Magnet Wire

National Electrical Manufacturers Association

NEMA MW 750-2009 (R2014)

Dynamic Coefficient of Friction of Film-Insulated Magnet Wire

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

www.nema.org

NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by a consensus among persons engaged in its development at the time it was approved. Consensus does not necessarily mean there was unanimous agreement among every person participating in the development process.

The National Electrical Manufacturers Association (NEMA) standards and guideline publications, of which the document herein is one, are developed through a voluntary standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. Although NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the documents, nor does it independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its standards and guideline publications.

NEMA disclaims liability for any personal injury, property, or other damages of any nature, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, express or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any particular purpose(s) or need(s). NEMA does not undertake to guarantee the performance of any individual manufacturer's or seller's products or services by virtue of this standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstance. Information and other standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health- or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

CONTENTS

FOREWORD

NEMA MW 750-2009 (R2014) was prepared by the NEMA Magnet Wire Technical Committee.

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

Senior Technical Director, Operations
National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

This Standards Publication was approved by the NEMA Magnet Wire Section. Approval of a standard does not necessarily imply that all Section members voted affirmatively or participated in its development. At the time of approval, the Magnet Wire Section was composed of the following members:

Alconex Specialty Products	Fort Wayne, IN
CONDUMEX	Mexico City, Mexico
Elektrisola, Inc.	Boscawen, NH
Magnekón	San Nicolas de los Garza, NL, Mexico
MWS Wire Industries	Westlake Village, CA
Rea Magnet Wire Company	Fort Wayne, IN
Superior Essex	Fort Wayne, IN

This document was approved as Authorized Engineering Information on 2014.

INTRODUCTION

As magnet wire is transferred from its packaging to coils, the designed path takes the wire over, around, and through guides, blocks, corners, and so forth, all of which are intended to help place the wire at the designed location in the coil.

The force required to pull the wire through the designed winding path, exclusive of the bending force, is that which is necessary to overcome the friction developed between the magnet wire and the various surfaces that come in contact with the wire. This force is directly related to the surface characteristics of the film insulation, the contact surfaces, and the applied lubrication.

HISTORY

Various devices have been used to measure the coefficient of friction of magnet wire. Several were discussed in Paper #4 at the NEMA session of the 1971 Electrical/Electronics Insulation Conference.

In 1961, Parussel described a tester to measure the coefficient of friction of film-insulated magnet wire. The design was subsequently standardized and incorporated in German Standards Institute (DIN) specifications. A tester similar to the Parussel design made by Excel Industries was later demonstrated to the NEMA Magnet Wire Technical Committee. At that time, an interest was expressed in redesigning the tester to simplify the operation.

In 1973, NEMA Engineering Bulletin No. 4 was developed by the NEMA Magnet Wire Section to describe the subject of coefficient of friction testing and provide a test method, including the final equipment description. Eventually, the original supplier of this equipment discontinued its interest in supplying equipment, and the Research Department of the Indiana Institute of Technology supplied a new design. In 1978, this test method was introduced for discussion at a meeting of International Electrotechnical Commission (IEC) Technical Committee 55, *Winding Wires*.

One of the critical elements of the test procedure was the selection of the surface that would be in contact with the wire specimen. Supplying and maintaining a prescribed steel surface ground to the applicable specifications was found to be cost prohibitive. As a proposed solution, representatives from The Netherlands recommended the use of synthetic sapphire elements for the load block surface. Their experience indicated that these synthetic sapphires would provide excellent life at low cost. The elements were subsequently adopted for the test surface.

Earlier versions of this equipment used a dynamometer to measure the tangential force (F_d). Since the value on the dynamometer continually varies, it was necessary for the operator to estimate the average force that occurs during the test. More precision and accuracy are required so that the gage repeatability and reproducibility can be improved for this test. The dynamometer has been replaced with a force transducer selected for this work, which is a linear variable differential transformer (LVDT). The data are collected from the pressure transducer readout by computer or microprocessor. Statistical analysis can be performed on this data set resulting in mean, min, max, and standard deviation.

< This page is intentionally left blank >

SECTION 1
GENERAL

1.1 SCOPE

This document describes a method and the equipment used for determining the dynamic coefficient of friction of film-insulated round magnet wire of sizes 14-44 AWG.

1.2 DEFINITION OF FRICTION

Friction is the resistance to motion existing when a solid object is moved tangentially over the surface of another solid object which it touches, or when an attempt is made to produce such a motion. If a normal load (L) presses two surfaces together, a tangential force may be applied up to some limiting value X, and the surfaces will still remain at rest. Sliding only starts when the tangential force exceeds the static force F_s. Almost as soon as the motion starts, the tangential force takes on a characteristic value F_d, which always acts in the direction opposite to the relative velocity of the surfaces. The value of F_s is often approximately 30 percent larger than F_d, but sometimes F_s equals F_d. The ratio F_s/L is the static coefficient of friction μ_s, while the ration F_d/L is the dynamic coefficient of friction μ_d. The coefficients of friction are essentially a material property of the contacting surfaces and of the contaminants and other films (such as lubricants) at their interface. The coefficients of friction are independent of the load and the contact area; the dynamic coefficient of friction is also independent of the sliding velocity. This last law does not apply when the presence of a lubricant creates viscous flow in the intermediate liquid layer. In this case, the dynamic coefficient of friction normally increases with increasing sliding velocity.

1.3 EQUIPMENT DESCRIPTION

The design of typical test equipment is illustrated in **FIGURE 1**. **FIGURE 2** contains detailed drawings of synthetic sapphires and **PHOTO 1** is a photograph of the load block. The tester is supplied with a wire guiding system and a take-up, which pulls the wire over the test bed at 50 ft/min (15 m/min) as shown in **PHOTO 2**. The test block is aligned parallel with the test bed and the test weights are perpendicular to the wire specimen.

As the wire is pulled under the test block (synthetic sapphires), the friction between the wire surface and the sapphire surface develops a longitudinal force, which is transferred to the measuring system by a shaft supported by two sets of linear ball bearings in contact with the measuring system. The force indicated by the measuring system is divided by the load on the test surface to obtain the dynamic coefficient of friction.

The measuring system in **FIGURE 1** shows the dynamic coefficient of friction tester with a load cell in place to measure the force. An LVDT may also be used to measure the force instead of a load cell. The electrical output from the force measurement device is fed into a computer or into a microprocessor that collects data measurements, usually 1000 points. Statistics are performed on this data set so that proper interpretation of the results can be made.

1.4 DISCUSSION

Values for the dynamic coefficient of friction are characteristic of the type of lubrication and the magnet wire specimen surface. The dynamic coefficient of friction values are generally not dependent on wire size. Wire lubricated with a mineral oil typically will have a mean dynamic coefficient of friction in the range of 0.09 to 0.16. Wire lubricated with a paraffin wax will typically have a mean dynamic coefficient of friction ranging from 0.03 to 0.06 and will be more consistent in value as evidenced by a lower standard