



BSI Standards Publication

Measurement procedures for materials used in photovoltaic modules

Part 1-6: Encapsulants — Test methods for determining
the degree of cure in Ethylene-Vinyl Acetate

National foreword

This British Standard is the UK implementation of EN 62788-1-6:2017+A1:2020. It is identical to IEC 62788-1-6:2017, incorporating amendment 1:2020. It supersedes [BS EN 62788-1-6:2017](#), which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by **A1** **A1**.

The UK participation in its preparation was entrusted to Technical Committee GEL/82, Photovoltaic Energy Systems.

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

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

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 580 51007 6

ICS 27.160

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2017.

Amendments/corrigenda issued since publication

Date	Text affected
31 July 2020	Implementation of IEC amendment 1:2020 with CENELEC endorsement A1:2020

English Version

Measurement procedures for materials used in photovoltaic
modules - Part 1-6: Encapsulants - Test methods for determining
the degree of cure in Ethylene-Vinyl Acetate
(IEC 62788-1-6:2017)

Procédures de mesure des matériaux utilisés dans les
modules photovoltaïques - Partie 1-6: Encapsulants -
Méthodes d'essai pour déterminer le degré de
durcissement dans l'éthylène-acétate de vinyle
(IEC 62788-1-6:2017)

Messverfahren für Werkstoffe, die in Photovoltaik-Modulen
verwendet werden - Teil 1-6: Verkapselungssstoffe -
Prüfverfahren zur Bestimmung des Aushärtungsgrads der
Ethylen-Vinyl-Acetat-Verkapselung
(IEC 62788-1-6:2017)

This European Standard was approved by CENELEC on 2017-03-03. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 82/1197/FDIS, future edition 1 of IEC 62788-1-6, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62788-1-6:2017.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2017-12-03
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2020-03-03

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62788-1-6:2017 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 61215 (series)	NOTE	Harmonized as EN 61215 (series).
ISO 11357-2	NOTE	Harmonized as EN ISO 11357-2.
ISO 11357-3	NOTE	Harmonized as EN ISO 11357-3.

Foreword to amendment A1

The text of document 82/1691/FDIS, future IEC 62788-1-6/A1, prepared by IEC/TC 82 "Solar photovoltaic energy systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62788-1-6:2017/A1:2020.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-03-30
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2023-06-30

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62788-1-6:2017/A1:2020 was approved by CENELEC as a European Standard without any modification.

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61215-1	-	Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1: Test requirements	EN 61215-1	-
ISO 291	2008	Plastics - Standard atmospheres for conditioning and testing	EN ISO 291	2008
ISO 6427	2013	Plastics - Determination of matter extractable by organic solvents (conventional methods)	EN ISO 6427	2014
ISO 10147	-	Pipes and fittings made of crosslinked polyethylene (PE-X) - Estimation of the degree of crosslinking by determination of the gel content	EN ISO 10147	2012
ISO 11357-1	2009	Plastics - Differential scanning calorimetry - (DSC) - Part 1: General principles	-	-
ISO/IEC 17025	2005	General requirements for the competence of testing and calibration laboratories	EN ISO/IEC 17025	2005
ASTM D2765-11	-	Standard Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics	-	-
ISO 6721-1	-	Plastics - Determination of dynamic mechanical properties - Part 1: General principles	EN ISO 6721-1	-
ISO 14577-1	-	Metallic materials - Instrumented indentation test for hardness and materials parameters - Part 1: Test method	EN ISO 14577-1	-

This page deliberately left blank

CONTENTS

FOREWORD	4
1 Scope	6
2 Normative references	6
3 Terms and definitions	7
4 Principle	8
5 DSC secondary method	8
5.1 Instrument and equipment for the secondary method	8
5.1.1 General	8
5.1.2 Electronic balance	8
5.1.3 Differential scanning calorimeter	8
5.1.4 Instrument calibration	9
5.2 Specimen preparation for the secondary method	9
5.2.1 Sampling and storage	9
5.2.2 Preparation procedures	9
5.3 Test requirements for the secondary method	10
5.3.1 Environment requirements	10
5.3.2 Parameter settings (residual enthalpy method)	10
5.3.3 Parameter settings (melt/freeze method)	10
5.3.4 Parameter settings (combined enthalpy and melt/freeze method)	10
5.4 Test procedure for the secondary method	11
5.5 Calculation and expression of the results for the secondary method	11
5.5.1 Enthalpy method	11
5.5.2 Melt/freeze method	12
5.6 Uncertainty of measurements for the secondary method	16
6 The primary method	16
6.1 Principle for the primary method	16
6.2 Instrument and equipment for the primary method	17
6.2.1 Electronic balance	17
6.2.2 Soxhlet extractor	17
6.2.3 Thimble	17
6.2.4 Heating apparatus	17
6.2.5 Handling apparatus	18
6.2.6 Solvent	18
6.3 Specimen preparation for the primary method	18
6.3.1 Sampling and storage	18
6.3.2 Preparation procedures	18
6.4 Test requirements for the primary method – Environment requirements	19
6.5 Test procedure for the primary method	19
6.6 Calculation and expression of the results for the primary method	19
7 Test report	19
8 Indentation secondary method	20
8.1 General	20
8.2 Principle	21
8.3 Instrument and equipment for the indentation method	21
8.4 Instrument calibration	22

8.5	Correlation of the degree of cure.....	22
8.6	Specimen preparation for the indentation method	22
8.7	Test procedure for the indentation method	23
Annex A (informative) Limitations of the primary and secondary measurement methods.....		24
Bibliography.....		26
Figure 1 – Example result for the DSC residual enthalpy method		12
Figure 2 – Location of temperatures and temperature ranges used in the melt/freeze DSC method		13
Figure 3 – Example of the temperature bounds applied for an automated software integration algorithm		15
Figure 4 – Representation of the measurement profile for an EVA test specimen.....		16
Figure 5 – Example of the correlation applied between G_i (indentation) and $G_{\%}$ (gel content)		22
Table 1 – Summary of the results for the example measurements shown in Figure 2		14

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 1-6: Encapsulants – Test methods for determining the degree of cure in Ethylene-Vinyl Acetate

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 since 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.

International Standard IEC 62788-1-6 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this standard is based on the following documents:

FDIS	Report on voting
82/1197/FDIS	82/1231/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "<http://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 publication 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.

MEASUREMENT PROCEDURES FOR MATERIALS USED IN PHOTOVOLTAIC MODULES –

Part 1-6: Encapsulants – Test methods for determining the degree of cure in Ethylene-Vinyl Acetate

1 Scope

This part of IEC 62788 defines the terminology, test equipment, test environment, specimen preparation, test procedures, and test report for measuring the degree of cure of Ethylene-Vinyl Acetate (EVA) encapsulation sheet used in photovoltaic (PV) modules. The differential scanning calorimetry (both residual enthalpy and melt/freeze protocols) and gel content methods are included herein. This procedure can be used by material- or module-manufacturers to verify that the cross-linking additive is present and is active. The procedure can also be used to verify the module manufacturing (lamination) process for the purposes of quality- and process-control. The procedure can also be used to assess the uniformity of the EVA formulation within a roll as well as to compare variation of the EVA formulation from roll to roll. This procedure can be applied to uncured or recently cured EVA sheet as well as uncured or recently cured EVA from PV modules.

This test procedure can also be applied to cross-linking ethylenic co-polymers other than EVA. The temperatures identified for the calorimetry measurements in this procedure have been optimized for EVA. Therefore, if the test procedure is applied to other encapsulation materials, the range of the test temperatures can have to be adjusted based on the active temperature of the curing agent and/or the melt/freeze temperature of the base material.

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

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

ISO 291:2008, *Plastics – Standard atmospheres for conditioning and testing*

ISO 6427:2013, *Plastics – Determination of matter extractable by organic solvents (conventional methods)*

ISO 6721-1, *Plastics – Determination of dynamic mechanical properties – Part 1: General principles*

ISO 11357-1:2009, *Plastics – Differential scanning calorimetry (DSC) – Part 1: General principles*

ISO 10147:2011, *Pipes and fittings made of crosslinked polyethylene (PE-X) – Estimation of the degree of cross-linking by determination of the gel content*