BS ISO 11311:2011

BSI Standards Publication

Nuclear criticality safety — Critical values for homogeneous plutonium-uranium oxide fuel mixtures outside of reactors

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of ISO 11311:2011.

The UK participation in its preparation was entrusted to Technical Committee NCE/9, Nuclear fuel cycle technology.

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 62437 7

ICS 27.120.30

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 31 July 2011.

Amendments issued since publication

Date	Text affected

INTERNATIONAL STANDARD

ISO 11311

First edition
2011-07-01

Nuclear criticality safety — Critical values for homogeneous plutonium-uranium oxide fuel mixtures outside of reactors

Sûreté-criticité — Valeurs critiques pour oxydes mixtes homogènes de plutonium et d'uranium hors réacteurs

Reference number
ISO 11311:2011(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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 11311 was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 5, *Nuclear fuel cycle*.

Introduction

This International Standard provides specifications to establish process and equipment limits for controlling the nuclear criticality hazard (e.g. choice of process monitoring modes, choice of equipment geometry) in facilities (outside of nuclear reactors) involving mixed uranium-plutonium oxide (MOX) fuel.

The criticality risk for this type of fuel results from the presence of the fissile nuclides ^{239}Pu, ^{241}Pu and ^{235}U, and from other fissionable nuclides, such as ^{242}Pu, ^{240}Pu and ^{238}U, more or less neutron absorbing.

The systems considered are uniform and homogeneous mixtures, moderated and reflected by water. The geometries concerned are single units of spheres, cylinders and slabs. A limited number of important safety parameter values are then selected.

Actually, regarding the field of MOX fuel, there are insufficient directly representative experiments of damp powders for establishing the bias between calculations and measurements. Therefore, an inter-code comparison is done to conservatively estimate critical values for different fissile material specifications.

Because the use of calculation codes can be associated with different nuclear libraries, the preceding comparison is extended to the results obtained with the most common nuclear data libraries.

Consequently, this International Standard provides reference critical values for the safety parameters selected. These values are determined by inter-code comparisons with an acceptable accuracy and are defined as the lowest calculated critical values of the selected safety parameters. These values will help nuclear criticality safety assessors during their analysis to make technical prescriptions for criticality risk prevention and for production purposes.

Nuclear criticality safety — Critical values for homogeneous plutonium-uranium oxide fuel mixtures outside of reactors

1 Scope

This International Standard specifies common reference critical values (of which the effective neutron multiplication factor, k_{eff} is equal to 1) for homogeneous water-moderated plutonium-uranium oxide mixtures based on an inter-code comparison of calculated critical values.

It is applicable to operations with unirradiated mixed uranium-plutonium oxide (MOX) outside nuclear reactors.

A classical validation approach for these systems is difficult because of the paucity of critical experiments for MOX fuel.

Various reference systems, in terms of isotopic compositions, thicknesses of water reflection, and densities of oxide are evaluated by different combinations of calculation codes and nuclear data libraries (i.e. different calculation schemes, see Annex B).

The critical values defined in this International Standard are the lowest of those calculated by each of these calculation schemes and accepted as credible.

The values in this International Standard are reference values and not absolute critical values.

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.

ISO 921, *Nuclear energy — Vocabulary*

ISO 1709, *Nuclear energy — Fissile materials — Principles of criticality safety in storing, handling and processing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 921 apply.

4 Reference systems concerned by this International Standard

4.1 Reference fissile media

4.1.1 Description

The reference fissile media are homogeneous and uniform mixtures of uranium and plutonium dioxides in water.

4.1.2 Plutonium content

The plutonium content in the mixture, w_{Pu}, expressed as a percentage mass fraction, is defined by Equation (1):

$$w_{Pu} = \frac{m_{Pu}}{m_U + m_{Pu}} \quad (1)$$

where

m_{Pu} is the mass, in grams, of plutonium in the mixture;

m_U is the mass, in grams, of uranium in the mixture.

Plutonium contents used in the reference fissile media are:

a) $w_{Pu} = 35{,}0\ \%$;

b) $w_{Pu} = 12{,}5\ \%$.

4.1.3 Oxide density ranges

Two ranges of oxide ($UO_2 + PuO_2$) density, expressed in grams per cubic centimetre, are considered:

— up to 3,50 g/cm^3, if the plutonium content is 35,0 % mass fraction;

— up to 11,03 g/cm^3, if the plutonium content is 12,5 % mass fraction.

NOTE The latter density is the theoretical dry density for this specific isotopic MOX composition.

4.1.4 Isotopic composition

4.1.4.1 Notation

In this subclause, the following notation is used:

$m_{^iU}$ is the mass, in grams, of isotope i of uranium;

$m_{U,total}$ is the mass, in grams, of uranium;

$m_{^iPu}$ is the mass, in grams, of isotope i of plutonium;

$m_{Pu,total}$ is the mass, in grams, of plutonium.

4.1.4.2 Uranium

The uranium composition considered corresponds to natural uranium:

$$m_{^{235}U} / m_{U,total} = 0{,}718\ \%$$

$$m_{^{238}U} / m_{U,total} = 99{,}282\ \%$$

NOTE The fissile systems with depleted uranium are bounded by the natural uranium systems considered in this International Standard.

4.1.4.3 Plutonium

Three plutonium compositions, P0, P5 and P20, are considered:

c) composition P0 is defined by:

$$m_{^{239}\mathrm{Pu}} / m_{\mathrm{Pu,total}} = 100{,}000\ \%$$

d) composition P5 is defined by:

$$m_{^{239}\mathrm{Pu}} / m_{\mathrm{Pu,total}} = 95{,}000\ \%$$

$$m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} = 5{,}000\ \%$$

e) composition P20 is defined by:

$$m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} = 20{,}000\ \%$$

$$m_{^{241}\mathrm{Pu}} / m_{^{240}\mathrm{Pu}} = \mathrm{R}_1 = 11/17$$

$$m_{^{242}\mathrm{Pu}} / m_{^{241}\mathrm{Pu}} = \mathrm{R}_2 = 1/11$$

$$\begin{aligned} m_{^{239}\mathrm{Pu}} / m_{\mathrm{Pu,total}} &= 1 - m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} - m_{^{241}\mathrm{Pu}} / m_{^{240}\mathrm{Pu}} - m_{^{242}\mathrm{Pu}} / m_{^{241}\mathrm{Pu}} \\ &= 1 - m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} - (m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} \times \mathrm{R}_1) - (m_{^{240}\mathrm{Pu}} / m_{\mathrm{Pu,total}} \times \mathrm{R}_1 \times \mathrm{R}_2) \end{aligned}$$

4.1.5 Resulting fissile media

The six reference fissile media resulting from these physical and chemical forms and from these isotopic compositions are presented in Annex A.

4.2 Moderation conditions

Two water moderation degrees are considered:

a) a limited moderation corresponding to a water mass fraction less than or equal to 3,0 %, according to Equation (2):

$$w_{\mathrm{H_2O}} = \frac{m_{\mathrm{H_2O}}}{m_{\mathrm{H_2O}} + m_{\mathrm{PuO_2}} + m_{\mathrm{UO_2}}} \leq 3\% \qquad (2)$$

where

$m_{\mathrm{H_2O}}$ is the mass, in grams, of water in the mixture;

$m_{\mathrm{PuO_2}}$ is the mass, in grams, of plutonium dioxide in the mixture;

$m_{\mathrm{UO_2}}$ is the mass, in grams, of uranium dioxide in the mixture.

NOTE This degree of moderation is selected because MOX fuel is usually fabricated from mixtures of nearly dry powder and hydrogenated additives.

b) optimum moderation (minimal critical values obtained whatever the moderator-to-fuel ratio is).

These moderations are considered homogeneous in the fissile medium.

The mixture of MOX and water leads to a decrease in the MOX density from the theoretical density (full crystal dry density) as the water content increases in the mixture. For each mixture of MOX and water, the sum of their volume fractions (actual density divided by theoretical density) is unity.

In the case of a MOX density up to 3,50 g/cm^3, an initial void fraction is defined by this maximal density divided by the theoretical MOX density. The initial void fraction then allows a certain water content in the mixture with a constant MOX density. A further increase in the water content leads to a decrease in the MOX density. For each mixture of MOX and water, the sum of their volume fractions and the void fraction is unity.

4.3 Geometrical models

Critical values are given for the three following simple geometries of the fissile material:

— sphere;

— infinite length cylinder;

— infinite section slab.

4.4 Reflecting conditions

The critical values are given for a 2,5 cm and a 30,0 cm water reflector. The water reflector is close-fitting around the fissile material, with a free boundary beyond the reflector.

5 Critical values

5.1 Presentation of the results

Annex C (for a 30 cm water reflection) and Annex D (for a 2,5 cm water reflection) specify the lowest values of critical dimensions for a sphere, an infinite length cylinder, and an infinite section slab. These critical dimensions are the radius, in centimetres, and the volume, in litres, of the sphere, the diameter, in centimetres, of the infinite cylinder, and the thickness, in centimetres, of the infinite slab geometry. The critical volume of a sphere is the minimal critical volume whatever the credible fissile material geometry is.

Annex E (for a 30 cm water reflection) and Annex F (for a 2,5 cm water reflection) specify the lowest values of the critical parameters for the three reference geometries, in terms of mass, in kilograms, of actinide (U and Pu) for a sphere, linear density, in grams per centimetre, of actinide for a cylinder, and surface density, in grams per centimetre squared, of actinide for a slab geometry.

Each of these results is the lowest value resulting from the comparison of 12 to 17 values calculated with different calculation routes among those given in Annex B. For each value, at least four different computer codes and four different data libraries were used.

NOTE 1 All the computational results are extracted from References [1] to [7]. These calculations were performed with a temperature of 293 K.

NOTE 2 The results from References [1] to [7] show that the critical values for MOX with depleted uranium are not notably lower than the critical values in Annexes C to F for MOX with natural uranium.

5.2 Requirements

5.2.1 Nuclear criticality safety assessors preparing specifications relative to fissile systems described in Clause 4 shall compare their own critical values with the critical values presented in Annexes C to F.

5.2.2 In the absence of technical arguments, the nuclear criticality safety assessors shall use the lowest values between their own critical values and the critical values presented in Annexes C to F. Otherwise, they shall justify the use of higher values by safety margin considerations.

5.2.3 The nuclear criticality safety assessors shall interpret any discrepancy observed between the results of their own calculation code and the results of this International Standard.

6 Subcritical limits and margin of safety

Subcritical limits and a margin of safety shall be determined in accordance with ISO 1709. The margin of safety shall take into account the lack of applicable experiments and the interpretation required in 5.2.3.

Annex A
(informative)

Reference fissile media

Mass fraction of plutonium[a] w_{Pu} %	MOX density g/cm³	Isotopic composition of uranium[b] % mass fraction ^{235}U	^{238}U	Plutonium composition designation	Isotopic composition of plutonium[c] % mass fraction ^{239}Pu	^{240}Pu	$^{241}Pu/^{240}Pu$	$^{242}Pu/^{241}Pu$
35,0	≤3,5	0,718	99,282	P0	100	—	—	—
				P5	95	5	—	—
				P20	d	20,00	11/17	1/11
12,5	≤11,03	0,718	99,282	P0	100	—	—	—
				P5	95	5	—	—
				P20	d	20,00	11/17	1/11

a See 4.1.2.

b See 4.1.4.2.

c See 4.1.4.3.

d The mass fraction of ^{239}Pu is the complement to make up to 100 %.

Annex B
(informative)

Criticality schemes used for the calculations

B.1 Types of calculation scheme

The calculations of critical values are carried out using criticality codes or packages and group-wise or point-wise nuclear data libraries. Two main types of calculation scheme are used:

— deterministic calculation schemes directly giving critical values by iteration of a discrete ordinate method to solve the equation of neutron transport;

— calculation schemes using the Monte-Carlo method to solve the equation of neutron transport — critical values are then obtained by interpolation with the effective multiplication factor.

B.2 List of codes and libraries used

The calculation schemes listed in Table B.1 were used to prepare this International Standard. All the calculation specifications specified in Clause 4 were not evaluated with all these calculation schemes. However, for each specification, at least four different computer codes and four different data libraries were used.

Table B.1 — Schemes used for calculation of criticality

Computer code	Computation method	Code module	Cross-section library	Number of energy groups	Angular quadrature matrix	Scattering matrix
APOLLO2	Discrete ordinate	SN-Normes	CEA93-V4 (JEF2.2)	172	S8	P3[a]
APOLLO2	Discrete ordinate	SN-Normes	CEA93-V6 (JEF2.2)	172	S16	P3
SCALE 4.4a	Discrete ordinate	XSDRNPM (CSAS1X)	ENDF/B-V	238	S32	P5
SCALE 4.4a	Discrete ordinate	XSDRNPM (CSASI)	ENDF/B-V	238	S8	P5
SCALE 5.1	Discrete ordinate	XSDRNPM (CSAS1X)	ENDF/B-VI	238	S16-64	P5
SCALE 5.1	Discrete ordinate	XSDRNPM (CSAS1X)	ENDF/B-V	238	S16-64	P5
APOLLO2 - MORET4	Monte-Carlo	—	CEA93-V4 (JEF2.2)	172	—	—
TRIPOLI 4	Monte-Carlo	—	JEF2.2	—	—	—
MCNP 4C	Monte-Carlo	—	JENDL 3.2	—	—	—
MCNP5 R.140	Monte-Carlo	—	ENDF/B-VII.0	—	—	—
MCNP5 R.140	Monte-Carlo	—	ENDF/B-VI	—	—	—
MCNP5 R.140	Monte-Carlo	—	ENDF/B-V	—	—	—
MCNP5 R.140	Monte-Carlo	—	JENDL 3.3	—	—	—
MCNP5 R.140	Monte-Carlo	—	JENDL 3.2	—	—	—
MCNP5 R.140	Monte-Carlo	—	JEFF 3.1	—	—	—
MCNP5 R.140	Monte-Carlo	—	JEF2.2	—	—	—
MONK 8b	Monte-Carlo	—	JEF2.2	—	—	—
MONK 8b	Monte-Carlo	—	ENDF/B-VI	—	—	—
MONK 8b	Monte-Carlo	—	JENDL 3.2	—	—	—

[a] Heavy nuclei from CEA93-V4 library are of P1 order.

Annex C
(normative)

Critical dimensions for a water reflection of 30 cm

Plutonium mass fraction[a] w_{Pu} %	MOX density g/cm^3	Plutonium composition designation[b]	Water mass fraction, w_{H_2O} ≤ 3 %				Optimal water content			
			Sphere		Cylinder	Slab	Sphere		Cylinder	Slab
			Radius cm	Volume l	Diameter cm	Thickness cm	Radius cm	Volume l	Diameter cm	Thickness cm
35,0	≤3,5	**P0**	27,4	86,1	35,1	13,4	12,9	9,0	16,7	6,1
		P5	29,6	108	38,7	15,8	14,3	12,2	18,9	7,8
		P20	31,4	129	41,3	17,6	16,9	20,2	22,8	10,2
12,5	≤11,03	**P0**	21,5	41,6	28,9	12,5	14,3	12,2	18,8	7,7
		P5	24,9	64,6	34,2	16,0	15,7	16,2	21,1	9,2
		P20	27,3	85,2	38,0	18,9	18,8	27,8	25,6	12,0

a See 4.1.2.

b See 4.1.4.3 and Annex A.

Annex D
(normative)

Critical dimensions for a water reflection of 2,5 cm

Plutonium mass fraction[a] w_{Pu} %	MOX density g/cm³	Plutonium composition designation[b]	Water mass fraction, $w_{H_2O} \leq 3$ %				Optimal water content			
			Sphere		Cylinder	Slab	Sphere		Cylinder	Slab
			Radius cm	Volume l	Diameter cm	Thickness cm	Radius cm	Volume l	Diameter cm	Thickness cm
35,0	≤3,5	**P0**	35,4	185	49,5	25,8	14,8	13,5	20,6	10,4
		P5	37,4	219	52,7	27,9	16,3	18,1	22,9	11,9
		P20	38,8	244	54,8	29,3	18,9	28,2	26,9	14,5
12,5	≤11,03	**P0**	25,2	67,0	36,3	20,3	16,2	17,8	22,8	11,9
		P5	28,8	100	41,9	24,0	17,7	23,2	25,1	13,3
		P20	31,2	127	45,6	26,5	20,9	38,2	29,8	16,3

a See 4.1.2.

b See 4.1.4.3 and Annex A.

Annex E
(normative)

Critical parameters for a water reflection of 30 cm

Plutonium mass fraction[a] w_{Pu} %	MOX density g/cm³	Plutonium composition designation[b]	Water mass fraction, w_{H_2O} ≤ 3 %			Optimal water content		
			Sphere	Cylinder	Slab	Sphere	Cylinder	Slab
			Mass (U+Pu) kg	**Linear density** (U+Pu) g/cm	**Surface density** (U+Pu) g/cm²	**Mass** (U+Pu) kg	**Linear density** (U+Pu) g/cm	**Surface density** (U+Pu) g/cm²
35,0	≤3,5	**P0**	266	2 985	41,4	1,53	31,8	0,74
		P5	337	3 636	48,9	1,87	37,0	0,83
		P20	400	4 138	54,4	3,12	55,2	1,12
12,5	≤11,03	**P0**	303	4 750	90,6	4,96	97,8	2,19
		P5	468	6 663	115	6,12	114	2,45
		P20	621	8 260	137	10,5	174	3,34

[a] See 4.1.2.

[b] See 4.1.4.3 and Annex A.

Annex F
(normative)

Critical parameters for a water reflection of 2,5 cm

Plutonium mass fraction[a] w_{Pu} %	MOX density g/cm^3	Plutonium composition designation[b]	Water mass fraction, $w_{H_2O} \leq 3$ %			Optimal water content		
			Sphere **Mass** (U+Pu) kg	**Cylinder** **Linear density** (U+Pu) g/cm	**Slab** **Surface density** (U+Pu) g/cm^2	**Sphere** **Mass** (U+Pu) kg	**Cylinder** **Linear density** (U+Pu) g/cm	**Slab** **Surface density** (U+Pu) g/cm^2
35,0	≤3,5	**P0**	574	5 959	79,8	2,00	39,9	0,87
		P5	679	6 741	86,2	2,42	45,9	0,96
		P20	755	7 122	90,6	3,95	67,2	1,28
12,5	≤11,03	**P0**	486	7 509	147	6,4	121	2,54
		P5	728	10 006	173	7,8	141	2,82
		P20	924	11 838	192	13,2	211	3,80

a See 4.1.2.

b See 4.1.4.3 and Annex A.

Bibliography

[1] BORDY, J.-M. *A comparison of critical values, relatives to homogeneous UO2 — PuO_2 — H_2O media representing mixed Uranium — Plutonium oxide fuels, achieved with APOLLO2-SN, MORET4, TRIPOLI4 and SCALE4.4*, SEC/T/01.202, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France, 2001

[2] EVO, S. *Critical values for homogenous mixed plutonium-uranium oxide fuels (MOX), “CRISTAL V1” results*, DSU/SEC/T/2005-299, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France, 2005

[3] SHIMIZU, Y., HOPPER, C.M. *Computation results from parametric study to determine bounding critical system of homogeneously water-moderated mixed uranium oxide*, ORNL/TM-2000/151. Oak Ridge National Laboratary (ORNL), USA, 2000

[4] BONNET, J., FERNEX, F. *Critical values for mixed fuels $(U+Pu)O_2$ obtained with the XSDRNPM code*, NT 12148.00.0001, AREVA NC/SGN, France, 2001

[5] ELLIS, D. *MONK8B calculations for homogeneous water-moderated mixed-plutonium-uranium oxides (MOX) in support of the development of an ISO MOX standard*, SCN-201, Sellafield Ltd., UK, 2008

[6] MENNERDAHL, D. *Reference values for mixed plutonium and uranium oxide (MOX) powder — Support for ISO and ANS standards*, EMS/NC/2007-03 Rev 3, EMS, Sweden, 2008

[7] SHIMIZU, Y. *ISO personal communication at TC 85/SC 5/WG 8 meeting in Avignon*, France, 2003, Japan Nuclear Cycle Development Institute (JNC), Japan

ICS 27.120.30
Price based on 13 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.™