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Fibre-reinforced plastic composites — Standard qualification plan (SQP) for composite materials, including reduced qualification plan (RQP) and extended qualification plan (EQP) schemes

Composites plastiques renforcés de fibres — Plan de qualification normalisé (PQN) pour matériaux composites, y compris les programmes pour plan de qualification réduit (PQR) et plan de qualification étendu (PQE)

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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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

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

This document has been prepared to provide suppliers, designers, end-users and regulators of fibre-reinforced plastic/composite materials, with an initial qualification framework aimed at reducing the substantial costs involved in qualifying materials against different bespoke company specifications, with varying degrees of commonality. Indeed, the cost associated with qualifying materials can prevent the use of new materials in certain applications or even the development of new materials themselves. In addition, designers and end-users often find that appropriate data for materials selection and preliminary design are not readily available or comparable. Widespread use of this document for initial qualification is intended to lead to a reduction in qualification costs and increased availability of reliable and robust materials data across a wide range of sectors and applications. It provides for more detailed qualification procedures, including calculation of B-basis design allowable, compared to ISO 10350-2.

Material suppliers are intended to adopt this procedure for obtaining the required data to support initial material selection and qualification; and to supply the specified data, in the format given in Annex A, at the same time as release of the material evaluated. This will greatly extend the availability of consistent and comparable materials data based on agreed individual, international test methods to support users, fabricators and regulators.

Validation has been undertaken for thermoset systems, which are currently the most abundant and established matrix-based systems. However, it is accepted[1] that the calculations, and therefore the property data, can also be applied to similar thermoplastic matrix-based systems.

Therefore, thermoplastic matrix-based systems can also be covered by the document, providing the underpinning test method's technical aspects are met regarding failure mode etc.; with the exclusion of property tests specifically designed for uncured thermoset materials, where indicated.

It is noted that, simultaneously, the underpinning test methods are themselves being reviewed for application to a wider range of fibre formats and matrices. Validation data will be added for thermoplastic matrix-based systems when international precision trials are conducted.

Fibre-reinforced plastic composites — Standard qualification plan (SQP) for composite materials, including reduced qualification plan (RQP) and extended qualification plan (EQP) schemes

1 Scope

1.1 This document specifies a procedure for the initial qualification of composite materials in order to allow quality control, material selection and preliminary design to be undertaken. It provides a single procedure allowing quicker and lower cost qualification compared to multiple bi-lateral qualification against different bespoke user needs. This document focuses on developing B-basis design allowables.

1.2 The procedure comprises a standard qualification plan (SQP) that includes the minimum common test requirements for more highly anisotropic composite materials. Further test requirements are encompassed in an extended qualification plan (EQP), which includes options representing specific in-service features. A reduced qualification plan (RQP) scheme, using the same core structure of test plate preparation and test methods as the SQP, is available for less highly anisotropic and tending towards nominally isotropic composite materials.

1.3 The procedure is suitable for fibre-reinforced thermoset, and thermoplastic, based material systems intended for structural or semi-structural applications. Individual test method standards referred to in this document provide more details as to the classes and types of composite materials that are covered in each case.

1.4 Annexes A and B are included to support presentation of the data obtained in a consistent database and to provide statistical procedures for the determination of B-basis design allowables, respectively.

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 62, *Plastics — Determination of water absorption*

ISO 75-3, *Plastics — Determination of temperature of deflection under load — Part 3: High-strength thermosetting laminates and long-fibre-reinforced plastics*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 527-4, *Plastics — Determination of tensile properties — Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites*

ISO 527-5, *Plastics — Determination of tensile properties — Part 5: Test conditions for unidirectional fibre-reinforced plastic composites*

ISO 1172, *Textile-glass-reinforced plastics — Prepregs, moulding compounds and laminates — Determination of the textile-glass and mineral-filler content — Calcination methods*

ISO 1183 (all parts), *Plastics — Methods for determining the density and relative density of non-cellular plastic*

ISO 1268 (all parts), *Fibre-reinforced plastics — Methods of producing test plates*

ISO 1675, *Plastics — Liquid resins — Determination of density by the pyknometer method*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 6603-2, *Plastics — Determination of puncture impact behaviour of rigid plastics — Part 2: Instrumented impact testing*

ISO 6721-11, *Plastics — Determination of dynamic mechanical properties — Part 11: Glass transition temperature*

ISO 9782, *Plastics — Reinforced moulding compounds and prepregs — Determination of apparent volatile-matter content*

ISO 10119, *Carbon fibre — Determination of density*

ISO 10352, *Fibre-reinforced plastics — Moulding compounds and prepregs — Determination of mass per unit area*

ISO 11357-1, *Plastics — Differential scanning calorimetry (DSC) — Part 1: General principles Differential scanning calorimetry (DSC) — Part 1: General principles*

ISO 11357-2, *Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and glass transition step height*

ISO 11359-2, *Plastics — Thermomechanical analysis (TMA) — Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature*

ISO 11667, *Fibre-reinforced plastics — Moulding compounds and prepregs — Determination of resin, reinforced-fibre and mineral-filler content — Dissolution methods*

ISO 12815, *Fibre-reinforced plastic composites — Determination of plain-pin bearing strength*

ISO 12817, *Fibre-reinforced plastic composites — Determination of open-hole compression strength*

ISO 14125, *Fibre-reinforced plastic composites — Determination of flexural properties*

ISO 14126, *Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction*

ISO 14127, *Carbon-fibre-reinforced composites — Determination of the resin, fibre and void contents*

ISO 14129, *Fibre-reinforced plastic composites — Determination of the in-plane shear stress/shear strain response, including the in-plane shear modulus and strength, by the plus or minus 45 degree tension test method*

ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*

ISO 15024, *Fibre-reinforced plastic composites — Determination of mode I interlaminar fracture toughness, GIC, for unidirectionally reinforced materials*

ISO 15034, *Composites — Prepregs — Determination of resin flow*

ISO 15040, *Composites — Prepregs — Determination of gel time*

ISO 15114, *Fibre-reinforced plastic composites — Determination of the mode II fracture resistance for unidirectionally reinforced materials using the calibrated end-loaded split (C-ELS) test and an effective crack length approach*

ISO 16012, *Plastics — Determination of the linear dimensions of specimens*

ISO 18352, *Carbon-fibre-reinforced plastics — Determination of compression-after-impact properties at a specified impact-energy level*

EN 821-1, *Advanced technical ceramics — Monolithic ceramics — Thermo-physical properties — Part 1: Determination of thermal expansion*

EN 2823, *Aerospace series — Fibre reinforced plastics — Determination of the effect of exposure to humid atmosphere on physical and mechanical characteristics*

ASTM D5766, *Fibre-reinforced plastic composites — Determination of the open-hole, tensile strength*

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:

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

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

3.1
preimpregnate
prepreg
material in thin sheets of tows, tape, fabric, or mat impregnated with resin ready to be moulded, and cured if thermoset based

Note 1 to entry: It may be stored before use (normally refrigerated for thermoset based systems).

Note 2 to entry: Used as a generic term in this document to refer to an intermediate product requiring application of pressure and/or heat to form the final product.

3.2
compound
intimate admixture of a polymer or polymers with other ingredients such as reinforcements, fillers, plasticizers, catalysts and colorants ready to be formed, and cured if thermoset based

3.3
preform
dry fibre preform suitable for infiltration by the matrix, normally thermoset based, to provide the final material

3.4
batch
quantity of material formed during the same process and having identical characteristics throughout based on a single supply of fibres, matrices and other additives

3.5
manufacturing run
single manufacturing process for test plates run by a single operator at a single time

3.6
plate and specimen coordinate axes
1-axis (or direction) where the material contains a known axis of preferred fibre orientation (e.g. dominant fibre direction for unidirectional prepregs)

Note 1 to entry: For materials prepared as test plates, the in-plane direction transverse to the 1-axis is defined as the 2-axis. Where any direction of preferred orientation is not known, the 1-axis is taken as the production direction of the composite or the reinforcement (e.g. warp directions for fabrics).

Note 2 to entry: For fully unidirectional materials, specimens cut parallel to the “1”-direction, results are identified by the subscript “11” (e.g. E11). Similarly, for specimens cut parallel to the “2”-direction are identified by the subscript “22” (e.g. E22). For multidirectional laminates, mats and fabrics, results are identified by the subscripts “XX” and “YY” for specimens cut parallel to the X and Y directions respectively. The X, Y and Z coordinate system for any material are equated to the “1”-, “2”- and “3”- directions.

Note 3 to entry: A scheme for designating multiple direction lay-ups is given in the ISO 1268-4:2005, Annex A.

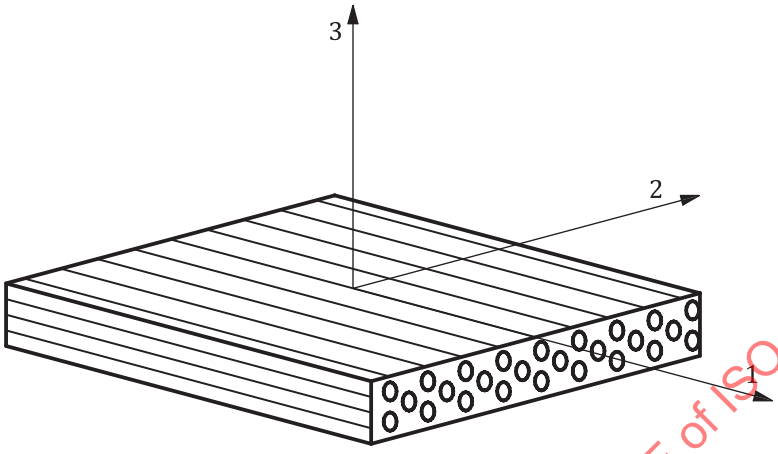

Figure 1 — Unidirectional reinforced composite plate element showing orthogonal axes

3.7
A-basis design allowable
statistically-based material property with a 95 % lower confidence bound on the first percentile of a specified population of measurements

Note 1 to entry: It is also a 95 % lower tolerance bound for the upper 99 % of a specified population.

3.8
B-basis design allowable
statistically-based material property with a 95 % lower confidence bound on the tenth percentile of a specified population of measurements

Note 1 to entry: It is also a 95 % lower tolerance bound for the upper 90 % of a specified population.

4 Principle

To provide an initial “standard qualification plan" based on accepted international test methods, in combination with specified material preparation and batch test requirements. The standard qualification plan (SQP) provides a minimum data set for the initial materials release suitable for material selection and preliminary design phases, using a B-basis design allowable. The SQP is suitable for high quality /high anisotropy preimpregnates (prepregs). An RQP allows less highly anisotropic materials to be more easily and quickly evaluated. The EQP provides test methods for coupon level tests for assessing simulated service requirements, such as, resistance to strain-concentrations (e.g. a hole) and simulated damage.

NOTE It is noted that for A-basis design allowables, the number of specimens is increased to the order of 100 times, using increased number of batches and/or manufacturing runs depending on the sensitivity of the measured properties to these two factors[2].

5 Test methods and specimen conditioning

Tables 1 and 2 specify the properties, test methods/applicable standards and batches to be used in the SQP/RQP. Table 3 provides the same information for the EQP. The full title of each standard is given in Clause 2. In addition, Tables 2 and 3 give “non-room temperature” test conditions, including after hot

wet conditioning. These conditions can be adjusted for non-aerospace applications as agreed with end users (see 9.3).

Specimens shall be conditioned according to ISO 291 for ambient/room temperature (RT) testing. Testing at non-ambient temperatures or after hot/wet conditioning shall be conditioned according to the relevant test method, the material specification or by agreement between supplier and user's requirements.

In the absence of this information, the standard values for aerospace applications shall be used.

NOTE Guidance on preferred non-ambient test temperatures to be used is given in ISO 3205[3].

6 Test matrices and specimen sampling

The prescribed qualification test regime (using the test methods listed in Clause 5) is detailed in Tables 1 to 3. Tables 1 to 3 set out the numbers of batches of specimens per test method and per test condition. The test requirements in these standards shall be adhered to regarding scope, specimen size, failure criteria, etc.

Specimens shall be prepared and tested from either 1 or 3 batches of material depending on the criticality of the data (i.e. the importance of the data for use in design, material selection, etc.). Specimens shall be taken from 3 batches of material in order for measured values to be as representative as possible of the material being tested and these batches shall be taken from the production of the material over an extended timescale. In addition, to account for the processing variability associated with test plate/panel manufacture, two plates shall be fabricated from each material batch, using independent manufacture processes. Five specimens shall be extracted per plate for each test method, giving a total of 30 specimens per property for a particular test condition.

In a similar manner, those properties measured using only 1 batch of material shall be determined from 10 specimens prepared from 2 plates (prepared using independent manufacture processes) from the single batch.

Some test methods specify less than 5 specimens, but for this document 5 specimens per plate shall be used.

Specimen selection and traceability (as described above) is illustrated in Figure 2.

NOTE At least two independent manufacture processes are required to fabricate all 6 plates, i.e. one lay-up and cure cycle (Manufacture A) for plates 1, 3 and 5; and one lay-up and cure cycle (Manufacture B) for plates 2, 4 and 6 for a conventional thermoset resin based pre-preg.

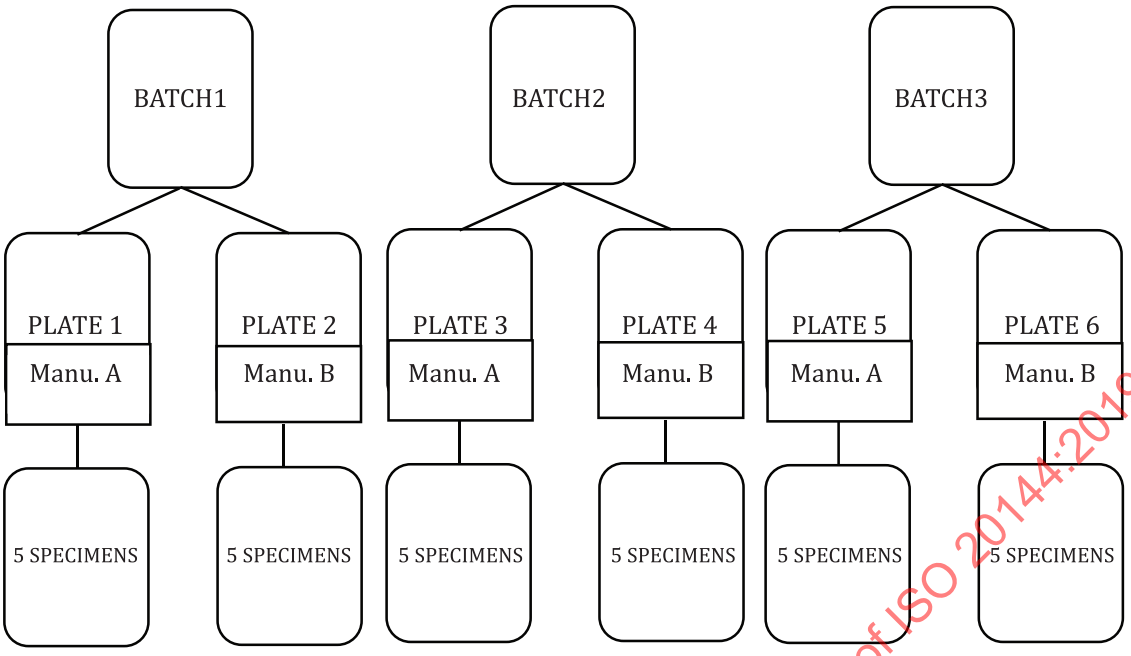

Figure 2 — Batch, plate and specimen traceability

7 Apparatus

The equipment used in the work shall have a valid calibrated certificate traceable to SI units for the measurements made, as required by the relevant test method standard; or be shown to have been calibrated immediately prior to the measurements being made using transfer devices traceable to SI units.

Table 1 — Standard qualification plan — Constituent and composites properties — Batch requirements

	Property	Standard	Unit	No. of material batches	Test conditions and supplementary instructions
				SQP	
		CONSTITUENT PROPERTIES			
1	Mass per unit area	ISO 10352	g/m^2	3	
2	Fibre mass per unit area	ISO 10352	g/m^2	3	
3	Fibre and matrix volume fractions	ISO 11667	%	3	
4	Gel time[a]	ISO 15040	minutes	3	Not applicable to a thermoplastic matrix
5	Matrix flow[a]	ISO 15034	% weight change	3	Not applicable to a thermoplastic matrix
6	Glass transition temperature[a]	ISO 11357-2	°C	3	Indicator of service temperature for thermoset matrices, but not applicable to thermoplastic matrices
7	Percentage of volatile content[a]	ISO 9782	%	3	Not applicable to a thermoplastic matrix
8	Density of fibre	ISO 10119	g/cm^3	3	Carbon fibre based, but usable for other fibres depending on the method
9	Deflection temperature under load	ISO 75-3	°C	3	Guide to maximum service temperature
10	Density of matrix	ISO 1675	g/cm^3	3	
		COMPOSITE PROPERTIES			
11	Coefficient of thermal expansion	EN 821-1/ ISO 11359-2	%/°C	1	ISO 11359-2 only suitable for values greater than 10^5 %/°C
12	Moisture uptake — ambient	ISO 62	%	1	Distilled water at 23 °C, report saturation value
13	Moisture uptake —hot/wet	EN 2823	%	1	Conditioning in 70 °C/85 % atmosphere, report saturation value
14	Glass transition temperature by DMA	ISO 6721-11	°C	3	Relevant to service temperature for thermoset matrices, but not for thermoplastic matrices. Tg is taken as the inflection point of storage modulus vs temperature plot.
15	Final ply thickness	ISO 16012	mm	3	Divide plate thickness by number of "ply" layers to obtain a nominal "ply" thickness.

[a] Test method not suitable for thermoplastic matrix.

Table 1 *(continued)*

Property		Standard	Unit	No. of material batches	Test conditions and supplementary instructions
				SQP	
16	Fibre, matrix and void volume percent	ISO 14127/ ISO 1172	%	3	ISO 14127 – carbon-fibre based systems ISO 1172 – glass-fibre based systems ISO 1183 to be used for the required density measurement

[a] Test method not suitable for thermoplastic matrix.

Table 2 — Standard qualification plan — Composite mechanical properties — Batch requirements

Property		Symbol	Standard	Unit	Test condition						Test conditions and supplementary instructions
					DRY				70 °C/85 % RH		
					−55°C[a]	RT	70 °C	125 °C[a]	RT	70 °C	
17	Tension	σ_{Mt11}	Unidirectional ISO 527-5 Multidirectional ISO 527-4	MPa	1	3	1			1	Refer to standard for specimen dimensions and test details. () = not required for balanced fabrics ν_{21} normally calculated from the following relationship for orthotropic materials: $\nu_{21} = \nu_{12}\,(E_{22}/E_{11})$ NOTE $\nu = \mu$ in ISO 527
		σ_{Mt22}		MPa	1	1	(1)			(1)	
		E_{t11}		GPa	1	3	1			1	
		E_{t22}		GPa	1	1	(1)			(1)	
		ε_{Mt11}		%	1	3	1			1	
		ε_{Mt22}		%	1	1	(1)			(1)	
		ν_{12}				1					
		ν_{13}				1					
		ν_{21}									
		ν_{23}				1					
18	Compression	σ_{Mc11}	ISO 14126 unidirectional, multidirectional	MPa	1	3	1			3	Refer to standard for specimen dimensions and test details. Type A, B_1 and B_2 specimens, testing by Method 1 (shear loading) or Method 2 (end loading) (1) = not required for balanced fabrics
		σ_{Mc22}		MPa		1	(1)			1	
		E_{c11}		GPa	1	3	1			3	
		E_{c22}		GPa		1	(1)			1	
		ε_{Mc11}		%	1	3	1			3	
		ε_{Mc22}		%		1	(1)			1	
19	Shear ± 45° tension	τ_{M12}	ISO 14129	MPa	1	3	1	1	1	1	
		γ_{M12}		%	1	3	1	1	1	1	
		G_{12}		GPa	1	3	1	1	1	1	
20	Interlaminar shear strength (ILSS)	τ_{M1}	ISO 14130	MPa	1	3	1	3	1	3	
		τ_{M2}		MPa		1	1				
21	Flexural	σ_{Mf11}	ISO 14125	MPa		3					Refer to standard for specimen dimensions and test details. Provide details of which method used. Method A (3-point flexure) is the default method.
		σ_{Mf22}		MPa		3					
		E_{f11}		MPa		3					
		E_{f22}		MPa		3					
		G_{13}		GPa		3					

Table 3 — Extended qualification plan — Composite mechanical properties — Batch requirements

Property		Symbol	Standard	Unit	Test condition						Test conditions and supplementary instructions
					DRY				70 °C/85 % RH		
					−55 °C	RT	70 °C	125 °C	RT	70 °C	
22	Open hole tension	σ_{OHT} (K_{OHT})	ASTM D 5766	MPa	1(1)	3(1)				3(1)	Quasi-isotropic lay-up. N.B. K_{OHT} is a dimensionless stress concentration factor calculated using σ_{OHT} and the unnotched tensile strength (using ISO 527-4 and determined from bracketed number of batches)
23	Open hole compression	σ_{OHC} (K_{OHC})	ISO 12817	MPa	1(1)	3(1)				3(1)	Quasi-isotropic lay-up. NOTE K_{OHC} is a dimensionless stress concentration factor calculated using σ_{OHC} and the unnotched compressive strength (using ISO 14126 and determined from bracketed number of batches)
24	Plane-pin bearing strength	σ_p	ISO 12815	MPa	1	3				3	Quasi-isotropic lay-up, plain pin — unrestrained (i.e. no washer, nuts or applied torque)
25	Instrumented impact	F_M	ISO 6603-2	N		3				3	Quasi-isotropic lay-up. Refer to standard for additional information required with results e.g. specimen size, support parameters, failure criterion, etc.
		l_M		mm							
		E_M		J							
		E_P		J							
		l_P		mm							
26	Compression-after-impact strength	A_D	ISO 18352	mm^2		3				3	Quasi-isotropic lay-up material, report A_D — projected area of damage using ultrasonic c-scanning
		σ_{MCAI}		MPa							
		ε_{MCAI}		%							
27	Mode I fracture energy	G_{IC}	ISO 15024	J/m^2		3				1	Recommended for fully unidirectional lay-up only.
28	Mode II fracture energy	G_{IIC}	ISO 15114	J/m^2		3				1	Recommended for fully unidirectional lay-up only.

8 Test plate preparation and specimen machining

Specimens shall be cut from test plates manufactured according to the fabrication method given in ISO 1268 (all parts) for the type of material, and related process route, under test, or nearest equivalent. Machining shall be performed in accordance with ISO 2818 (additional guidance is given in Reference [4]), as applicable, and the dimensions of the specimen shall comply with those given in the relevant test method standard (see recommended standards in Tables 1 to 3).

9 Test requirements

9.1 Standard qualification plan

The test methods, test conditions and units specified in Tables 1 to 2 shall be used. Specific details on preparing and testing specimens are given in the individual test methods. Where the test method has different procedures for different types of reinforcement or matrix, the appropriate procedure shall be used for the type of composite material under test.

Where required (see Tables 2 to 3), measurements of a property shall be made along the 1 and 2 axes. In addition, where required (as indicated in Tables 2 to 3), specimens shall be tested at temperatures other than ambient (see ISO 3205, ISO 291). Temperatures and conditioning requirements should be according to the test method used, the relevant material specification or by agreement between supplier and user. In the absence of this guidance, the aerospace requirements should be used [i.e. at −55 °C and 70 °C (DRY) and/or after conditioning for 1,000 h at 70 °C/85 % RH (HOT-WET)]. The conditions used shall be recorded according to Clause 13.

NOTE Guidance on preferred non-ambient test temperatures to be used is given in ISO 3205[3].

9.2 Extended qualification plan

The methods listed in Table 3 enable the response of the material under evaluation to different strain concentrations (e.g. ASTM D 5766, ISO 12815 and ISO 12817). Two further methods assess response to impact loads and subsequent crack growth. Finally, two methods are given for assessing the interlaminar crack resistance energy under opening mode (i.e. Mode I – ISO 15024) and shear mode (Mode II – ISO 15114).

9.3 Reduced qualification plan

In certain cases such as for nominally isotropic (mats), low anisotropy (e.g. balanced fabrics,) or pseudo-isotropic (e.g. unidirectional [45/90/45/0]2s lay-ups), there is no requirement to test in the "2" direction.

It is not necessary to test batches at −55 °C, at 125 °C or after hot-wet conditioning at 70 °C/85 % RH, unless the application is intended for the aerospace sector or equivalent. For other sectors, in addition to RT tests, test temperatures and conditioning requirements should be according to the test method used, the relevant material specification or by agreement between supplier and user.

10 Presentation of results — Standardized data sheets

The presentation of data shall be as set out in the standardized Report Sheets 1 to 4 given in Annex A, Tables A.1 to A.4, in addition to the metadata information required as appropriate. This should include the matrix used, the type and form of the reinforcing fibres; and the processing methods used to produce the test specimens. The report sheet should be adjusted when different test temperatures are adopted.

11 Statistical analysis

The statistical analysis of the test results for design values shall use the procedures, including recommendations for the determination of B-basis design allowables, given in Annex B.

12 Precision

An interlaboratory analysis was undertaken by 12 organizations (3 Oms, 4 research organizations, 1 material supplier, 3 instrument manufacturers and 1 regulator). Results were analysed according to ISO 5725[5] (using 95 % confidence limits) in order to assess the repeatability (measure of within site scatter) and reproducibility (measure of between site scatter) of 5 test methods selected from the SQP. Tests were performed on carbon fibre-epoxy pre-preg unidirectional materials from two independent suppliers. Test plates were manufactured at NPL according to the fabrication method given in the appropriate part of ISO 1268 and following material supplier's guidance. All plates were autoclave cured at 120 °C. Specimens were extracted from test plates in accordance with ISO 2818. Machining operations were performed using a diamond grit coated circular saw, with water used as a coolant/lubricant. Specimens were machined to the dimensions and tolerances given in the appropriate test standards.

The test methods used were:

— ISO 527-5 (see also ISO 527-1);

— ISO 14126;

— ISO 14125;

— ISO 14130;

— ISO 6721-11.

See Tables 4 to 7.

Table 4 — Repeatability and reproducibility values and mean value for Material 1

Property		Repeatability conditions		Reproducibility conditions		Mean result
		S_r	r	S_R	R	
Tension	σ_{Mt11}	92,5	259	118	329	2 167 MPa
	E_{t11}	3,28	*9,19*	6,79	19,0	133 GPa
	ν_{12}	0,02	0,06	0,02	0,07	0,34
Compression	σ_{Mc11}	95,7	268	181	507	1 170 MPa
	E_{c11}	10,1	28,3	10,1	28,3	111 GPa
Flexure	σ_{Mf11}	97,5	273	135	379	1 677 MPa
	E_{f11}	3,06	8,58	4,72	13,2	119 GPa
ILSS	σ_{M1}	2,91	8,16	*5,58*	15,6	97,6 MPa
DMA	T_g	1,18	3,29	4,62	12,9	123 °C
	T_{onset}	1,71	4,79	8,67	24,3	102 °C
	T_{loss}	1,13	3,15	9,63	27,0	133 °C
	$T_{tan\ delta}$	*1,61*	4,51	13,3	37,3	147 °C

Table 5 — Repeatability and reproducibility values as percentages of mean value for Material 1

Property		Value as percentage of mean, %			
		Repeatability conditions		Reproducibility conditions	
		S_r	r	S_R	R
Tension	σ_{Mt11}	4,27	12,0	5,45	15,2
	E_{t11}	2,46	6,88	5,09	14,2
	ν_{12}	5,95	17,0	7,14	19,9
Compression	σ_{Mc11}	8,18	22,9	15,5	43,3
	E_{c11}	9,10	25,5	9,10	25,5
Flexure	σ_{Mf11}	5,81	16,3	8,05	22,6
	E_{f11}	2,57	7,21	3,97	11,1
ILSS	σ_{M1}	2,98	8,36	5,72	16,0
DMA	T_g	0,96	2,67	3,76	10,5
	T_{onset}	1,68	4,70	8,50	23,8
	T_{loss}	*0,85*	2,37	7,24	20,3
	$T_{tan\ delta}$	1,10	3,07	9,05	25,4

Table 6 — Repeatability and reproducibility values and mean value for Material 2

Property		Repeatability conditions		Reproducibility conditions		Mean result
		S_r	r	S_R	R	
Tension	σ_{Mt11}	112	312	159	447	2 651 MPa
	E_{t11}	3,88	10,9	5,51	15,4	122 GPa
	ν_{12}	0,02	0,05	0,02	0,07	0,33
Compression	σ_{Mc11}	129	360	177	497	987 MPa
	E_{c11}	4,46	12,5	5,57	15,6	110 GPa
Flexure	σ_{Mf11}	70,7	198	72	202	1 372 MPa
	E_{f11}	1,46	4,07	4,10	11,5	111 GPa
ILSS	σ_{M1}	1,35	3,78	2,57	7,21	83,6 MPa
DMA	T_g	1,36	3,80	7,52	21,1	126 °C
	T_{onset}	1,30	3,64	12,2	34,2	110 °C
	T_{loss}	0,96	2,69	5,43	15,2	131 °C
	$T_{tan\ delta}$	1,08	3,03	15,5	43,4	150 °C

Table 7 — Repeatability and reproducibility values as percentages of mean value for Material 2

Property		Value as percentage of mean, %			
		Repeatability conditions		Reproducibility conditions	
		S_r	r	S_R	R
Tension	σ_{Mt11}	4,22	11,8	6,00	16,9
	E_{t11}	3,17	8,92	4,51	12,6
	ν_{12}	5,44	15,4	7,25	19,9
Compression	σ_{Mc11}	13,1	36,5	17,9	50,4
	E_{c11}	4,05	11,4	5,06	14,2
Flexure	σ_{Mf11}	5,15	14,4	5,25	14,7
	E_{f11}	1,32	3,67	3,69	10,4
ILSS	σ_{M1}	1,61	4,52	3,07	8,62

Table 7 *(continued)*

Property		Value as percentage of mean, %			
		Repeatability conditions		Reproducibility conditions	
		S_r	r	S_R	R
DMA	T_g	1,08	3,02	5,97	16,7
	T_{onset}	1,18	3,31	11,1	31,1
	T_{loss}	0,73	2,05	4,15	11,6
	$T_{tan\ delta}$	0,72	2,02	10,3	28,9

13 Test report

In addition to completed Report Data Sheets 1-4 (see Annex A), the test report shall include the following information:

a) a reference to this document, i.e. ISO 20144:2019;

b) complete identification of the material tested, including type, source, manufacturer's code number and test plate manufacture details, where these are known;

c) the date of measurements;

And, in addition, for each test method conducted:

d) a reference to the standard used;

e) the method of preparing the specimens;

f) the specimen dimensions;

g) the conditioning procedures used;

h) the test conditions used;

i) the number of specimens tested;

j) the type(s) of failures obtained;

k) the individual test results;

l) the mean and standard deviations (95 % confidence level);

m) statement as to whether any test specimens from a data set have been rejected and, if so, the reasons why;

n) any operation not specified in this or referenced documents, as well as any incident likely to have affected the result.

Annex A
(normative)

Report sheets

Table A.1 — Report sheet 1 — Standard qualification plan — Material record sheet

Material Record Sheet		No:	
Material code:			
Fibre type:		Fibre code:	
Fibre format:			
Fibre supplier:			
Matrix type:		Matrix code:	
Matrix supplier:			
Prepreg type[a]:		Prepreg code[a]:	
Prepreg supplier[a]:		Pre-preg Ply-thickness[a]:	
Manufacturing process:			
Test plates lay-up(s) and thickness:			
Consolidation conditions temperature and pressure:			
Post-cure conditions[b]:			
Manufacturing date(s)			
Specimen machining method(s)			
Test machine grades(s)			
Comments:			
Signature		Date:	

[a] An intermediate product requiring heat and/or consolidation.

[b] Not applicable to thermoplastic matrix.

Table A.2 — Report Sheet 2 — Standard qualification plan — Constituent and composite properties

	Property	Standard	Unit	Mean, $\dot{x}$	Standard deviation, s	Comments
CONSTITUENT PROPERTIES						
1	Mass per unit area	ISO 10352	g/m^2			
2	Fibre mass per unit area	EN 2559	g/m^2			
3	Fibre and matrix volume fraction	ISO 11667	%			
4	Gel time[a]	ISO 15040	minutes			
5	Resin flow[a]	ISO 15034	% weight change			
6	Glass transition temperature	ISO 11357-2	°C			
7	Percentage of volatile content[a]	EN 2558	%			
8	Density of fibre	ISO 10119	g/cm^3			
9	Analysis by DSC	ISO 11357-1	Variable			
10	Density of matrix	ISO 1675	g/cm^3			
COMPOSITE PROPERTIES						
11	Coefficient of thermal expansion	CEN EN 821-1 or ISO 11359-2	%/°C			α_1
						α_2
						α_3
12	Moisture uptake (ambient)	EN 3615	%			
13	Moisture uptake (hot/wet)	EN 2378	%			
14	Glass transition temperature by DMA	ISO 6721-11	°C			
15	Ply thickness	ISO 16012	mm			
16	Fibre, matrix and void volume percent	ISO 14127	%			φ_f
						φ_r
						φ_v

[a] Not for thermoplastic matrix.

Table A.3 — Report Sheet 3 — Standard Qualification Plan — Composite mechanical properties

	Property	Sym-bol	Standard	Unit	Test condition												Comments
					DRY								70 °C/85 % RH				
					−55 °C		RT		70 °C		125 °C		RT		70 °C		
					$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	
17	Tension	σ_{Mt11}	Unidirectional ISO 527-5 Multidirectional ISO 527-4	MPa													Note if ν_{12} is measured or calculated.
		σ_{Mt22}		MPa													
		E_{t11}		GPa													
		E_{t22}		GPa													
		ε_{Mt11}		%													
		ε_{Mt22}		%													
		ν_{12}															
		ν_{13}															
		ν_{21}															
		ν_{23}															
18	Compression	σ_{Mc11}	ISO 14126 unidirectional, multidirectional	MPa													
		σ_{Mc22}		MPa													
		E_{c11}		GPa													
		E_{c22}		GPa													
		ε_{Mc11}		%													
		ε_{Mc22}		%													
19	Shear ± 45° tension	τ_{M12}	ISO 14129	MPa													
		γ_{M12}		%													
		G_{12}		GPa													
20	ILSS – through thickness	τ_{M1}	ISO 14130	MPa													
		τ_{M2}		MPa													
21	Flexural	σ_{Mf11}	ISO 14125	MPa													
		σ_{Mf22}		MPa													
		E_{f11}		MPa													
		E_{f22}		MPa													
		G_{13}		GPa													

Table A.4 — Report Sheet 4 — Extended Qualification Plan — Composite mechanical properties

	Property	Symbol	Standard	Unit	Test Condition												Comments
					DRY								70 °C/85 % RH				
					−55 °C		RT		70 °C		125 °C		RT		70 °C		
					$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	$\dot{x}$	s	
22	Open hole tension	σ_{OHT} (K_{OHT})	ASTM D5766	MPa													
23	Open hole compression	σ_{OHC} (K_{OHC})	ISO 12817	MPa													
24	Plane pin-bearing	σ_p	ISO 12815	MPa													
25	Instrumented Impact	F_M	ISO 6603-2	N													
		l_M		mm													
		E_M		J													
		E_P		J													
		l_P		mm													
26	Compression-after-impact	A_D	ISO 18352	mm^2													
		σ_{MCAI}		MPa													
		ε_{MCAI}		%													
27	Mode I fracture energy	G_{IC}	ISO 15024	J/m^2													
28	Mode II fracture energy	G_{IIC}	ISO 15114	J/m^2													
NOTE = not required or by special request only.																	

Annex B
(normative)

Determination of statistical parameters

B.1 General

This annex details a procedure used for calculating B-basis design allowables for properties measured from tests on 30 specimens from a minimum of 3 batches of material. The approach is based on the methods given in Reference [2]. The flow chart in Figure B.1 provides a step by step guide to the statistical analysis process for B-basis design allowables.

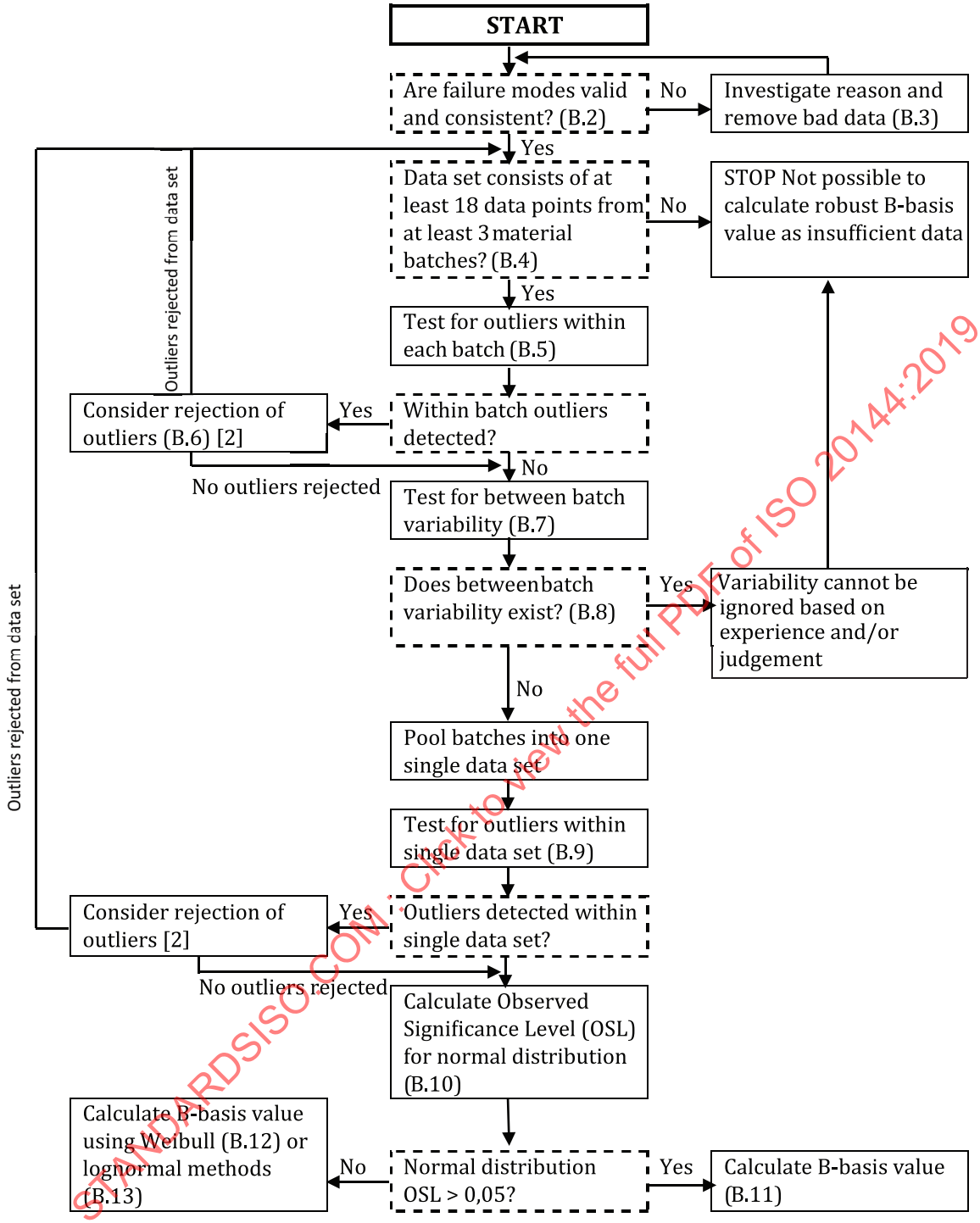

Figure B.1 — Step by step procedure for calculating B-basis design allowables for data generated via this document

B.2 Validity and consistency of failure modes

For a particular strength property, the failure modes observed should be valid and consistent for a given environmental condition. Specimens observed to fail in non-acceptable modes (in accordance with the relevant test standard) should not be included in the data set. In addition, if a range of acceptable failure modes are observed within a data set, then the data should be further examined to see if there is a correlation between strength and the mode of failure. Should such a correlation exist then investigation

of specimen manufacturing and preparation, as well as testing parameters should be undertaken to determine the cause of the different failure modes.

B.3 Investigation and removal of bad data

Should physical evidence be identified that invalidates a test result (e.g. incorrect failure mode), then this result should be deemed a bad data point and removed from the data set.

B.4 Quantity of data

The SQP recommends that properties be measured from tests on specimens prepared from either 1 or 3 batches of material depending on the criticality of the data (see Clause 6); equating to tests on either 10 or 30 specimens, respectively. In accordance with the guidance provided in Reference [2] statistically robust B-basis values should only be derived from data groups consisting of at least 18 specimens sampled from at least 3 material batches. Therefore, within the SQP it is only possible to calculate B-basis design allowable values for properties measured from 3 batches of material. For these cases, the number of specimens tested (30) is more than enough to satisfy the minimum specimen number (18) stipulated in Reference [2]. For those properties measured from a single batch of material (i.e. 10 specimens), the statistical analysis of these data should be limited to calculation of mean and standard deviation.

B.5 Test for outliers within each batch

The mean and standard deviation for each batch data set are calculated using Formulae (B.1) and (B.2), respectively:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{B.1}$$

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \tag{B.2}$$

where

$\bar{x}$ is the data set mean;

x_i is the individual observation in a data set;

n is the number of observations in a data set;

s is the standard deviation of data set.

Each data set shall be examined for the presence of outliers. The maximum normed residual (MNR) method shall be used for quantitative screening of outliers. Formula (B.3) shows the MNR quantity as the maximum absolute deviation from the data set mean divided by the data set standard deviation. This quantity is calculated for each observation in each data set and the resulting values compared to a critical value calculated for a data set size, n, using Formula (B.4):

$$\text{MNR} = \max_i \frac{\left|x_i - \bar{x}\right|}{s} \tag{B.3}$$

$i = 1, 2, \ldots\ldots, n$