INTERNATIONAL STANDARD

ISO 21494

First edition
2019-02

Space systems — Magnetic testing

Systèmes spatiaux — Essais magnétiques

Reference number
ISO 21494:2019(E)

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Published in Switzerland

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Foreword

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The magnetic torque, which is created by the interaction between a geomagnetic field and the remnant magnetic moment of the spacecraft, has considerable disturbance on the flight attitude of the spacecraft. The magnetic field of the spacecraft itself will affect a magnetometer scientific payload sensitive to spacecraft-induced magnetic fields. Thus, magnetic tests on Earth-orbiting or interplanetary spacecraft missions with very stringent requirements on magnetic cleanliness are needed in order to ensure that the spacecraft's inherent magnetic properties meet the design goals.

This document provides magnetic test requirements and methods for measuring and evaluating magnetic properties of the spacecraft. The magnetic test methods outlined in this requirements document are effective enough to verify the compliance of magnetic requirements imposed on the spacecraft and to ensure the success of spacecraft flight missions free of magnetic interference and magnetic contamination due to magnetic materials and induced current-generated magnetic fields of the spacecraft.

Space systems — Magnetic testing

1 Scope

This document specifies magnetic test methods including magnetic field test methods, magnetic moment test methods, magnetization and demagnetization test methods and magnetic compensation test methods. This document is applicable to magnetic tests on several levels: spacecraft-level, subsystem-level and unit-level.

This document gives guidelines for conducting magnetic tests both in zero-magnetic field environment provided by magnetic test facilities and in the presence of the geomagnetic field environment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 14644-1, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
equipment under test
EUT
object under the magnetic test on system, subsystem or unit level generally

3.2
remnant magnetic moment
magnetic moment of the EUT in a zero-magnetic field environment when the EUT is not in a powered on operational mode, that is mostly due to the residual magnetic fields from spacecraft materials

3.3
stray magnetic moment
magnetic moment of the EUT in zero-magnetic field environment when the EUT is in a powered on operational mode

3.4
induced magnetic moment
additional magnetic moment of the EUT generated in an external magnetic field environment when the EUT is not in a powered on operational mode, that is mostly due to soft magnetic materials that easily magnetize in an external magnetic field

3.5
remnant magnetic field
magnetic field produced by the remnant magnetic moment of the EUT as measured at a distance from the magnetic moment location and falls off as the inverse cube of the distance from the magnetic moment location

3.6
stray magnetic field
magnetic field produced by the stray magnetic moment of the EUT in a powered on operational mode

3.7
induced magnetic field
magnetic field produced by the induced magnetic moment of the EUT and mostly due to soft magnetic materials that easily magnetize in an external magnetic field

3.8
zero-magnetic field
magnetic field within a certain volume reduced to very low levels when the geomagnetic field is compensated by a cancelling magnetic field provided by a typical main coil system such as a Helmholtz coil or Braunbeck coil system

3.9
controllable magnetic field
magnitude of magnetic field within a certain volume that is controlled by adjusting electric current of a typical main coil system such as a Helmholtz coil or Braunbeck coil system

3.10
magnetization field
magnetic field used for magnetization tests of the EUT when exposed to a uniform and steady magnetic field for a certain period of time and provided by a magnetization and demagnetization coil system

3.11
demagnetization field
magnetic field used for demagnetization tests of the EUT by exposing them in an alternating sinusoidal magnetic field with a continuously attenuated amplitude and provided by a magnetization and demagnetization coil system

3.12
main coil system
coil system, usually composed of Helmholtz or Braunbeck coils and energized by power supplies, that can provide a zero-magnetic field environment within a given volume of the coil system or that can generate a controllable magnetic field environment by applying the system with calibrated electric current levels

3.13
magnetization and demagnetization coil system
coil system, usually composed of a Helmholtz coil and energized by power supplies, that can provide magnetization and demagnetization fields by applying the system with electric current

3.14
magnetic field stability
variation of the magnetic field at the same location during a certain period

3.15
magnetic field homogeneity
ratio (given in %) of the maximum magnetic field deviation in the volume divided by the magnetic field at the centre of the volume, or the range (given in ± values) of the maximum magnetic field deviation in the volume

3.16
homogeneous volume of magnetic field
spatial volume that satisfies the requirement of magnetic field homogeneity

3.17
soft magnetic material
ferromagnetic material with low field strength (coercivity) that can be magnetized and demagnetized easily

EXAMPLE Invar and Kovar materials.

3.18
hard magnetic material
ferromagnetic material with high field strength (coercivity) that cannot be demagnetized easily

EXAMPLE Permanent magnets.

3.19
compensation magnet
permanent magnet used for magnetic compensation

4 Abbreviated terms

EUT	Equipment Under Test
IMF	Initial Magnetic Field
RMF	Remnant Magnetic Field
SMF	Stray Magnetic Field
IDMF	Induced Magnetic Field
IMDM	Initial Magnetic Dipole Moment
RMDM	Remnant Magnetic Dipole Moment
SMDM	Stray Magnetic Dipole Moment
IDMDM	Induced Magnetic Dipole Moment
MFAM	Magnetic Field After Magnetization
MFAD	Magnetic Field After Demagnetization
MDMAM	Magnetic Dipole Moment After Magnetization
MDMAD	Magnetic Dipole Moment After Demagnetization

5 Requirements

5.1 EUT requirements

When a spacecraft requires the protection of a magnetic sensitive payload such as a magnetometer sensor or plasma search coil and the control of magnetic torque for attitude control, a magnetic

cleanliness control plan shall be instituted based on properties and constraints, which are related to mission objectives. This plan should:

a) Prepare magnetic control guidelines, outlining examples on how to control magnetic materials, what materials are acceptable, how to perform tests and to model the overall spacecraft based on magnetic moment results.

b) Establish a magnetic moment budget or allocation list for parts, units, subsystems and spacecraft in the actual magnetic field environment on the orbit, such as the magnetic moment or field of the EUT at low levels of magnetic field and the delta of magnetic moment or field between unpowered and powered mode.

c) Include the steps for reducing magnetic sources. Outline of detailed proven methods for the reduction and cancellation of magnetic fields, elimination of magnetic materials replaced with non-magnetic materials etc.

d) Define magnetic test methods and requirements for parts, units, subsystems and spacecraft.

The steps for reducing magnetic sources include avoiding hard magnetic materials, limiting the use of soft magnetic materials, applying self-compensating configuration of magnetic sources, designing all current carrying and electrical grounding elements to minimize stray magnetic field and stray magnetic moment by self-cancelling methods including solar array backwiring.

5.2 Test requirements

In order to check and control the magnetic properties of the EUT, the magnetic test should be conducted. An example of magnetic test flow is:

a) IMF and IMDM measurement.

b) Magnetization test.

c) MFAM and MDMAM measurement.

d) Demagnetization test.

e) MFAD and MDMAD measurement.

f) Magnetic compensation test.

g) RMF, SMF, RMDM and SMDM measurement after magnetic compensation.

h) IDMF and IDMDM measurement.

References [1]–[5] recommend the magnetic test requirements.

6 Test items

Magnetic test items described in this document refer to magnetic field test, magnetic moment test, magnetization test, demagnetization test and magnetic compensation test.

Magnetic test items are tailored based upon magnetic test requirements for each unique mission or plan. The logic flow of test items is defined according to magnetic requirements imposed for each specific spacecraft.

The magnetic field of the spacecraft will affect precision measurements of magnetic sensitive payload such as magnetometers or plasma wave search coils. Therefore, the spacecraft has requirements on magnetic cleanliness imposed by the sensitivity of the scientific payloads requiring low levels of magnetic fields. According to the requirements, the magnetic field test shall be conducted to predict magnetic cleanliness level of the spacecraft with the goal of meeting the reduced magnetic field levels needed by the sensitive payloads.

The magnetic disturbance torque acting on the spacecraft is equal to the cross-product of the remnant magnetic moment of the spacecraft and the ambient magnetic flux density. If required, the magnetic moment test shall be conducted to predict the flight attitude changes caused by the magnetic disturbance torque of the spacecraft.

Magnetization and demagnetization tests shall be conducted if the spacecraft is easily influenced by the external magnetic fields while on the orbit. Demagnetization tests shall be conducted as a final step in the magnetic testing process well before its launching if the spacecraft may have inadvertently become magnetized after the magnetic tests.

Magnetic compensation tests shall be conducted if the magnetic properties of the spacecraft do not satisfy the overall magnetic cleanliness requirements.

The spacecraft-level magnetic tests for qualification and acceptance are recommended to be conducted after the vibration test. This provides an opportunity to eliminate or reduce any magnetization of the flight hardware caused by the magnetic fields associated with the vibration shaker test facilities, especially for a spacecraft with magnetically sensitive payloads.

References [6]–[7] provide examples of actual implementation of the approach in recent missions requiring magnetic cleanliness.

7 Test room environments

The requirements of test room environments are as follows:

a) Temperature, cleanliness and humidity shall meet customer's requirements.

b) The air cleanliness in test room shall comply with ISO 14644-1.

8 Magnetic field test methods

8.1 Test purpose

The purpose of magnetic field test is to measure and evaluate magnetic field of the EUT and verify whether it conforms to magnetic field requirements of the EUT.

Magnetic field test methods include RMF, SMF and IDMF measurements of the locations sensitive to magnetic field on the EUT and RMF, SMF and IDMF distribution measurements on a sphere around the EUT.

RMF is mainly generated by magnets, electro-magnets in off-state or residual perm-up (or magnetization) due to hysteresis of soft magnetic materials in the EUT. SMF is generated by electric current flowing within the EUT when in a powered on operational mode. RMF and SMF are independent of the environmental magnetic field. RMF and SMF tests should be conducted in zero-magnetic field.

IDMF is mainly generated by the soft magnetic materials in the EUT. If an external magnetic field is applied to the EUT, the magnetic field measurement result of the EUT may be different in zero-magnetic field. This difference is called IDMF. IDMF disappears when the external field is ceased. IDMF test should be conducted in the controllable magnetic field.

8.2 Test facilities

The test facilities are mainly composed of the main coil system, turntable, fixtures/brackets and magnetic field measuring instruments or test magnetometer sensors. The main coil system shall be able to provide the zero-magnetic field or controllable magnetic field within a given volume where the EUT will be located in the centre of the turntable. The controllable magnetic field also can be provided by the additional coil system. The main coil system access opening shall be large enough to allow the

transit of the EUT and its non-magnetic fixture and/or holding brackets into the zero-magnetic field volume. The magnitude, homogeneity and stability of the zero-magnetic field and the controllable magnetic field shall satisfy test requirements.

The turntable shall be rotated from 0° to 360° along the vertical axis, with all angles easily identifiable. The ball bearing capacity of the turntable shall be more than the total weights of the EUT and its fixed bearing. Proof loading of the turntable shall be conducted prior to the test to ensure proper rotation without galling the bearings. The turntable is not required for the magnetic field measurement of locations sensitive to magnetic field on the EUT. The turntable shall be required for the magnetic field distribution measurement on a sphere around the EUT.

The test facilities shall be made of non-magnetic materials. Copper, aluminium, titanium, brass, treated wood and other non-metallic materials are recommended.

The fluxgate magnetometers are recommended for measuring the magnetic field of the EUT. The measurement range and resolution of the magnetometers should be adapted to the required results and accuracy of the magnetic test.

The test facilities and measurement instruments shall be calibrated periodically or in advance of testing and used during its useful-life.

8.3 Procedures for magnetic field test

Two procedures for magnetic field test methods in Annex A are provided as examples: (1) test procedure for locations sensitive to magnetic field on the EUT and (2) test procedure for magnetic field distribution measurement on a sphere around the EUT. The procedures for the magnetic field test shall be selected according to magnetic test requirements.

9 Magnetic moment test methods

9.1 Test purpose

The purposes of magnetic moment tests are to measure and evaluate magnetic moments of the EUT and verify whether it conforms to magnetic moment requirements of the EUT.

The magnetic dipole moment is the major part of the magnetic moment of the EUT, so magnetic moment test methods include RMDM, SMDM and IDMDM measurements of magnetic dipole method, near-field method and multiple magnetic dipole method.

RMDM is generated by magnets, electro-magnets in off-state or residual perm-up (or magnetization) due to hysteresis of soft magnetic materials in the EUT. SMDM is generated by electric current flowing within the EUT. RMDM and SMDM are independent of the environmental magnetic field. RMDM and SMDM tests are conducted in the zero-magnetic field or geomagnetic field.

IDMDM is the induced magnetic dipole moment in soft magnetic materials caused by an external magnetic field. This magnetic moment contribution changes instantaneously with the magnitude and the direction of the external magnetic field. IDMDM test is conducted in the controllable magnetic field.

9.2 Test facilities

The test facilities and measurement instruments for the magnetic moment test in zero-magnetic field shall be the same as those described in 8.2 for the magnetic field test.

The turntable is not required for the magnetic moment measurement of the magnetic dipole method. The turntable shall be required for the magnetic moment measurement with the near-field method and multiple magnetic dipole modelling method.

The main coil system shall be unnecessary for the magnetic moment test in the geomagnetic field. The turntable, fixture/bracket and measurement instruments shall be the same as those described in 8.2.

