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INTERNATIONAL STANDARD

Superconductivity –
Part 8: AC loss measurements – Total AC loss measurement of round superconducting wires exposed to a transverse alternating magnetic field at liquid helium temperature by a pickup coil method

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FOREWORD

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International Standard IEC 61788-8 has been prepared by IEC technical committee 90: Superconductivity.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

– extending the applications of the pickup coil method to the a.c. loss measurements in metallic and oxide superconducting wires with a round cross section at liquid helium temperature,
– u1 in accordance with the decision at the June 2006 IEC/TC90 meeting in Kyoto.

The text of this standard is based on the following documents:

FDIS	Report on voting
90/243/FDIS	90/249/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61788 series, under the general title: *Superconductivity*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

Magnetometer and pickup coil methods are proposed for measuring the AC losses of composite superconducting wires in transverse time-varying magnetic fields. These represent initial steps in standardization of methods for measuring the various contributions to AC loss in transverse fields, the most frequently encountered configuration.

It was decided to split the initial proposal mentioned above into two documents covering two standard methods. One of them describes the magnetometer method for hysteresis loss and low frequency (or sweep rate) total AC loss measurement, and the other describes the pickup coil method for total AC loss measurement in higher frequency (or sweep rate) magnetic fields. The frequency range is 0 Hz to 0,06 Hz for the magnetometer method and 0,005 Hz to 60 Hz for the pickup coil method. The overlap between 0,005 Hz and 0,06 Hz is a complementary frequency range for the two methods.

This standard covers the pickup coil method. The test method for standardization of AC loss covered in this standard is partly based on the Versailles Project on Advanced Materials and Standards (VAMAS) pre-standardization work on the AC loss of Nb-Ti composite superconductors [1][1)].

1) Numbers in square brackets refer to the bibliography.

SUPERCONDUCTIVITY –

Part 8: AC loss measurements – Total AC loss measurement of round superconducting wires exposed to a transverse alternating magnetic field at liquid helium temperature by a pickup coil method

1 Scope

This part of IEC 61788 specifies the measurement method of total AC losses by the pickup coil method in composite superconducting wires exposed to a transverse alternating magnetic field. The losses may contain hysteresis, coupling and eddy current losses. The standard method to measure only the hysteresis loss in DC or low-sweep-rate magnetic field is specified in IEC 61788-13 [2].

In metallic and oxide round superconducting wires expected to be mainly used for pulsed coil and AC coil applications, AC loss is generated by the application of time-varying magnetic field and/or current. The contribution of the magnetic field to the AC loss is predominant in usual electromagnetic configurations of the coil applications. For the superconducting wires exposed to a transverse alternating magnetic field, the present method can be generally used in measurements of the total AC loss in a wide range of frequency up to the commercial level, 50/60 Hz, at liquid helium temperature. For the superconducting wires with fine filaments, the AC loss measured with the present method can be divided into the hysteresis loss in the individual filaments, the coupling loss among the filaments and the eddy current loss in the normal conducting parts. In cases where the wires do not have a thick outer normal conducting sheath, the main components are the hysteresis loss and the coupling loss by estimating the former part as an extrapolated level of the AC loss per cycle to zero frequency in the region of lower frequency, where the coupling loss per cycle is proportional to the frequency.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-815:2000, *International Electrotechnical Vocabulary (IEV) – Part 815: Superconductivity*

3 Terms and definitions

For the purposes of this document, the following terms and definitions, as well as those of IEC 60050-815, apply.

3.1
AC loss
P
power dissipated in a composite superconductor due to application of time-varying magnetic field or electric current

[IEC 60050-815:2000, 815-04-54]

3.2
hysteresis loss
P_h
loss of the type whose value per cycle is independent of frequency arising in a superconductor under a varying magnetic field

NOTE This loss is caused by the irreversible magnetic properties of the superconducting material due to pinning of flux lines.

[IEC 60050-815:2000, 815-04-55]

3.3
eddy current loss
P_e
loss arising in the normal conducting matrix of a composite superconductor or the structural material when exposed to a varying magnetic field, either from an applied field or from a self-field

[IEC 60050-815:2000, 815-04-56, modified]

3.4
(filament) coupling (current) loss
P_c
loss arising in multi-filamentary superconducting wires with a normal matrix due to coupling current

[IEC 60050-815:2000, 815-04-59]

3.5
(filament)coupling time constant
τ
characteristic time constant of coupling current directed perpendicularly to filaments within a strand for low frequencies

[IEC 60050-815:2000, 815-04-60]

3.6
shielding current
current induced by an external magnetic field applied to a superconductor and which includes coupling current and eddy current after a field change in composite superconductors

3.7
critical (magnetic) field strength
H_c
magnetic field strength corresponding to the superconducting condensation energy at zero magnetic field strength

[IEC 60050-815:2000, 815-01-21]

3.8
magnetization (of a superconductor)
magnetic moment divided by the volume of the superconductor

NOTE The macroscopic magnetic moment is also equal to the product of the shielding current and the area of the closed path in a composite superconductor together with the magnetic moment of any penetrated trapped flux.

3.9
magnetization method for AC loss
method to determine the AC loss of materials from the area of the loop of the magnetization curve

NOTE When pickup coils are used to measure the change in flux, which is then integrated to get the magnetization of stationary coiled specimens, the method is called the pickup coil method.

[IEC 60050-815:2000, 815-08-15, modified]

3.10
pickup coil method
method to determine the AC loss of materials by evaluating electromagnetic power flow into the materials by pickup coils

NOTE The pickup coil arrangement consists essentially of a primary winding (a superconducting magnet supplied with a time varying current) and a pair of secondary windings (pickup coils), one of which (the main pickup coil) contains the specimen to be measured and the other (the compensation coil) plays two roles: 1) it compensates the signal from the main pickup coil when empty; 2) it supplies the field sweep information.

Here the coaxial and concentric arrangement of the pickup coils as shown in Figure 1 is used as the standard one for the AC loss measurement. In order to obtain sufficient volume of the wire specimen to be measured and at the same time to expose it to a transverse magnetic field, it must be wound into a coil. The specimen so prepared is also referred to as the "coiled specimen".

3.11
background loss
apparent loss obtained by the pickup coil method in the case where no specimen is located inside the pickup coils

NOTE The background loss gives the experimental error in the system of the AC loss measurement by the pickup coil method. It results from phase shift of electrical signal in the compensation process, an additional magnetic moment induced in many components of experimental hardware, and external noise. The background loss can be reduced by adjusting the experimental setup and compensated by subtracting it from measured AC loss as shown in 7.4.2.

3.12
effective cross-sectional area of the coiled specimen
total specimen volume divided by the larger of the specimen coil height or the pickup coil height

3.13
bending strain
ε_b
strain in percent arising from pure bending defined as $\varepsilon_b = 100\ r / R$, where r is a half of the specimen thickness and R is the bending radius

[IEC 60050-815:2000, 815-08-03]

NOTE In the pickup coil method, the coiled specimen by react and wind technique is prepared with an attention to the permissive level of bending strain.

3.14
***n*-value (of a superconductor)**
n
exponent obtained in a specific range of electric field strength or resistivity when the voltage current $U(I)$ curve is approximated by the equation $U \propto I^n$

[IEC 60050-815:2000, 815-03-10]

4 Principle

The test consists of applying an alternating transverse magnetic field to a specimen and detecting the magnetic moment of shielding currents induced in the specimen by means of pickup coils for the purpose of estimating the AC losses defined in 3.1.