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# Plastics pipes and fittings — Utilisation of thermoplastics recyclates

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Part 2: Recommendations for relevant characteristics

## National foreword

This Published Document is the UK implementation of CEN/TS 14541-2:2022. Together with BS EN 14541-1:2022, it supersedes PD CEN/TS 14541:2013, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PRI/88/1, Plastics piping for non-pressure applications.

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

This Technical Specification has been prepared by CEN/TC 155 to stimulate the use of thermoplastics recyclates.

The UK committee, PRI/88/1, supports the use of recycled materials in the manufacture of plastic piping systems. However, the UK committee voted against this Technical Specification for the following reasons.

- The intended purpose of the document is not clearly described, which could lead to its incorrect use.
- The document covers recyclates, and the term 'recyclate' excludes 'reworked material' (as defined in BS EN 14541-1:2022). The inclusion of reworked material (in clause 5.4) is not consistent with the intended use of the document.
- The cracked round bar test (CRB) included in Annex A is not yet validated for the characterization of recyclates.

The UK committee gives the following advice concerning the Scope and contents of PD CEN/TS 14541-2:2022.

- To characterize the recyclate supplied to a manufacturer for the production of pipes and fittings, a specification is agreed between the supplier of the recyclate and the manufacturer. The relevant product standard should provide sufficient information for the supplier of the recyclate and the manufacturer to prepare an agreed specification for each grade of thermoplastic recyclate.
- PD CEN/TS 14541-2:2022 is intended to support those developing product standards in CEN TC 155 by listing characteristics and associated test methods for thermoplastics recyclates (PVC-U, PVC-C, PE, PP, and ABS). For a specific application, some or all the listed characteristics should be selected; additional characteristics may also be selected.
- PD CEN/TS 14541-2:2022 is not intended to be used directly by the supplier of the recyclate and the manufacturer of the recyclate for the preparation of an agreed specification. The relevant product standard should contain sufficient information for the supplier of the recyclate and the manufacturer to prepare an agreed specification for each grade of thermoplastic recyclate and should always be consulted.
- PD CEN/TS 14541-2:2022 covers thermoplastic recyclates, defined in BS EN 14541-1:2022 as plastics material resulting from the recycling of pre-consumer and post-consumer plastics products. This does not include reworked material (previously referred to as own reprocessed material) and clause 5.4 is therefore not applicable.

- PD CEN/TS 14541-2:2022 does not provide recommendations on the quantity or type of recyclates that are appropriate for a specific application.
- PD CEN/TS 14541-2:2022 does not cover the recycling processes or transport of materials.
- Normative statements are included in clauses 6.4 and 6.5 with respect to uncoated calcium carbonate. It should be noted that there is currently no test method for assessing the type of calcium carbonate present in recyclates.
- The cracked round bar (CRB) test included in Annex A is a modification of ISO 18489. Research aiming to demonstrate that this modified CRB test is suitable for the characterization of batches of thermoplastics recyclates (PVC-U, PVC-C, PE, PP, and ABS) is not yet complete. Inclusion of details related to the proposed method in this (CEN/TS) document offers suppliers and manufacturers an opportunity to gain experience with the use of this method and contribute to its development. Inter-laboratory trials are needed to confirm that the test delivers reliable and consistent results. It is the opinion of the UK committee that the modified CRB test included in Annex A is not yet sufficiently stable to form part of an agreed specification or a normative test in a product standard.

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English Version

Plastics pipes and fittings - Utilization of thermoplastics  
recyclates - Part 2: Recommendations for relevant  
characteristics

Tubes et raccords en plastique -  
Utilisation de recyclats thermoplastiques  
- Partie 2 : Recommandations pour les  
caractéristiques pertinentes

Kunststoff-Rohrleitungen und -Formstücke -  
Verwendung von thermoplastischen Rezyklaten  
- Teil 2: Empfehlungen für relevante Eigenschaften

This Technical Specification (CEN/TS) was approved by CEN on 13 March 2022 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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EUROPEAN COMMITTEE FOR STANDARDIZATION  
COMITÉ EUROPÉEN DE NORMALISATION  
EUROPÄISCHES KOMITEE FÜR NORMUNG

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## Contents

Page

European foreword .....	iii
Introduction .....	iv
<b>1 Scope</b> .....	<b>5</b>
<b>2 Normative references</b> .....	<b>5</b>
<b>3 Terms and definitions</b> .....	<b>5</b>
<b>4 Abbreviations</b> .....	<b>5</b>
<b>5 Guidance for agreed specification and quality plan of the supplier</b> .....	<b>6</b>
5.1 General .....	6
5.2 Agreed specification .....	6
5.3 Quality plan of the supplier .....	6
5.4 Reworked material .....	6
<b>6 Characteristics of recyclates</b> .....	<b>7</b>
6.1 General .....	7
6.2 PVC-U .....	7
6.3 PVC-C .....	8
6.4 PE 8	
6.5 PP 9	
6.6 ABS 10	
<b>Annex A (informative) Testing PVC-U, PP and PE recyclates with CRB-method</b> .....	<b>11</b>
<b>Bibliography</b> .....	<b>16</b>

## European foreword

This document ([CEN/TS 14541-2:2022](#)) has been prepared by Technical Committee CEN/TC 155 “Plastics piping systems and ducting systems”, the secretariat of which is held by NEN.

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

This document, together with Part 1 of the EN 14541 series, supersedes [CEN/TS 14541:2013](#).

The EN 14541 series consists of the following parts under the general title *Plastics pipes and fittings - Utilisation of thermoplastics recyclates*:

- *Part 1: Vocabulary*;
- *Part 2: Recommendations for relevant characteristics* (this document).

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

## Introduction

The EN 14541 series is intended to give recommendations to the value chain of thermoplastic piping systems to stimulate the use of thermoplastics recyclates as defined in the European circular economy policy.

Part 1 of the EN 14541 series defines the relevant terms and definitions related to the use of thermoplastics recyclates in thermoplastics piping systems.

This document (part 2 of the EN 14541 series) is a CEN Technical Specification in which recommendations are given for product standards related to the relevant characteristics for defining (e.g. fingerprinting) commonly used thermoplastics recyclates intended to be used in thermoplastics piping systems.

This document is intended to support specification writers of product standards within CEN TC 155 in defining the relevant characteristics for thermoplastics recyclates (PVC-U, PVC-C, PE, PP, and ABS) to be specified in the relevant product standards for use in thermoplastics piping systems. The product standards should specify relevant characteristics and applicable tolerances to be included within the agreed specification. For a specific application, specification writers may specify additional characteristics.

This document introduces the Cracked Round Bar (CRB) test for slow crack growth resistance of recycled PE, PP and PVC-U material.

This document is extended, compared with the [CEN/TS 14541:2013](#), and covers next to PE, PP and PVC-U also PVC-C and ABS.

This document is not intended as a standalone specification for use of recyclates in plastic piping systems.

Different CEN Technical Committees are dealing with recycled Plastics. In particular CEN/TC 249 "Plastics". CEN/TC 249 "Plastics" developed a series of CEN publications on 'Plastics Recycling' which consists of: [EN 15343](#) [1], [EN 15344](#) [2], [EN 15345](#) [3], [EN 15346](#) [4], [CEN/TS 16010](#) [5] and [CEN/TS 16011](#) [6].

Other documents touching recycling are e.g. ISO 15270 [7] and Waste Framework Directive [8].



## 1 Scope

This document provides guidance and information for drafting product standards to specify characteristics and test methods for the utilization of thermoplastics recyclates (PVC-U, PVC-C, PE, PP, ABS) in pipes, fittings and ancillaries for thermoplastics piping systems.

This document covers recyclates with an agreed specification from all sources.

NOTE 1 This document does not cover characteristics for reworked material.

NOTE 2 This document does not cover recycling processes (e.g. chemical or mechanical).

NOTE 3 This document does not define if recycled material can be used in a specific application. The possible use of recyclates will be defined in the applicable product standard.

This document provides guidance about the relevant characteristics to be included in the agreed specification for recyclates.

This document is applicable without prejudice to any existing legislation.

For the recycling process, the transport, the testing and the use of thermoplastics recyclates, National and/or European regulations (e.g. hygienic aspects) can apply.

NOTE 4 For example, threshold levels for substances of very high concern (SVHC) as defined in the REACH-legislation which can possibly be present in thermoplastic recyclates.

## 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.

[EN 14541-1](#), *Plastics pipes and fittings - Utilisation of thermoplastics recyclates - Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in [EN 14541-1](#) 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 <https://www.electropedia.org/>

## 4 Abbreviations

ABS	acrylonitrile butadiene styrene
CRB	cracked round bar
MFR	melt mass-flow rate
PE	polyethylene
PP	polypropylene
PVC-C	chlorinated poly(vinyl chloride)
PVC-U	unplasticized poly(vinyl chloride)

OIT      oxidation induction time

## 5 Guidance for agreed specification and quality plan of the supplier

### 5.1 General

The conditions for the use of recyclates should be defined in the applicable product standard.

This document provides recommended characteristics (see [Clauses 6.2, 6.3, 6.4, 6.5 and 6.6](#)) to be considered for inclusion in the agreed specification(s) of a product standard. Additional characteristics may need to be considered depending on the application.

The product standard should define the documentation that should be used to cover all deliveries and to verify conformity with the agreed specification.

Depending on the application of the products, different requirements regarding the use and/or quality control of reworked material and recyclates may apply.

### 5.2 Agreed specification

A specification should be agreed, between the supplier of the recyclate and the manufacturer, for each grade of thermoplastic recyclates.

The following minimum information should be included in the agreed specification:

- the relevant characteristics as specified in the referring product standard;
- the values, units and tolerances for each characteristic;
- the defined batch size(s);
- the agreed sampling procedures, sample preparation methods, and testing frequencies.

NOTE      Guidance on sampling procedures, sample preparation and testing can be found in [CEN/TS 16010](#) [5] and [CEN/TS 16011](#) [6].

When drafting an agreed specification, the following should be considered:

- the recycling process and sources of the material being mindful of risk of impurities;
- the processing of the material into the end product;
- the required characteristics of the end product;
- possible limitations of sources for the recyclable material;
- the intended dosage level of the material.

### 5.3 Quality plan of the supplier

It is recommended that the quality plan of the supplier of recyclates is not less stringent than the relevant requirements of EN ISO 9001 [9].

### 5.4 Reworked material

In [EN 14541-1](#), reworked material is defined as “plastics material from rejected unused products or trimmings capable of being reclaimed within the same process that generated it”.

This is a general definition, where the responsible product standard writers should specify detailed conditions for the use of reworked material within the material clause of the Product standards.

The requirements for the use of reworked material in a product standard, will vary depending on the application area, which means there may be more options for use in non-pressure application area than in the pressure application area.

## 6 Characteristics of recyclates

### 6.1 General

[Clauses 6.2](#) to [6.6](#) give guidance for characteristics and corresponding test methods suitable for an agreed specification between the supplier of recyclates and the product manufacturer. The certificate of analysis to demonstrate conformity with the agreed specification shall be made by either the supplier of recyclates or the product manufacturer as agreed between the parties.

### 6.2 PVC-U

Recommended characteristics for the agreed specification for PVC-U recyclates are shown in [Table 1](#).

NOTE Other characteristics can be relevant depending on application.

**Table 1 — Characteristics for PVC-U recyclates**

Characteristic	Unit	Test method	Comment
Density	kg/m <sup>3</sup>	EN ISO 1183-1 <a href="#">[18]</a> or EN ISO 1183-2 <a href="#">[19]</a>	--
Bulk density	kg/m <sup>3</sup>	<a href="#">EN 15346:2014</a> , Annex B <a href="#">[4]</a>	Only applicable for micronized material or granules
PVC-content	--	<a href="#">EN ISO 1158</a> <a href="#">[25]</a>	PVC content is calculated from chlorine content result of <a href="#">EN ISO 1158</a> <a href="#">[25]</a> according to <a href="#">EN 1905</a> <a href="#">[11]</a>
Filler content by ash rest	% by mass	EN ISO 3451-5 <a href="#">[22]</a>	--
Particle size	mm	The applicable test method should be stated in the agreed specification	--
Source of the material	--	--	To be specified by the recyclate supplier
Impurities (solid contaminants content)	--	The test method (such as <a href="#">EN 15346:2014</a> , Annex C), evaluation of sheets or evaluation of micronized material, or mesh/melt filtering should be stated in the agreed specification	<a href="#">CEN/TS 17627:2021</a> <a href="#">[10]</a> could also be considered.
Slow crack growth resistance	--	<a href="#">Annex A</a>	If referred to in the product standard to gain experience, the <a href="#">Annex A</a> should be used.
Vicat softening temperature	°C	EN ISO 2507-1 <a href="#">[20]</a>	--
Impact strength	kJ/m <sup>2</sup>	EN ISO 179-1 <a href="#">[14]</a> or EN ISO 180 <a href="#">[16]</a>	--
Tensile properties	--	<a href="#">EN ISO 527-2</a> <a href="#">[37]</a>	Tensile modulus, tensile stress at yield, strain at yield etc. can all be derived from the test given.

### 6.3 PVC-C

Recommended characteristics for the agreed specification for PVC-C recyclates are shown in [Table 2](#).

NOTE Other characteristics can be relevant depending on application.

**Table 2 — Characteristics for PVC-C recyclates**

Characteristic	Unit	Test method	Comment
Density	kg/m <sup>3</sup>	EN ISO 1183-1 [18] or EN ISO 1183-2 [19]	
Bulk density	kg/m <sup>3</sup>	<a href="#">EN 15346:2014</a> , Annex B [4]	Only applicable for micronized material or granules
Chlorine content	% by mass	<a href="#">EN ISO 158</a> [25]	--
Particle size	mm	sieve analysis	--
Impurities (solid contaminants content)	--	The test method (such as <a href="#">EN 15346:2014</a> , Annex C), evaluation of sheets or evaluation of micronized material or mesh/melt filtering should be stated in the agreed specification	--
Source of the material	--	--	To be specified by the recyclate supplier
Vicat softening temperature	°C	EN ISO 2507-1 [20]	--
Impact strength	kJ/m <sup>2</sup>	EN ISO 179-1 [14] or EN ISO 180 [16]	--
Tensile properties	--	<a href="#">EN ISO 527-2</a> [37]	Tensile modulus, tensile stress at yield, strain at yield etc. can all be derived from the test given.

### 6.4 PE

Recommended characteristics for the agreed specification for PE recyclates are shown in [Table 3](#).

PE recyclate shall not contain uncoated CaCO<sub>3</sub> (calcium carbonate).

NOTE Other characteristics can be relevant depending on application.

**Table 3 — Characteristics for PE recyclates**

Characteristic	Unit	Test method	Comment
Density	kg/m <sup>3</sup>	EN ISO 1183-1 [18] or EN ISO 1183-2 [19]	--
Thermal Stability OIT	min	EN ISO 11357-6 [23]	Test temperature should be specified within the agreed specification
MFR	g/10 min	EN ISO 1133-1 [17]	--
Ash residue	%	EN ISO 3451-1 [21]	Temperature should be specified within the agreed specification
Extraneous polymers	--	IR analyses or DSC	Attention should be paid to the maximum level of PP
Volatile matter	mg/kg	<a href="#">EN 12099</a> [12]	Although the scope of <a href="#">EN 12099</a> [12] is limited, it is considered relevant.
Shape	--	Visual inspection	For example, ground, micronized, pellets, flakes.

Characteristic	Unit	Test method	Comment
Moisture	mg/kg	<a href="#">EN ISO 15512 [24]</a>	--
Bulk density	kg/m <sup>3</sup>	<a href="#">EN 15344:2021</a> , Annex B [2]	Only applicable for powder or granules
Impact strength	kJ/m <sup>2</sup>	EN ISO 179-1 [14] or EN ISO 180 [16]	--
Tensile properties	--	<a href="#">EN ISO 527-2 [37]</a>	Tensile modulus, tensile stress at yield, strain at yield etc. can all be derived from the test given.
Flexural Modulus	MPa	EN ISO 178 [13]	--
Slow crack growth resistance	--	<a href="#">Annex A</a>	If referred to in the product standard to gain experience, the <a href="#">Annex A</a> should be used.
Impurities (solid contaminants content)	--	A test method (described in <a href="#">EN 15344:2021</a> , Annex A), and/or mesh/melt filtering should be stated in the agreed specification	<a href="#">CEN/TS 17627:2021 [10]</a> could also be considered.
Source of the material	--	--	To be specified by the recycle supplier

## 6.5 PP

Recommended characteristics for the agreed specification for PP recyclates are shown in [Table 4](#).

PP recycle shall not contain uncoated CaCO<sub>3</sub> (calcium carbonate).

NOTE Other characteristics can be relevant depending on application.

**Table 4 — Characteristics for PP recyclates**

Characteristic	Unit	Test method	Comment
Density	kg/m <sup>3</sup>	EN ISO 1183-1 [18] or EN ISO 1183-2 [19]	--
Thermal Stability OIT	min	EN ISO 11357-6 [23]	Test temperature should be specified within the agreed specification
MFR	g/10 min	EN ISO 1133-1 [17]	--
Ash residue	%	EN ISO 3451-1 [21]	Temperature should be specified within the agreed specification
Extraneous polymers		IR analysis or DSC	Attention should be paid to the maximum level of PE
Volatile matter	mg/kg	<a href="#">EN 12099 [12]</a>	Although the scope of <a href="#">EN 12099 [12]</a> is limited, it is considered relevant.
Shape	--	Visual inspection	For example, ground, micronized, pellets, flakes.
Moisture	mg/kg	<a href="#">EN ISO 15512 [24]</a>	--
Bulk density	kg/m <sup>3</sup>	<a href="#">EN 15345:2007</a> , Annex A [3]	Only applicable for powder or granules
Impact strength	kJ/m <sup>2</sup>	EN ISO 179-1 [14], EN ISO 179-2 [15] or EN ISO 180 [16]	--

Characteristic	Unit	Test method	Comment
Tensile properties	--	<a href="#">EN ISO 527-2 [37]</a>	Tensile modulus, tensile stress at yield, strain at yield etc. can all be derived from the test given.
Flexural Modulus	MPa	EN ISO 178 [13]	--
Slow crack growth resistance	--	<a href="#">Annex A</a>	If referred to in the product standard to gain experience, the <a href="#">Annex A</a> should be used.
Impurities (solid contaminants content)	--	The test method e.g. mesh/melt filtering should be stated in the agreed specification	<a href="#">CEN/TS 17627:2021 [10]</a> could be considered.
Source of the material	--	--	To be specified by the recycle supplier

## 6.6 ABS

Recommended characteristics for the agreed specification for ABS recyclates are shown in [Table 5](#).

NOTE Other characteristics can be relevant depending on application.

**Table 5 — Characteristics for ABS recyclates**

Characteristic	Unit	Test method	Comment
Density	kg/m <sup>3</sup>	EN ISO 1183-1 [18] or EN ISO 1183-2 [19]	--
Bulk density	kg/m <sup>3</sup>	To be specified by the supplier	Only applicable for powder or granules
MFR	g/10 min	EN ISO 1133-1 [17]	--
Moisture	%	<a href="#">EN ISO 15512 [24]</a>	--
Ash content	%	To be agreed between the manufacturer and supplier	--
Impurities (solid contaminants content)	--	The test method e.g. mesh/melt filtering should be stated in the agreed specification	<a href="#">CEN/TS 17627:2021 [10]</a> could be considered.
Vicat softening temperature	°C	EN ISO 2507-1 [20]	--
Flexural modulus	MPa	EN ISO 178 [13]	--
Tensile stress at Yield	MPa	<a href="#">EN ISO 527-2 [37]</a>	--
Impact strength	kJ/m <sup>2</sup>	EN ISO 179-1 [14] or EN ISO 180 [16]	--
Source of the material	--	--	To be specified by the recycle supplier

## Annex A (informative)

### Testing PVC-U, PP and PE recyclates with CRB-method

#### A.1 General

The cracked round bar test (CRB) was developed to characterize the slow crack growth resistance of different PE pressure pipe grades. In parallel to this research, the CRB method was standardized and as result [ISO 18489 \[26\]](#) was published.

Within further studies the principle of applicability of CRB test to other thermoplastic polymers as well as to thermoplastic recyclates has been successfully proven [\[27\]](#) [\[28\]](#) [\[29\]](#) [\[30\]](#). Further investigation is in progress.

Based on experience gained so far it seems realistic to extend the scope of [ISO 18489 \[26\]](#) to other thermoplastic polymers, like PP and PVC, by specifying the right test parameters.

However, to enable the application of CRB test to PE, PP and PVC recyclates before [ISO 18489 \[26\]](#) is revised, the specific test parameters and procedures are described in [A.3](#).

#### A.2 Principle

To characterize the slow crack growth resistance of a thermoplastics recyclate, a CRB failure curve should be determined according to [ISO 18489 \[26\]](#).

This failure curve should be included as reference failure curve in the agreed specification for a particular thermoplastics recyclate.

For quality assurance or batch control of thermoplastics recyclates, 2 (short-term) CRB verification tests should be executed. Both verification results should exceed the values of the failure curve.

#### A.3 Procedure

##### A.3.1 Sample preparation

###### A.3.1.1 General

In general, specimens for CRB testing can be manufactured from compression moulded sheets as well as from extruded or injection moulded finished products such as pipes or fittings. The sample source should have a minimum solid wall thickness of 14 mm. The machining into CRB specimens should follow [EN ISO 2818 \[31\]](#) and [ISO 18489 \[26\]](#).

The material source and sample preparation may influence the test results due to different processing history. For a comparison of CRB test results for material ranking, quality assurance or batch control, it is essential that specimens are always prepared by the same procedure (either compression moulding, extrusion or injection moulding), using the same processing conditions.

Sample preparation from compression moulded sheets is recommended as this processing techniques creates the lowest amount of processing related residual stresses inside the specimens. General guidelines for compression moulding of thermoplastic materials are provided in [EN ISO 293 \[32\]](#).

Recommendations for sample preparation with thermoplastic recyclates of PE, PP, and PVC-U are provided in [A.3.1.2](#) to [A.3.1.4](#).

### A.3.1.2 Sample preparation PE

Specific conditions for compression moulding of PE are given in EN ISO 17855-2:2016, 3.4 [33] and ISO 16770:2019, 7.2 [34].

### A.3.1.3 Sample preparation PP

Specific conditions for compression moulding of PP are given in EN ISO 19069-2:2016, 3.4 [35].

### A.3.1.4 Sample preparation PVC-U

Specific conditions for compression moulding of PVC-U are given in EN ISO 21306-2:2019, 3.4 [36]. As an alternative, PVC-U can be directly extruded into solid rods with a sufficient diameter. Such extruded rods should be free of voids or cavities. With ISO 18489 [26] allows screw threads on the CRB specimens for thread grip systems, with PVC-U only cylindrical bars and clamping grips should be used to avoid potential failure in the clamping area instead of the notch.

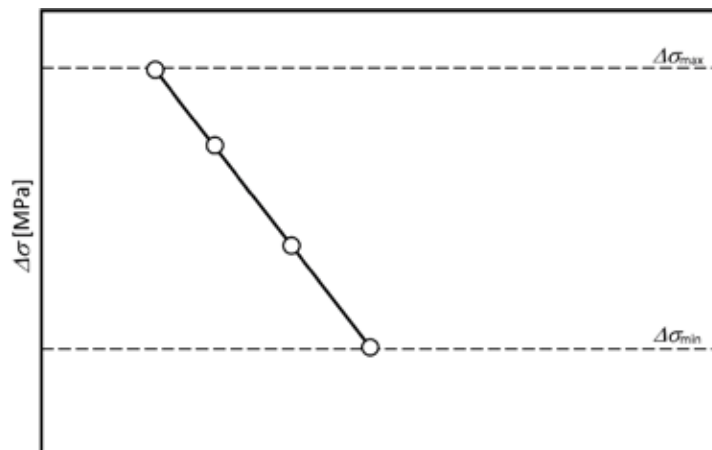
## A.3.2 CRB failure curve

### A.3.2.1 General

To characterize the slow crack growth resistance of a thermoplastics recyclate, a CRB failure curve should be determined according to ISO 18489 [26]. This failure curve should be based on at least four single CRB tests at different testing loads  $\Delta\sigma$  (Figure A.1).

This failure curve should be included as reference failure curve in the agreed specification for a particular thermoplastics recyclate.

Depending on the tested material, different testing loads  $\Delta\sigma$  may apply within the range of  $\Delta\sigma_{\min}$  to  $\Delta\sigma_{\max}$  and also different test frequencies  $f$  apply for PE, PP, and PVC-U (see A.3.2.2 to A.3.2.4).



#### Key

- CRB data point reference failure curve

**Figure A.1 — Schematically determination of the reference failure curve with the CRB test method**

### A.3.2.2 PE test parameters

Test frequency  $f=10$  Hz.

Testing loads  $\Delta\sigma$  within the range of  $\Delta\sigma_{\min}=7$  MPa to  $\Delta\sigma_{\max}=10$  MPa.



Test temperature:  $(23 \pm 2)$  °C.

Waveform: sinusoid.

The failure mode: brittle crack growth.

NOTE Ductile behaviour using high stress levels will give misleading results.

#### A.3.2.3 PP test parameters

Test frequency  $f=5$  Hz.

Testing loads  $\Delta\sigma$  within the range of  $\Delta\sigma_{\min}=13$  MPa to  $\Delta\sigma_{\max}=16$  MPa.

Test temperature  $(23 \pm 2)$  °C.

Waveform sinusoid.

The failure mode: brittle crack growth.

NOTE Ductile behaviour using high stress levels will give misleading results.

#### A.3.2.4 PVC-U test parameters

Test frequency  $f=10$  Hz.

Testing loads  $\Delta\sigma$  within the range of  $\Delta\sigma_{\min}=7$  MPa to  $\Delta\sigma_{\max}=13$  MPa.

Test temperature  $(23 \pm 2)$  °C.

Waveform sinusoid.

The failure mode: brittle crack growth.

Ductile behaviour is never observed by PVC material; therefore, it is recommended to apply higher stress levels to obtain failure in reasonable time.

### A.3.3 Verification procedure

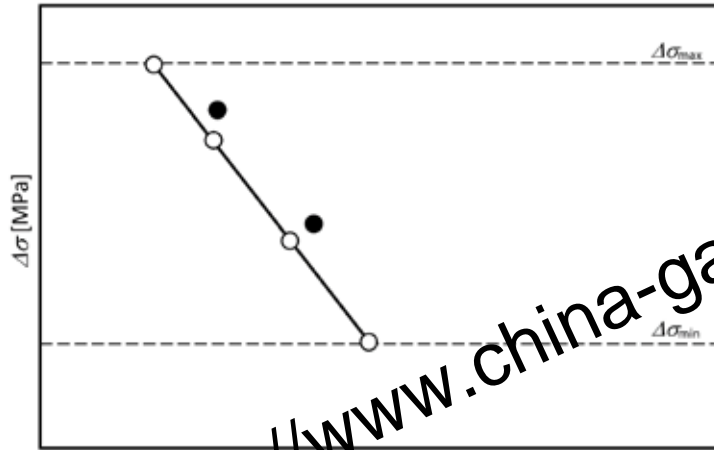
For quality assurance or iterative batch control of a thermoplastics recycle, within the respective testing load range two CRB tests at different  $\Delta\sigma$  in the upper and in the lower range, respectively, should be conducted.

The pass criteria are as follows:

- The failure cycle numbers  $N_f$  in both (batch) control tests exceed the respective values of the reference failure curve ([Figure A.2](#)) as specified in the agreed specification. The individual tests need not to be continued until fracture and may be stopped before failure.

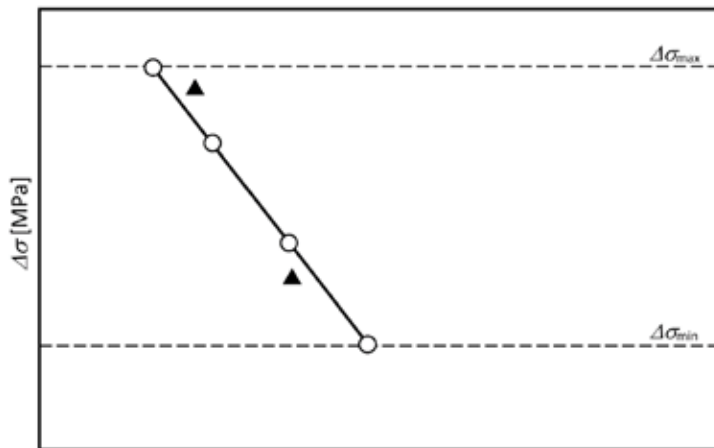
The fail criteria are as follows:

- The failure cycle numbers  $N_f$  in one or both (batch) control tests does not reach the respective values of the reference failure curve ([Figure A.3](#) and [Figure A.4](#)) as specified in the agreed specification.



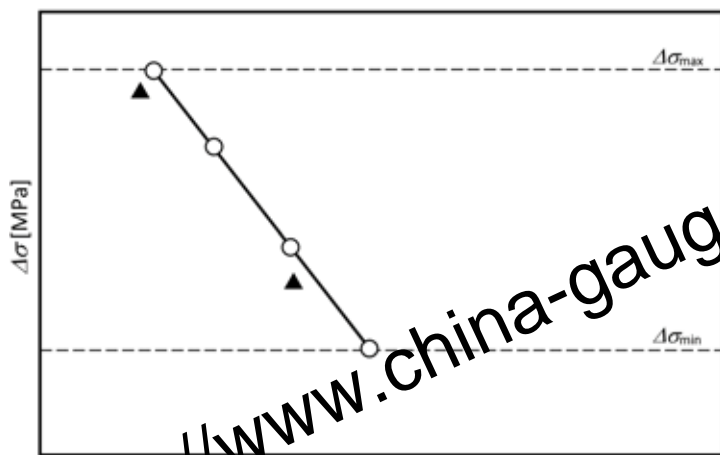
- Key**
- CRB data point reference failure curve
  - CRB data point batch control, passed

**Figure A.2 — Schematically illustration of the pass criteria with the CRB test method**



- Key**
- CRB data point reference failure curve
  - ▲ CRB data point batch control, failed

**Figure A.3 — Schematically illustration of a failure criteria with the CRB test method**



**Key**

- CRB data point reference failure curve
- ▲ CRB data point batch control, failed

**Figure A.4 — Schematically illustration of a failure criteria with the CRB test method**

## Bibliography

- [1] [EN 15343](#), *Plastics - Recycled Plastics - Plastics recycling traceability and assessment of conformity and recycled content*
- [2] [EN 15344:2021](#), *Plastics - Recycled plastics - Characterization of Polyethylene (PE) recyclates*
- [3] [EN 15345:2007](#), *Plastics - Recycled Plastics - Characterisation of Polypropylene (PP) recyclates*
- [4] [EN 15346](#), *Plastics - Recycled plastics - Characterization of poly(vinyl chloride) (PVC) recyclates*
- [5] [CEN/TS 16010](#), *Plastics - Recycled plastics - Sampling procedures for testing plastics waste and recyclates*
- [6] [CEN/TS 16011](#), *Plastics - Recycled plastics - Sample preparation*
- [7] ISO 15270, *Plastics - Guidelines for the recovery and recycling of plastics waste*
- [8] Directive 2008/98/EC on waste (Waste Framework Directive)
- [9] EN ISO 9001, *Quality management systems - Requirements (ISO 9001)*
- [10] [CEN/TS 17627:2021](#), *Plastics - Recycled plastics - Determination of solid contaminants content*
- [11] [EN 1905](#), *Plastics piping systems - Unplasticized poly(vinyl chloride) (PVC-U) pipes, fittings and material - Method for assessment of the PVC content based on total chlorine content*
- [12] [EN 12099](#), *Plastics piping systems - Polyethylene piping materials and components - Determination of volatile content*
- [13] EN ISO 178, *Plastics - Determination of flexural properties (ISO 178)*
- [14] EN ISO 179-1, *Plastics - Determination of Charpy impact properties - Part 1: Non-instrumented impact test (ISO 179-1)*
- [15] EN ISO 179-2, *Plastics - Determination of Charpy impact properties - Part 2: Instrumented impact test (ISO 179-2)*
- [16] EN ISO 180, *Plastics - Determination of Izod impact strength (ISO 180)*
- [17] EN ISO 1133-1, *Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics - Part 1: Standard method (ISO 1133-1)*
- [18] EN ISO 1183-1, *Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pycnometer method and titration method (ISO 1183-1)*
- [19] EN ISO 1183-2, *Plastics - Methods for determining the density of non-cellular plastics - Part 2: Density gradient column method (ISO 1183-2)*
- [20] EN ISO 2507-1, *Thermoplastics pipes and fittings - Vicat softening temperature - Part 1: General test method (ISO 2507-1)*
- [21] EN ISO 3451-1, *Plastics - Determination of ash - Part 1: General methods (ISO 3451-1)*
- [22] EN ISO 3451-5, *Plastics - Determination of ash - Part 5: Poly(vinyl chloride) (ISO 3451-5)*
- [23] EN ISO 11357-6, *Plastics - Differential scanning calorimetry (DSC) - Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT) (ISO 11357-6)*
- [24] [EN ISO 15512](#), *Plastics - Determination of water content (ISO 15512)*

- [25] [EN ISO 1158](#), *Plastics - Vinyl chloride homopolymers and copolymers - Determination of chlorine content*
- [26] [ISO 18489](#), *Polyethylene (PE) materials for piping systems - Determination of resistance to slow crack growth under cyclic loading - Cracked Round Bar test method*
- [27] Frank A, Pinter G, "Cyclic Cracked Round Bar Test: Final Results of International Round Robin Test:2014". doi:10.13140/RG.2.1.1817.6400.
- [28] Arbeiter F, Schrittester B., Frank A., Berer M., Pinter G. Cyclic tests on Cracked Round Bars as a quick tool to assess the long term behaviour of thermoplastics and elastomers. *Polym. Test.* 2015, 45 pp. 83–92
- [29] Frank A., Berger I.J., Messiha M., El-Ghoul, Schuler N., Storheil J.-M. et al. "Slow Crack Growth Resistance of Non-Virgin Polymers", in *Proc. Plastic Pipes XIX Conference*. Las Vegas, NV, USA:2018.
- [30] Andreas Frank, Marie Messiha, Thomas Koch, Jan Poduška, Pavel Hutař, Florian Arbeiter, Gerald Pinter, "Correlation of the cyclic cracked round bar test and hydrostatic pressure test for unplasticized polyvinylchloride", *Polym. Test.* 2021, 95
- [31] [EN ISO 2818](#), *Plastics - Preparation of test specimens by machining*
- [32] [EN ISO 293](#), *Plastics - Compression moulding of test specimens of thermoplastic materials*
- [33] EN ISO 17855-2:2016, *Plastics - Polyethylene (PE) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties*
- [34] [ISO 16770:2019](#), *Plastics - Determination of environmental stress cracking (ESC) of polyethylene - Full-notch creep test (FNCT)*
- [35] EN ISO 19069-2:2016, *Plastics - Polypropylene (PP) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties*
- [36] EN ISO 21306-2:2019, *Plastics - Unplasticized poly(vinyl chloride) (PVC-U) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties*
- [37] [EN ISO 527-2](#), *Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics (ISO 527-2:2012)*

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