NEMA Standards Publication

NEMA MS 4

Acoustic Noise Measurement Procedure for Diagnostic Magnetic Resonance Imaging Devices

National Electrical Manufacturers Association

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Preamble

This is one of a series of test standards developed by the medical diagnostic industry for the measurement of parameters governing the safety of Magnetic Resonance (MR) Imaging (MRI) systems. These test standards are intended for the use of equipment manufacturers, testing houses, prospective purchasers, and users alike.

Manufacturers are permitted to use these standards for the determination of system performance specifications. This standardization of performance specifications is of benefit to the prospective equipment purchaser. The parameters supplied with each NEMA measurement serve as a guide to those factors that can influence the measurement. These standards can also serve as reference procedures for acceptance testing and periodic quality assurance.

It must be recognized, however, that not all test standards lend themselves to measurement at the installation site. Some test standards require instrumentation better suited to factory measurements, while others require the facilities of an instrumentation laboratory to ensure stable test conditions necessary for reliable measurements.

The NEMA test procedures shall be carried out using the normal clinical operating mode of the system. For example, standard calibration procedures and standard reconstruction processes shall be used. No modifications to alter test results shall be used unless otherwise specified in these standards.

The NEMA Technical Committee of the MR Section has identified a set of key magnetic resonance safety parameters. This standard describes the measurement of one of these parameters.

Equivalence

It is intended and expected that manufacturers or others who claim compliance with these NEMA standard test procedures for the determination of safety parameters shall have carried out the tests in accordance with the procedures specified in the published standards.

In those cases where it is impossible or impractical to follow the literal prescription of a NEMA test procedure, a complete description of any deviation from the published procedure must be included with any measurement claimed to be equivalent to the NEMA standard. The validity or equivalence of the modified procedure will be determined by each reader.

Uncertainty of the Measurements

The measurement uncertainty of the safety parameter determined using this standard is to be reported, together with the value of the parameter. Justification for the claimed uncertainty limits shall also be provided by a listing and discussion of sources and magnitudes of error.

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Foreword

This standards publication is classified as a NEMA standard unless otherwise noted. It describes the test conditions and parameters that approximate the worst case acoustic noise levels that a particular magnet/gradient system combination produces when using pulsed gradient waveforms. This standard also describes how the acoustic noise levels are to be measured. In the absence of specific guidelines for sound level exposure with MR imaging equipment, this procedure references the OSHA guidelines for acoustic noise exposure and the IEC standards for sound level meters.

This standards publication has been developed by the Magnetic Resonance Section of the National Electrical Manufacturers Association. User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

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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 section was composed of the following members:

Computer Imaging Reference Systems—Norfolk, VA
GE Healthcare, Inc.—Milwaukee, WI
Hitachi Medical Systems America, Inc.—Twinsburg, OH
Medipattern Corp.—Toronto, Ontario
Neusoft Medical Systems, USA, Inc.—Houston, TX
Philips Healthcare—Bothell, WA
Siemens Healthcare, Inc.—Malvern, PA
Time Medical—Singapore
Toshiba America Medical Systems—Tustin, CA

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Introduction

Current passing through a wire placed in a magnetic field will generate a force orthogonal to both the direction of the field and the current (Lorentz force). Acoustic noise in MR imaging is caused by motion of the gradient coils and attached structures when a time-varying current is passed through the coils.

At a given magnetic field strength, the loudest noise will occur when pulsed waveforms are applied simultaneously to all three gradient coils at maximum amplitude and at a system-dependent resonant frequency. Though this condition may not be realized for most clinical imaging sequences, it nonetheless represents the worst case condition and is defined here as the Maximum Gradient Acoustic Noise (MGAN) of the system. The Maximum Clinical Acoustic Noise (MCAN) of the system is defined as the clinical imaging condition that produces the greatest acoustic noise. Typically, this occurs with pulse sequences that use high gradient current duty cycles and high gradient current amplitudes near system-dependent resonant frequencies.

To determine the acoustic noise of a system, either the MGAN or the MCAN can be measured and reported. The choice of using the MGAN or the MCAN is left to the discretion of the user.

Rationale

The sound generated by an MR system usually consists of a series of repetitive impulses. The relevant safety parameters required to characterize such a noise are the unweighted peak sound pressure level (L_{peak}) and the time integral of the A-weighted sound pressure level (L_{Aeq}). In MR applications, the peak sound pressure level is dependent on the peak amplitude of the individual pulses while the time integral of the A-weighted sound pressure level is dependent on the continuous exposure to a series of such pulses. This document describes methods to measure the worst case L_{peak} and L_{Aeq} of an MR System.

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Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 SCOPE

The purpose of this NEMA Standards Publication is to provide methods to determine the acoustic noise level of an MR system. Two measurement procedures are defined, Maximum Gradient Acoustic Noise (MGAN) and Maximum Clinical Acoustic Noise (MCAN).

This procedure has been designed for measuring peak sound pressure levels (SPL) up to 140 dB. Above 140 dB, the use of more sophisticated equipment and methods may be required.

1.2 REFERENCED STANDARDS

The following publications are adopted as indicated by reference in this standards publication. The mailing address of each referenced organization is also provided.

International Electrotechnical Commission
1, Rue de Varembe
Geneva, Switzerland

IEC 61672-1, 2002 *Sound Level Meters*

IEC 60601-2-33, 2002 *Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis*

Occupational Safety and Health Administration
Department of Labor
200 Constitution Avenue, N.W.
Washington, D.C. 20210

29 CFR 1910.95 *Occupational Noise Exposure*

American National Standards Institute
25 West 43rd Street
New York, NY 10036

ANSI S1.4-1983 *Sound Level Meters*

1.3 DEFINITIONS

1.3.1 SPL (Sound Pressure Level)

The SPL is defined as ten times the common logarithm of the ratio of the square of the measured sound pressure to the square of the standard reference pressure of 20 micropascals.

1.3.2 A-weighting

This refers to SPL frequency weighting. The ear does not respond uniformly to all frequencies. SPL measurements made with an A-weighting correspond to noise levels that are similar to those heard by the human ear (IEC 61672).

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