BS ISO 16063-42:2014

BSI Standards Publication

Methods for the calibration of vibration and shock transducers

Part 42: Calibration of seismometers with high accuracy using acceleration of gravity

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 16063-42:2014.

The UK participation in its preparation was entrusted to Technical Committee GME/21/2, Mechanical vibration, shock and condition monitoring - Vibration and shock measuring instruments and testing equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 80111 2

ICS 17.160

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2014.

Amendments issued since publication

Date	Text affected

BS ISO 16063-42:2014

INTERNATIONAL STANDARD

ISO 16063-42

First edition
2014-07-15

Methods for the calibration of vibration and shock transducers —

Part 42: **Calibration of seismometers with high accuracy using acceleration of gravity**

Méthodes pour l'étalonnage des transducteurs de vibrations et de chocs —

Partie 42: Étalonnage des diomomètres de haute exactitude utilisant l'accélération due à la pesanteur

Reference number
ISO 16063-42:2014(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

ISO 16063 consists of the following parts, under the general title *Methods for the calibration of vibration and shock transducers*:

— *Part 1: Basic concepts*

— *Part 11: Primary vibration calibration by laser interferometry*

— *Part 12: Primary vibration calibration by the reciprocity method*

— *Part 13: Primary shock calibration using laser interferometry*

— *Part 15: Primary angular vibration calibration by laser interferometry*

— *Part 16: Calibration by Earth's gravitation*

— *Part 21: Vibration calibration by comparison to a reference transducer*

— *Part 22: Shock calibration by comparison to a reference transducer*

— *Part 31: Testing of transverse vibration sensitivity*

— *Part 41: Calibration of laser vibrometers*

— *Part 42: Calibration of seismometers with high accuracy using acceleration of gravity*

The following parts are under preparation:

— *Part 17: Primary calibration by centrifuge*

— *Part 32: Resonance testing — Testing the frequency and the phase response of accelerometers by means of its excitation*

— *Part 33: Testing of magnetic field sensitivity*

— *Part 43: Calibration of accelerometers by model-based parameter identification*

Angular vibration calibration by comparison to reference transducers, calibration of hand-held accelerometer calibrators, and calibration of vibration transducers with built-in calibration coils are to form the subjects of future parts 23, 44 and 45.

Methods for the calibration of vibration and shock transducers —

Part 42: Calibration of seismometers with high accuracy using acceleration of gravity

1 Scope

This part of ISO 16063 specifies the instrumentation and procedure to be used for the accurate calibration of seismometer sensitivity using local gravitational acceleration (local Earth's gravitation; local value for the acceleration due to the Earth's gravity) as a reference value.

It is intended generally to be applied to a servo-type accelerometer with/without a velocity output, which usually has a mass position output in the category of a wide-band seismometer with a bandwidth from 0,003 Hz to 100 Hz.

The method specified enables the user to obtain static sensitivity for the seismometers up to 10^{-5} m/s^2 (which corresponds to 1 mGal and approximately 1 ppm of the gravitational acceleration).

The combined and expanded (k = 2) uncertainty of applied acceleration achieved by this method is 10^{-6} m/s^2 (0,1 mGal). When the absolute gravimeter described in this part of ISO 16063 is used, the uncertainty of applied acceleration can be suppressed to 5×10^{-8} m/s^2 (5 µGal). The relative expanded uncertainty of calibration, excluding the uncertainty due to the device under test (DUT), is 0,5 %.

The intended end-usage of the seismometer to be applied is as follows:

a) measurement and observation for the earth science including geophysics usage;

b) measurement and observation for disaster prevention, such as detecting the precursor of a land slide;

c) diagnosis for the soundness of a building structure and foundation soil in civil engineering;

d) observation for nuclear-test detection.

2 Normative references

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

IGSN-71, *International Gravity Standardization Network 1971*. (Morelli, 1974) Morelli, Carlo, ed., 1974, The International Gravity Standardization Net 1971: International Association of Geodesy Special Publication No. 4, 194p

3 Traceability of measurement

The traceability of measurement in this method is shown in Annex B.

4 Determination of local gravity

4.1 Method using absolute gravimeter

Determine the absolute local gravitational acceleration using a free-fall absolute gravimeter (FG-5 or other apparatus). The uncertainty of the thus-obtained local gravitational acceleration is approximately 5×10^{-8} m/s^2 (5 µGal).

4.2 Method using gravitational acceleration standardization network and relative gravimeter

At a reference point where the local gravitational acceleration has been established from the IGSN-71, the absolute local gravitational acceleration may be determined by using a relative gravimeter. In this case, no correction for latitude and altitude is required. The value of uncertainty of the relative gravimeter is to be specified by the manufacturer.

Geological survey institutes, meteorology institutes, geodetic surveys or geophysical institutions in each country may provide measured values of smaller uncertainty than those in IGSN-71 and, if available, those values may be used.

4.3 Method using gravitational acceleration standardization network

Calculate the local gravitational acceleration based on the latitude and altitude of the point at which measurements are to be conducted relative to the nearest geographical point in the IGSN-71 database.

The uncertainty of the thus-obtained local gravitational acceleration is approximately 10^{-5} m/s^2 (1 mGal). Here, this is only applied to the case without any geometrical anomaly.

Geological survey institutes, meteorology institutes, geodetic surveys or geophysical institutions in each country may provide measured values of smaller uncertainty than those in IGSN-71 and, if available, those values may be used.

Because an altitude difference of 1 m corresponds to a difference of approximately 3×10^{-6} m/s^2 (0,3 mGal), the uncertainty of altitude should be less than 2 m.

NOTE 1 The effect of a difference of 1° at a latitude of approximately 45° corresponds to approximately 1×10^{-6} m/s^2 (0,1 mGal).

NOTE 2 The local gravity map includes the values of the geoid and altitude components.

5 Requirements for apparatus and environmental conditions

5.1 Calibration environment

The standard reference atmospheric conditions are: (23 ± 3) °C and 75 % relative humidity maximum. The temperature, humidity and atmospheric pressure shall be measured and reported.

5.2 Base and vibration environment (seismic block for calibration apparatus)

The calibration apparatus shall be placed on a sufficiently heavy base which is sufficiently isolated from the building vibration.

5.3 Voltage-measuring instrumentation

The relative expanded measurement uncertainty (k = 2) contribution of the voltmeter by which the output voltage from the seismometer is measured shall be 0,1 % or less (see Table A.1).

5.4 Tuneable low-pass filter

a) **Cut-off frequency**

The cutoff frequency shall be 10 Hz, 30 Hz or 60 Hz. The typical cutoff frequency is 30 Hz.

b) **Attenuation rate (filter slopes)**

The attenuation or insertion loss shall be 24 dB per octave or greater in the stopband of the filter.

5.5 Power supply

The stability of the power supply and the ratio of signal-to-noise shall be adequate to meet the claimed uncertainty contribution(s) at the gain at which the sensitivity of the seismometer is being determined.

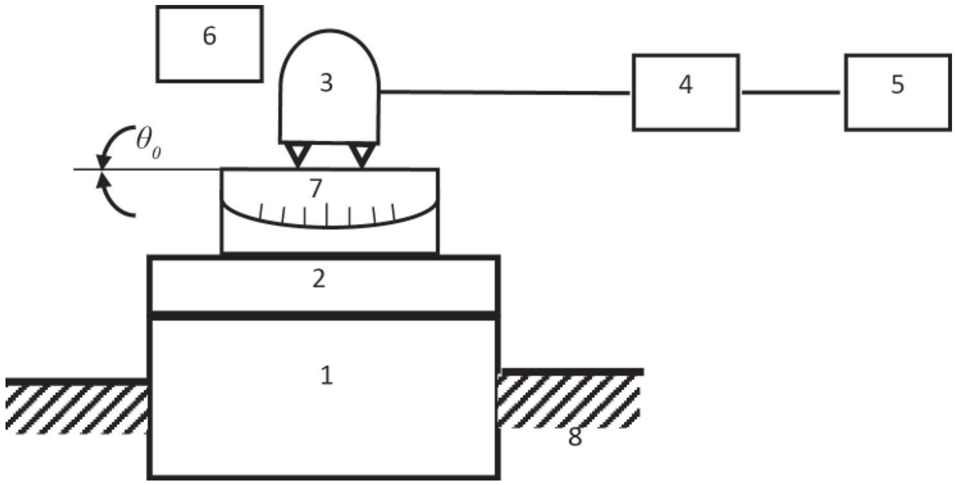
5.6 Tilt table

The angular resolution should be 0,05° or less and the uncertainty contribution should be less than 0,03°. The tilt table should have: sufficient rigidity to support the mass of the seismometer; a sufficiently small amount of backlash and hysteresis; and adequate linearity.

6 Method

6.1 Calibration principle

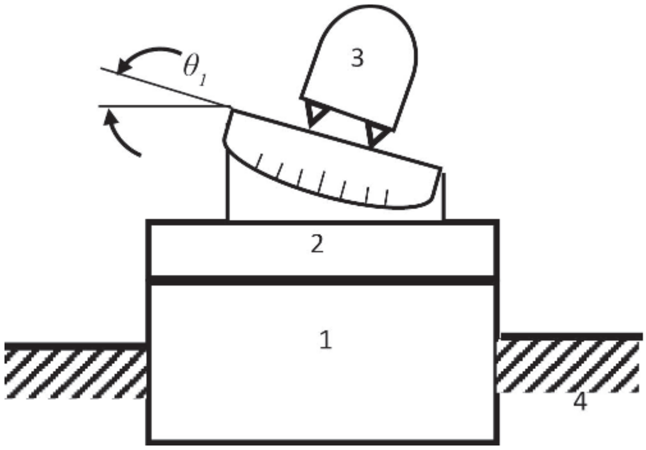
Figure 1 and Figure 2 show schematics of the calibration apparatus and an example of its operation.



Key

1 base
2 platform
3 seismometer
4 filter
5 voltmeter
6 environment instruments (temperature and atmospheric pressure)
7 tilt table
8 ground

Figure 1 — Calibration apparatus



Key

1 base

2 platform

3 seismometer

4 ground

Figure 2 — Case of applying arbitrary acceleration from the initial setting

Place a tilt table on a platform. The platform shall be rigidly connected to the base described in 5.2, namely, the seismic block for the calibration apparatus, and the horizontal plane of its top surface shall be normal to the local gravitational field. The angular deviation from the horizontal plane shall be smaller than 0,03°. The effect of the force component due to the deviation from the horizontal plane is approximately 10^{-7}. The deviation from the horizontal plane shall be confirmed by a tilt meter with sufficient resolution.

The vertical and horizontal components of acceleration applied to the seismometers on the tilt table, $a_{\theta v}$ or $a_{\theta h}$, are given as

$$a_{\theta v} = \cos\theta \, g$$

$$a_{\theta h} = \sin\theta \, g \qquad (1)$$

where θ is the tilt angle from the horizontal plane obtained by placing the tilt table and g is the local acceleration due to gravity. The vertical and horizontal components of the output signals of the seismometer are given by Formula (2).

Measured output signal from seismometer E is given by

$$E = S a_{\theta v} + B \quad \text{or} \quad E = S a_{\theta h} + B \qquad (2)$$

where

S	is the calculated sensitivity of the seismometer;
$a_{\theta v}$ or $a_{\theta h}$	is the induced acceleration to the sensitive axis of the accelerometer;
B	is the calculated bias component of the output;
E	is the measured output voltage of the seismometer.

When θv or θh are changed from $\theta 1$ to θn, each output signal of the seismometer for n times measurement is given as

$$E_1 = Sa_{\theta 1} + B$$

$$E_2 = Sa_{\theta 2} + B$$

$$E_n = Sa_{\theta n} + B \qquad (3)$$

Sensitivity of the seismometer S and bias component of the output B are given by linear regression as follows:

$$S = \frac{n\sum_{i=1}^{n} a_{\theta i} E_i - \sum_{i=1}^{n} a_{\theta i} \sum_{i=1}^{n} E_i}{n\sum_{i=1}^{n} \left(a_{\theta i}\right)^2 - \left(\sum_{i=1}^{n} a_{\theta i}\right)^2} \qquad (4)$$

$$B = \frac{\sum_{i=1}^{n} a_{\theta i}{}^2 \sum_{i=1}^{n} E_i - \sum_{i=1}^{n} a_{\theta i} E_i \sum_{i=1}^{n} a_{\theta i}}{n\sum_{i=1}^{n} \left(a_{\theta i}\right)^2 - \left(\sum_{i=1}^{n} E_i\right)^2} \qquad (5)$$

6.2 Calibration procedure

Place the seismometer on the tilt table such that the sensitive axis is aligned with the vertical axis. The deviation of the angle between sensitive axis and vertical axis shall be smaller than 0,03°. After these settings are precisely adjusted, the seismometer shall be accommodated to the environmental temperature.

A seismometer generally has an angular alignment error of its enclosure, called *case alignment*, related to its sensitivity axes. When calibrating the seismometer, as specified above, the axis for inputting acceleration should be adjusted to the sensitivity axis of the seismometer. Here, the true sensitivity axis is specified by the tilt angle which maximum output signal from seismometer is obtained. Otherwise, the uncertainty of the case alignment error should be included into the tilt angular uncertainty of the tilt table. The vertical or horizontal components of acceleration, $a_{\theta v0}$, $a_{\theta h0}$, applied to the seismometer on the tilt table under the initial tilt angle is given as

$$a_{\theta v0} = \cos\theta_0 \, g \quad \text{or} \quad a_{\theta h0} = \sin\theta_0 \, g$$

The outputs are measured the necessary number of times at the interval of a sampling frequency.

This should be recorded as V_0 under applied accelerations $a_{\theta v0}$ or $a_{\theta h0}$.

Then, change the tilt angle to θ_1. The vertical or horizontal components of accelerations, $a_{\theta v1}$ or $a_{\theta h1}$ are given as

$$a_{\theta v1} = \cos\theta_1 \, g \quad \text{or} \quad a_{\theta h1} = \sin\theta_1 \, g$$

After setting the angle of the tilt table, perform the measurement. Measure the outputs with the necessary number of times at the interval of a sampling frequency.

See also Figure 2.

7 Expression of results

Items of calibration results to be described are as follows.

- Sensitivity, *S*, given as described in 6.2 and expressed in units of volts per meter per second squared.
- Uncertainty: indicates the value relative to the described sensitivity. Specify the coefficient of expansion.
- Applied acceleration: the unit is (m/s^2).
- Method of setting local gravitational acceleration and its estimated uncertainty: refer to Clause 4.
- Environment: temperature, humidity and atmospheric pressure during a measurement period.
- Measurement method: methods using a horizontal platform and an additional tilt table.
- Setting of the filter.
- Number of measurements.

Annex A
(normative)

Expression of uncertainty of measurement in calibration

The expanded uncertainty of calibration $U(S)$ is given as

$$U(S) = ku(S)$$

where k is the coverage factor (generally 2) and $u(S)$ is the relative uncertainty.

The relative uncertainty is given as

$$u(S) = \frac{1}{S}\sqrt{\sum_{1}^{n} u_i^2(S)} \qquad (6)$$

Here, u_i (S) is the uncertainty component affecting to the sensitivity, where the conceivable factors causing each component are listed in Table A.1.

Table A.1 — Source of uncertainty list

I	**Standard uncertainty contribution** $u(x_i)$	**Source of uncertainty**	**Uncertainty contribution** $u_i(y)$
1	$u(\hat{u}_g)$	Local gravitational acceleration uncertainty.	$u_1(S)$
2	$u(\hat{u}_v)$	Voltmeter uncertainty.	$u_2(S)$
3	$u(\hat{u}_{av})$	Angle setting uncertainty of a platform, a tilt table (containing uncertainty due to mismatch between sensitive and vertical axes).	$u_3(S)$
4	$u(\hat{u}_{ah})$	Angle setting uncertainty of a platform, a tilt table (containing uncertainty due to mismatch between sensitive and horizontal axes).	$u_4(S)$
5	$u(\hat{u}_e)$	Experimental standard uncertainty of the number of measured points. (includes uncertainty due to vibration noise and other uncertainty sources)	$u_5(S)$
6	$u(\hat{u}_{asv})$	Angle setting uncertainty of a platform, a tilt table (containing uncertainty due to mismatch between sensitive and vertical axes of the seismometer itself).	$u_6(S)$
7	$u(\hat{u}_{ash})$	Angle setting uncertainty of a platform, a tilt table (containing uncertainty due to mismatch between sensitive and horizontal axes of the seismometer itself).	$u_7(S)$

Annex B
(informative)

Traceability of calibration measurement of seismometer

The traceability of calibration measurement of the seismometer is shown in Figure B.1.

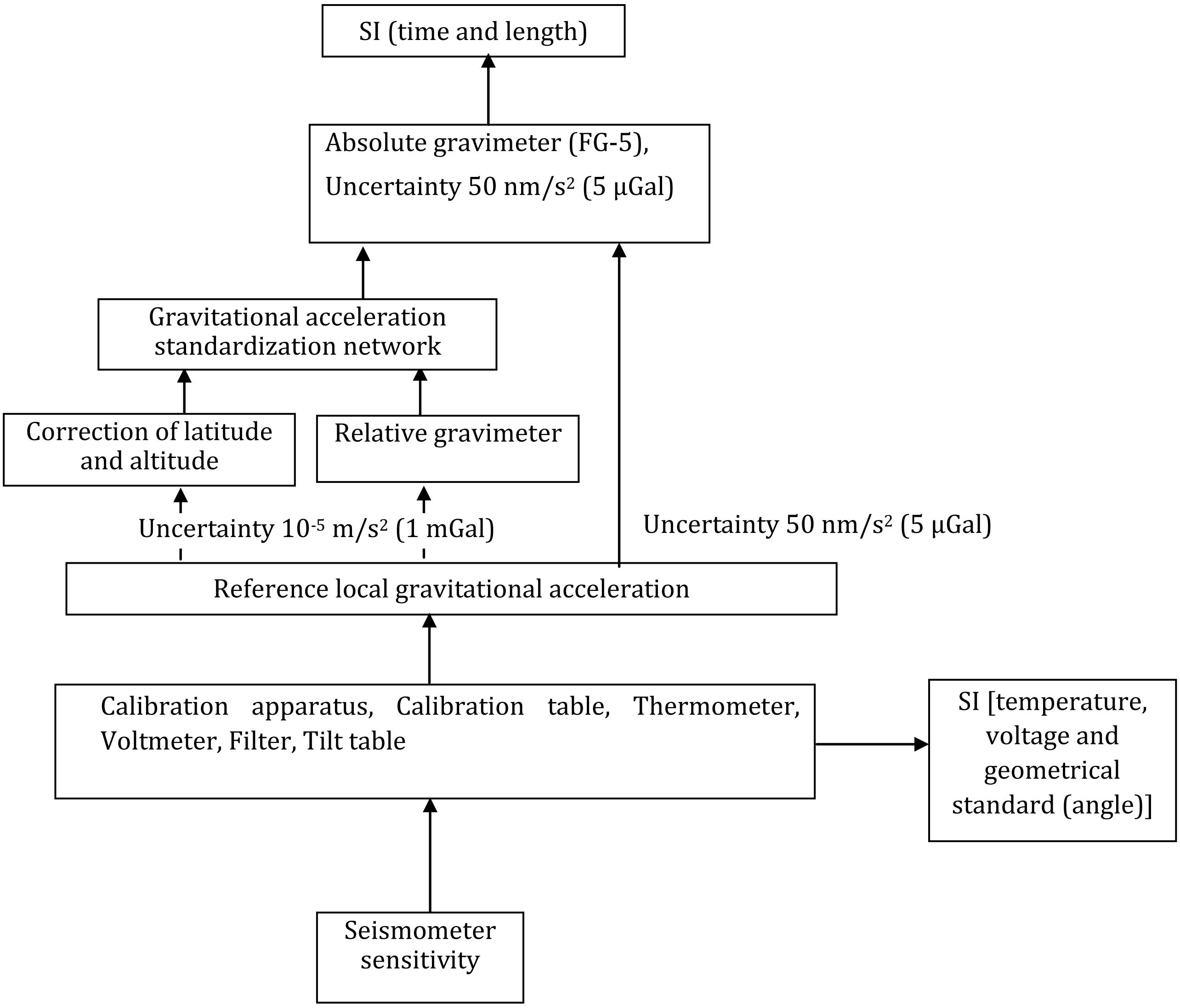


Figure B.1 — Traceability of a measurement

Bibliography

[1] ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

[2] ISO 8042, *Shock and vibration measurements — Characteristics to be specified for seismic pick-ups*

[3] ISO 16063-1, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

[4] ISO 5347-5:1993, *Methods for the calibration of vibration and shock pick-ups — Part 5: Calibration by Earth's gravitation*

[5] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*[1)]

1) Reissue of the *Guide to the expression of uncertainty in measurement* (GUM), 1995.

ICS 17.160

Price based on 9 pages

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™