IEC 62788-2-1

Edition 1.0 2023-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials – Frontsheet and backsheet – Safety requirements

Procédures de mesure des matériaux utilisés dans les modules photovoltaïques – Partie 2-1: Matériaux polymères – Face avant et face arrière – Exigences de sécurité

IEC 62788-2-1:2023-08(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, …). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

IEC 62788-2-1

Edition 1.0 2023-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials – Frontsheet and backsheet – Safety requirements

Procédures de mesure des matériaux utilisés dans les modules photovoltaïques – Partie 2-1: Matériaux polymères – Face avant et face arrière – Exigences de sécurité

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 27.160

ISBN 978-2-8322-6887-2

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 2-1: Polymeric materials – Frontsheet and backsheet – Safety requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects because each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62788-2-1 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
82/2123/FDIS	82/2148/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 62788 series, published under the general title *Measurement procedures for materials used in photovoltaic modules*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document provides test procedures and specifications for polymeric front- and backsheet constructions employed in a PV module for safety qualification on a component level. Test methods have been compiled to match the general requirements for polymeric materials used as relied-upon insulation defined in the IEC 61730 standard series in consideration of test methods in IEC TS 62788-2 (characterization of front- and backsheets), IEC TS 62788-7-2 [4][1](UV weathering test) and the retesting guidelines IEC TS 62915. This document provides clarifications on definitions of front- and backsheet construction types and related test requirements, and additional environmental stress testing, to which IEC 61730-1 refers. Separating out the component level testing into this document was considered to limit the complexity of the IEC 61730 standard series, also in view of the implementation of the test methods in the frame of IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE).

Test methods on a component level and PV module level are different for practical reasons. On a component level, the daylight filtered xenon test (IEC TS 62788-7-2) is applied for UV weathering, which is regarded as more representative to assess the durability of polymeric materials under outdoor weather conditions than the UVA test of IEC 61215-2. The latter has been developed in view of practicality of applying UV exposure to larger scale PV modules.

This document focusses on the safety relevant properties of front- and backsheets as required by IEC 61730.

The lamination protrusion test (aka DTI test) is required to measure the thickness of relied-upon insulation on the component level. The thickness of the RUI layer(s) is verified by MST 04 of IEC 61730-2 on PV module level. The test provides additional information needed for evaluation of the Comparative Tracking Index (CTI) and dielectric strength / breakdown voltage.

– The lamination protrusion test applies default lamination conditions, that are representative for a typical PV module manufacturing process. Using a 800 µm diameter solder wire that mimics severe solder peaks and/or slanted ribbons, the test serves as worst case scenario for measurement of potential displacement of material under lamination conditions. Even more harsh lamination process conditions can be selected as recommended by the manufacturer of the front- or backsheet.
– The lamination protrusion test is also used to identify additional inner layers of the front- or backsheet that potentially may be in contact with live parts and for which CTI shall be determined. Additional layers may require CTI depending on the construction of the PV module, e.g., due to specific sheet openings and through wiring for junction box connections with background provided in IEC 61730-1.
– The ratio of the measured distance through insulation (t_{DTI}) to the total thickness is used to calculate the effective dielectric strength or required withstand voltage when measured on final products that contain inner layers, which can be displaced under lamination conditions (see breakdown voltage test in 6.4).
– Because of the relationship with thermal endurance, t_{DTI} can be listed as a function of the module operating temperature rating.

1 Numbers in square brackets refer to the Bibliography.

This document specifies a suite of environmental stress tests to characterize the durability of the relied-upon insulation. In the evaluation of tensile testing a minimum elongation at break is considered in addition to retention of tensile strength, as this allows to differentiate known-bad and known-good materials. The thermal endurance performance, which is historically evaluated by tensile strength and dielectric strength in terms of TI or RTE (RTI), is therefore complemented by a thermal failsafe test to also evaluate elongation at break. The combination of these elements, tests covering thermal, damp heat and UV weathering stresses and evaluation of elongation at break, represents a step forward in safety testing of polymeric front- and backsheets that is still balanced in terms or practicality (duration) of testing.

The requirements in this document for model or variant designations and (re)testing of similar materials have been aligned with developments for the IEC TS 62915 module retesting guidelines. The current requirements provide a first step towards more detailed requirements which may be developed in a future revision of this document or a dedicated component retesting standard.

A future revision of this document may consider sequential testing on engineering coupons with (solder wire) bumps to better mimic the combination of UV and cyclic stress fatigue, that is currently discussed as the next level in endurance testing of polymeric front- and backsheets in IEC TS 62788-2 and IEC TS 63209-2[6]. However, method consolidation requires more time than available for this project.

In view of requirements for material identification in the context of the retesting guidelines (IEC TS 62915), approaches for “finger-printing” are provided in Annex A.

The requirements in this document may be used in the context of Manufacturing Quality Assurance of polymeric front- and backsheets as explained in the guideline IEC 62941[5].

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 2-1: Polymeric materials – Frontsheet and backsheet – Safety requirements

1 Scope

This document specifies the safety requirements for flexible polymeric front- and backsheet constructions, which are intended for use as relied-upon insulation in photovoltaic (PV) modules. The specifications in this document define the specific requirements of polymeric front- or backsheet constructions on the component level and cover mechanical, electrical, visual and thermal characterization in an unexposed state and/or after ageing.

This document covers class II and class 0 modules, as defined in IEC 61730-1. Class III modules are out of scope.

For qualification to IEC 61730-1 of a PV module using a polymeric front- or backsheet, the sheet must pass the requirements in this document for the specified module's safety class, rated system voltage, and module temperature rating.

Compliance with the safety requirements for a front- or backsheet on the component level does not replace the need for a safety qualification of the complete PV module, in which the front- or backsheet is integrated. The appropriate requirements for testing and qualification of PV modules, are defined in IEC 61730-1 and IEC 61215-1 (or IEC TS 62915 in case of retesting), with test methods provided by IEC 61730-2 and IEC 61215-2, respectively.

This document provides the requirements for qualification of front- and backsheets to be used in module safety qualification according to IEC 61730-1. Test method descriptions are provided in IEC TS 62788-2, along with additional characterization methods useful for performance or quality assurance.

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.

IEC 60216-1, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-3, *Electrical insulating materials – Thermal endurance properties – Part 3: Instructions for calculating thermal endurance characteristics*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative temperature index (RTI) of an insulating material*

IEC 60664-1, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 61215-1, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements*

IEC 61215-2, *Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC TS 62788-2, *Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets*

IEC TS 62915, *Photovoltaic (PV) modules – Type approval, design and safety qualification – Retesting*

IEC TS 63126:2020, *Guidelines for qualifying PV modules, components and materials for operation at high temperatures*

ISO 527-3, *Plastics – Determination of tensile properties – Part 3: Test conditions for films and sheets*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply, in addition to those in IEC TS 61836 and IEC TS 62788-2.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 General terms and definitions

3.1.1
FBST
front- or backsheet safety test in accordance with IEC 62788-2-1

3.1.2
tolerance
permitted deviation between the declared value of a quantity and the measured value

[SOURCE: IEC 60050-411[2]:1996,411-36-19]

3.2 Sheet types and orientations

3.2.1
air-side
side of the front- or backsheet oriented towards the outside of the PV module, i.e., away from the cells

3.2.2
backsheet
(combination of) outer layer(s) of the PV module, located as substrate on the back of the PV module and providing protection of the inner components of the PV module from external stresses and weather elements, as well as providing electrical insulation

3.2.3
frontsheet
(combination of) outer layer(s) of the PV module designed for prolonged exposure to direct sunlight (> 300 W/m^2) and providing protection of the inner components of the PV module from external stresses and weather elements, as well as providing electrical insulation

3.2.4
inner side
side of the front- or backsheet that is oriented to the solar cells, typically laminated to the encapsulant

3.2.5
machine direction
MD
direction along which the material layer was extruded or produced, extending out of a die or other manufacturing equipment in a production line

3.2.6
transverse direction
TD
direction perpendicular to which the material layer was extruded or produced

3.2.7
sun-facing side
side of the front- or backsheet that is oriented in direction of the sun-facing front side of the PV module

Note 1 to entry: Sun-facing sides are the air-side of a frontsheet and inner side of a backsheet.

3.3 Electrical insulation

3.3.1
breakdown voltage
V_{BD}
DC voltage at which electric breakdown occurs under prescribed test conditions, or in use

Note 1 to entry: Breakdown voltage testing in context of PV modules and components materials applies direct current (DC).

[SOURCE: IEC 60050-212[1]:2010, 212-11-34, modified – added symbol, and added Note 1 to entry.]

3.3.2
comparative tracking index
CTI
numerical index value related to the maximum voltage that a material can withstand without formation of a permanent and electrically conductive carbon (tracking) path and without a persistent flame occurring, when evaluated under specified test conditions defined in IEC 60112

Note 1 to entry: The mentioned maximum test voltage is not in conjunction with any system or operational voltage, but it is used for evaluation of material groups.

[SOURCE: IEC 60050-212:2010, 212-11-59, modified – it has been rephrased by also clarifying that CTI is an index value to evaluate material groups according to IEC 60112. Note 1 to entry added.]

3.3.3
distance through insulation
t_{DTI}
thickness of relied-upon insulation (RUI) after the lamination protrusion test, with the minimum allowable value defined by the rated system voltage

3.3.4
material group
category of insulation materials according to IEC 60664-1 as defined by the results of the CTI test

3.3.5
rated system voltage
$[V_{sys}]_{max}$
maximum system voltage for which a module is rated

3.3.6
relied-upon insulation
RUI
solid insulation system providing protection against electric shock in the final application, with material's requirements for thermal endurance and resistance against environmental stress factors

Note 1 to entry: Thin films used as polymeric front- or backsheet can consist of RUI plus additional layers that have other functions, e.g., they protect the polymeric materials from UV radiation (see Figure 1).

3.3.7
withstand voltage
V_w
DC voltage which the material under test can withstand for a defined minimum amount of time without occurrence of an electric breakdown

3.4 Temperatures

3.4.1
98th percentile module operating temperature
T_{98}
temperature at which a module is operating below more than 98 % of the time when deployed in a PV system

Note 1 to entry: The 98th-percentile temperature is calculated by ranking measured or calculated module temperature data taken at hourly (or more frequent) time intervals for a typical calendar year.

Note 2 to entry: For a standard year, the 98th percentile temperature is met or exceeded for 175,2 h.

3.4.2
rated module operating temperature
$[T_{98}]_{max}$
maximum allowed 98th percentile operating temperature (T_{98}) of the PV module

3.5 Tensile properties

3.5.1
elongation at break
ε_B
strain at which the specimen under test breaks

Note 1 to entry: Break defines the point in the tensile test, where the tensile stress drops below 50 % of its highest value.

3.5.2
tensile strength at break
σ_B
maximum engineering stress measured when a specimen is elongated in tension to the point of breaking

4 Designation and ratings

The front- or backsheet shall be evaluated for its intended use in a PV module, including designation as front- or backsheet, maximum module operating temperature, maximum system voltage and module safety class. Due to the coordinating requirements for temperature and system voltage ratings, a front- or backsheet may be rated for multiple sets of ratings (e.g. maximum V_{sys} and T_{98}).

Frontsheets are designed for prolonged exposure to direct sunlight (> 300 W/m^2). Backsheets are designed for exposure through glass and encapsulant on the interior side and restricted for use with indirect or limited direct sunlight (< 300 W/m^2) on the exterior side. Because of this, the test conditions for the UV weathering test (FBST 09) are different for front- and backsheets. A product can be assigned as a frontsheet, backsheet or both.

A front- or backsheet is rated for a maximum T_{98} module operating temperature. The module operating temperature is related to a combination of environment and mounting conditions as described in IEC 61730-1 and IEC TS 63126:

- IEC 61730-1 (by default) specifies PV modules with 98th percentile operating temperatures T_{98} ≤ 70 °C.
- IEC TS 63126 defines extended test conditions for high temperature operation with T_{98} ≤ 80 °C [level 1] or ≤ 90 °C [level 2]. The requirements for the thermal endurance test (FBST 06) depend on the specified $[T_{98}]_{max}$. IEC 62788-2-1 deviates from IEC TS 63126:2020, in that the UV weathering temperature conditions applied in the UV weathering test (FBST 08) shall be as specified in Table 3.

NOTE IEC TS 63126:2020 is currently under consideration for modification and will likely be changed to conform with this document.

In addition, a front- or backsheet is rated for a maximum system voltage and a module safety class. IEC 61730-1 defines PV module safety class and system voltage ratings. Front- and backsheets can be used in modules of safety class II (individual and/or system level electrical outputs at hazardous levels of voltage, current and power) and safety class 0 (intended for use in restricted access areas that are protected from public access by fences or other measures of the location that prevent general access).

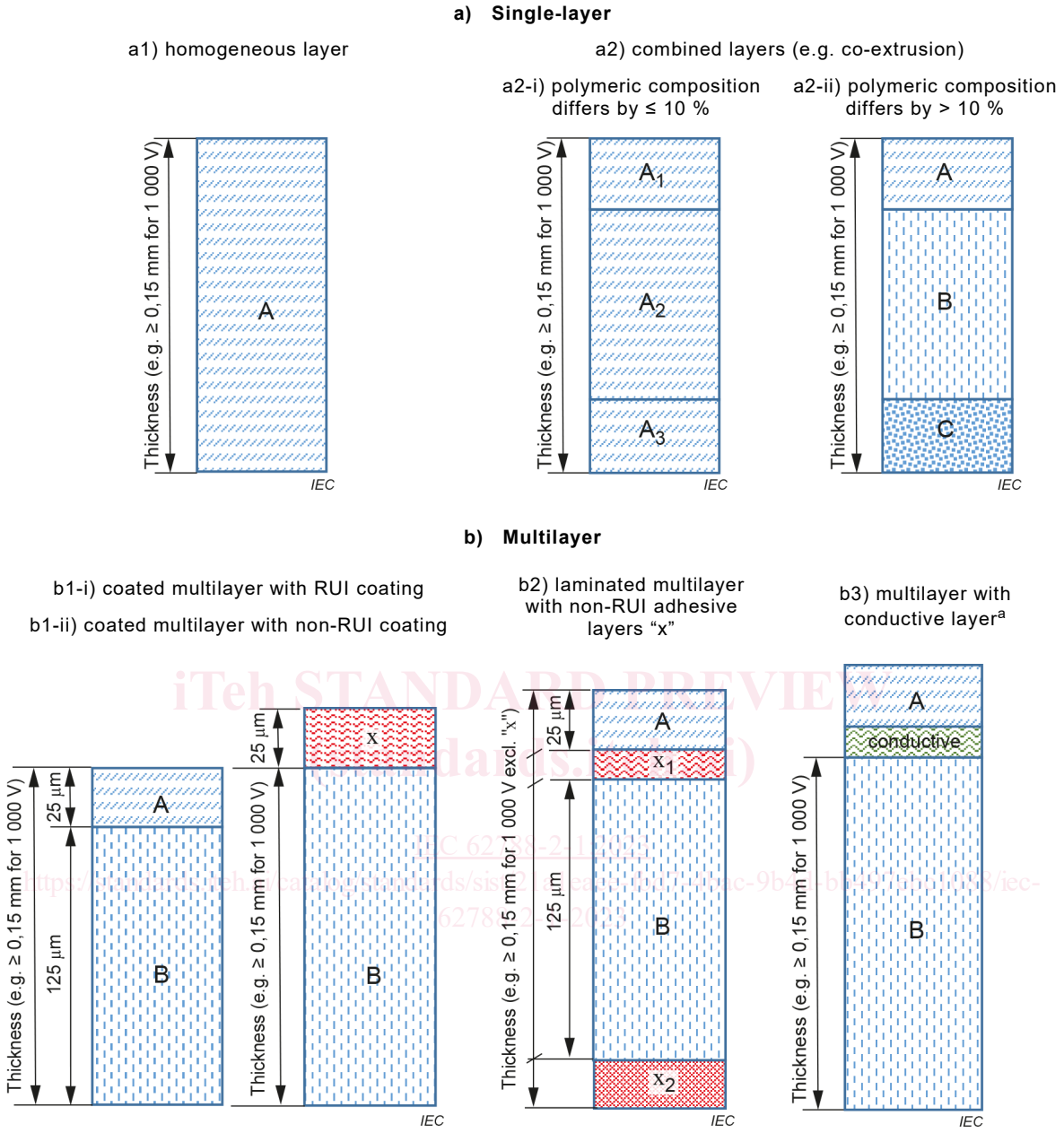
5 Requirements

5.1 General

5.1.1 Overview

Requirements for front- and backsheets are derived from insulation coordination requirements from IEC 60664 and IEC 61730-1, and additional requirements for long term reliability based on observations of field failures.

Requirements shall be met for the full front- or backsheet and also for individual layers designated as RUI (from here referred to as RUI layers). Typical constructions are described in Figure 1.



NOTE In actual front- or backsheet constructions the numbers of sublayers may differ from the examples shown.

[a] The case of a conductive layer as in example case b3) will require additional module level considerations for insulation coordination as described in IEC 61730-1.

Figure 1 – Schematic diagrams of typical constructions of front- or backsheets

5.1.2 Single-layer constructions

A single-layer construction is a front- or backsheet produced in one production step. It may consist of a single homogeneous layer (a1) or combined layers (a2) manufactured in one production process (e.g. co-extrusion) such that they cannot reasonably be separated without fundamentally changing their properties, e.g., residual strain or crystallinity, in ways that might affect their performance in a PV module. For combined layers, the thermal endurance requirements depend on the layer composition (see 5.3). If the polymeric composition differs by ≤ 10 % (by mass) between sub-layers or gradient zones within the material layer (a2-i) it is treated equivalent to a single homogeneous layer (a1). If the polymeric composition differs by > 10 % (a2-ii), the linearity of the Arrhenius plot shall be assessed (see 5.3). The 10 % criteria refers to differences in blending ratios and/or to copolymer ratios of the polymers.