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Solid recovered fuels — Determination of particle size distribution

Part 3: Method by image analysis for large dimension particles

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PTI/17, Solid biofuels.

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

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Feste Sekundärbrennstoffe - Bestimmung der Partikelgrößenverteilung - Teil 3: Bildanalysenverfahren für große Partikel

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Contents

Page

Foreword

This document (EN 15415-3:2012) has been prepared by Technical Committee CEN/TC 343 “Solid recovered fuels”, the secretariat of which is held by SFS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2012, and conflicting national standards shall be withdrawn at the latest by October 2012.

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

EN 15415, *Solid recovered fuels — Determination of particle size distribution*, consists of the following parts:

— *Part 1: Screen method for small dimension particles*

— *Part 2: Maximum projected length method (manual) for large dimension particles*

— *Part 3: Method by image analysis for large dimension particles*

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: 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, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document is dedicated to outlining an optical method for characterizing the size of pieces of solid recovered fuel (SRF) that exhibit an irregular shape and are generally large in size. Typical examples are shredded end-of-life tyres or demolition woods.

When such products reach the end-of-life stage, they continue to exhibit the very strong mechanical properties for which they were designed and fabricated. For instance, tyres are designed and fabricated to withstand cutting. Therefore, it is wise to minimise shredding when producing SRF from these end-of-life products. This results in a general in production of SRF pieces exhibiting an irregular shape and large size.

These SRF cannot be characterised using the sieving method specified in EN 15415-1 which utilises well-known distribution curves and a series of test sieves. Consequently, the method specified in this document is an optical method based on the determination of the maximum projected length and accompanied by an appropriate statistical evaluation. This maximum projected length approach is needed for sake of testing; but it is mainly needed to facilitate the use of these solid recovered fuels. Safe transportation (e.g. with conveyer) and introduction into the combustion zone are dependent on the design and operations adapted to such maximum length.

In this document, the maximum projected length determination is complemented with a characterisation of the filaments protruding from the SRF pieces (see 3.1).

This document is based on CEN/TS 14243, AFNOR XP T47-753, AFNOR XP T47-756, AFNOR XP T47-757, AFNOR NF X11-696:1989 and ISO 13320.

1 Scope

This European Standard specifies the determination of particle size distribution of solid recovered fuels using an image analysis method. It applies to both agglomerated and non-agglomerated solid, recovered, fuel pieces exhibiting an irregular shape, such as shredded end-of-life tyres and demolition woods. It provides the determination of the maximum projected length as well as parameters such as equivalent diameter. It also gives a characterisation of the filaments protruding from the SRF pieces.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15357:2011, *Solid recovered fuels — Terminology, definitions and descriptions*

ISO 565, *Test sieves — Metal wire cloth, perforated metal plate and electroformed sheet — Nominal sizes of openings*

ISO 3310-1 *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in EN 15357:2011 and the following apply.

3.1
filaments
filiform parts protruding from pieces of solid recovered fuel (SRF) generally of a metallic and or textile nature

[SOURCE: EN 15415-2:2012, 3.1]

3.2
format of a large piece of SRF
format based on the distribution of the maximum projected length

[SOURCE: EN 15415-2:2012, 3.2]

4 List of symbols and abbreviations

The following symbols and abbreviations are used in this document:

LDF	Lower dimension of the format (mm)
HDF	Higher dimension of the format (mm)
L	Maximum projected length
MS	Mass of the laboratory sample (kg)
MF	Mass of the fine pieces (kg)
MLM	Mass of the loose metal wires
NCC	Number of central classes
NCR	Number of classes in the range from *LDF* to *HDF*
TNP	Total number of pieces in the sample not including the fine pieces
MPF	Mass percentage of the fine pieces
MPM	Mass percentage of the loose metal wires
NPL	Number percentage of large pieces
MPL	Mass percentage of large pieces (optional)
NPC	Number percentage of *NCC*
MPC	Mass percentage of *NCC* (optional)
SRF	Solid recovered fuel
MLF	Minimum length of a filament (mm)
MLF1	Minimum length of a filament (mm) for the criterion average number of filaments per piece
MLF2	Minimum length of a filament (mm) for the criterion number percentage of pieces having at least one filament
ANPF	Average number per piece of filaments longer than *MLF1*
NPF	Number percentage of pieces having at least one filament longer than *MLF2*

NOTE In this document "mass percentage" is used for "mass fraction expressed as percent" to maintain continuity with other symbols and their abbreviations that do not designate mass fractions.

5 Principle

5.1 Principle of sampling

The main principle of sampling is to obtain a representative sample or representative samples from a whole lot (of defined material) from which a characteristic is to be determined. If the lot is to be represented by a sample, then it is necessary that every particle in the lot have an equal probability of being included in the sample (i.e. probabilistic sampling). Whenever this principle cannot be applied in practice, the sampler shall define a procedure as close as possible to probabilistic sampling in their judgement (i.e. judgemental sampling) and note the limitations in the sampling plan and sampling report.

In general, it is difficult to take samples in a way that satisfies the principle of correct sampling when a material is stationary (for example in a stockpile, big bag or silo). With regard to large pieces of irregular shape (e.g. pieces that include protruding filaments), it is necessary to take samples if the material is in movement.

NOTE The determination of properties other than dimensions can result in different sampling requirements. This is the case when determining physical properties such as bulk density or chemical composition.

5.2 Principle of the determination of dimension

A laboratory sample of at least $TNP > 100$ separate elements not passing through the *LDF* sieve is taken for the test. The mass of the laboratory sample, MS, is weighed to within ± 0,01 kg. Any elements consisting solely of metal wires released from the pieces of solid recovered fuel are not counted in the *TNP* pieces. They are collected and weighed together (MLM in kilograms).

After passing through a *LDF* sieve, the mass of the fine pieces, MF, is weighed to within ± 0,01 kg. The pieces not passing through the sieve (without loose metal wires) are used to determine the maximum lengths and constitute the test portion for determination purposes.

Each piece of this test portion is treated individually. As these pieces are not usually flat, the largest length is defined as the largest length projected onto a plane on which the piece in question lies. This length is measured to within ± 5 mm without deforming the piece and excluding protruding filaments.

The measurements of the different maximum projected lengths, L, are used for drawing a histogram (see Figure 1) that is a characteristic of the distribution of the pieces of the test portion, i.e. the laboratory sample without the fine pieces and without the loose metal wires. This histogram consists of the large pieces (a class larger than the *HDF* threshold dimension of the large pieces) and $NCR = 7$ classes of the same width between the *LDF* and *HDF* dimensions.

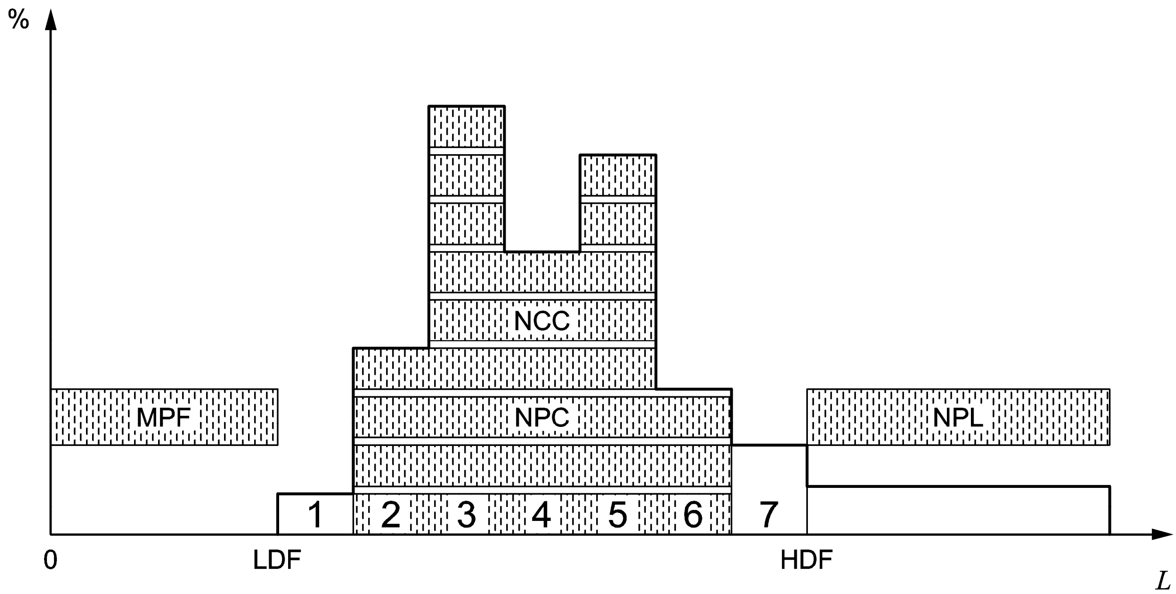


Figure 1 — Example of a histogram

The following three characteristics of the histogram are extracted from these measurements:

a) the number percentage of large pieces, NPL (and optionally, the mass percentage of large pieces, MPL, corresponding to the pieces larger than the higher dimension of the *HDF* format where *HDF* is one of the characteristics of the format of the product under consideration, e.g. 350 mm);

b) the mass percentage of the fine pieces, $MPF = 100 \times MF/MS$ (mass percentage of the pieces passing through the sieve with a mesh of LDF where LDF is one of the characteristics of the product format under consideration, e.g. 25 mm);

c) the number percentage, NPC (and optionally the mass percentage, MPC) of the pieces in the number of central classes (*NCC*) (2-3-4-5-6) amongst the classes $NCR = 7$ between the lower and higher dimensions of the format (LDF and HDF).

5.3 Principle of filaments characterisation

From the method for evaluating the filaments of shredded materials, the following two parameters are determined:

a) *ANPF*: average number per piece of filaments longer than *MLF1*;

b) *NPF*: number percentage of pieces having at least one filament longer than *MLF2*.

This evaluation is based on a measurement by image analysis as specified in the following sub-clauses which determine the filaments as filiform metallic and/or textile protruding wires (see 3.1) at least as long as *MLF*. The evaluation is generally combined with a determination by image analysis of the largest projected length (excluding filaments).

6 Apparatus

6.1 Vessel, large enough to contain at least 100 pieces.

6.2 Optical measurement system, automatic, for image analysis to determine the largest projected length of each piece, capable of measuring lengths (projected length of pieces or length of filaments) with an accuracy of ± 5 mm up to 500 mm.

6.3 Balance, with an accuracy of ± 0,01 kg.

6.4 Circular mesh sieve, in accordance with ISO 565 or ISO 3310-1, with a mesh of LDF.

7 Procedure

7.1 Preparation of the sampling plan

First the property required in the testing programme and the lot in relation to which it is defined, e.g. "maximum projected length on a SRF production of 300 Mg", shall be identified.

The lot size shall be based on management decisions about the production quality or specific customer requirements. It may be defined by the producer as a fixed quantity produced between machine settings, a fixed quantity of a production day/shift/week or simply a fixed quantity. With regard to certain pieces exhibiting large dimensions, the tools for taking an increment shall be sufficiently large so that the large pieces are equally sampled. Typically this results in a case of increments of more than 100 pieces (3 kg to 15 kg).

NOTE 1 Larger increments would slightly improve the sampling quality while increasing the size of the field sample, therefore complicating the size reduction into laboratory sample(s). It is preferable to increase the number of increments and thus directly increase the reproducibility.

For reference testing (contractual or pre-contractual) concerning SRF dimension(s), the field sample shall be a composite sample constituted of 3 increments taken on dates selected randomly along the period of time during which the lot is produced. If there is no SRF on a particular date at the sampling location, the increment shall be taken on another date preselected prior to sampling, unless this is caused by a major change in the production process (see below).

For routine testing concerning the dimension(s) of SRF, the field sample shall consist of 1 increment taken on a date selected randomly along the period of time during which the lot is produced. If there is no SRF on this date at the sampling location, the increment shall be taken on another date preselected prior to sampling, unless this is caused by a major change in the production process (see below).

NOTE 2 The random taking of three increments allows for a first approximation of the variability inside the considered lot. The random taking of one increment in routine testing also allows another evaluation of the variability when considering the lots obtained under comparable conditions.

In the case of a major change in the production process, consider a lot before and a lot after this change.

NOTE 3 Major changes can occur on the feed and on the production process. A major change would induce in the sample two different subpopulations, before and after the major change.

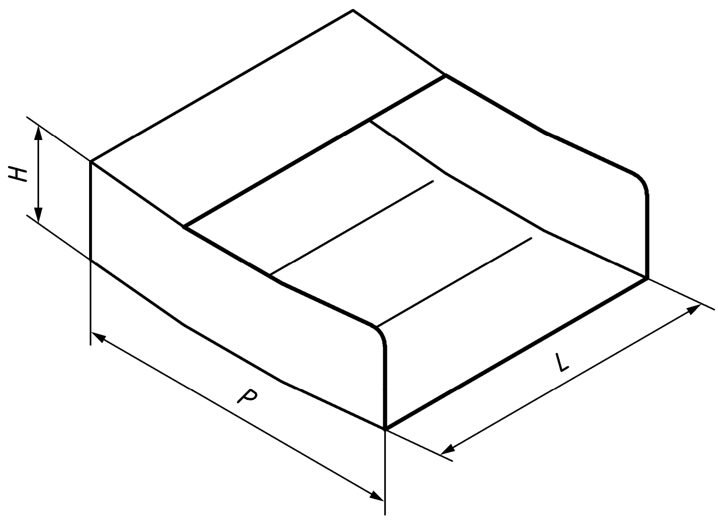
7.2 Procedure for taking the field sample and producing the laboratory sample(s)

Take the increment(s) at the output of the conveyer in the falling zone. The tool used shall be a typical rectangular open scoop, i.e. it shall not have an edge at one of the long side so as to be capable of "cutting" the entire flow. Such a scoop (see also Figure 2) shall have:

— a width, L, at least 1,5 times the width of the falling flow;

— a depth, P, at least 2/3 of the width, L, and at least 2,5 times the higher dimension, HDF;

— an edge height, H, at least to 1/3 of the width, L, and at least 2 times the higher dimension, HDF.



Key

H height
P depth
L width

Figure 2 —Example of scoop

This scoop may be moved for example, with a loader according to a detailed procedure adapted to the site condition. It may be the bucket of a loader, provided that its cleanliness conforms to the requirement of the dimension measurement, i.e. the absence of deposit. The increment taken shall be considered as valid if both two criteria are fulfilled, i.e., the increment consists of at least 100 pieces (after sieving of fines) and the mass of the increment does not exceed 15 kg.

NOTE The minimum size of the increment is specified as a minimum number of pieces in view of the statistical evaluation of the measurements of the maximum projected length of each piece. A specification in mass would result in significant differences depending on the size of the pieces.

For the determination of dimension(s), each increment shall constitute a laboratory sample. If there are several increments, determine the dimension of each increment and calculate the average of these dimensions. This is easier than reducing the size of the field sample prior to measuring the dimension.

7.3 Procedure for quantification of maximum projected length and characterisation of filaments

Carry out the following steps for this optical procedure:

a) identify the *LDF* and *HDF* dimensions in the test specifications and calculate the limits of the 7 classes of the same width. Deduce the limits of the central range defined by *NCC* classes 2-3-4-5-6;

NOTE 1 *HDF* and *LDF* should be different enough in order to define in practice the 7 classes.

b) take a laboratory sample of the SRF material in accordance with the sampling scheme using a vessel (6.1) for checking whether for the site in question the *TNP* criterion $>$ 100 elements after sieving at *LDF* is satisfied;

c) weigh the laboratory sample, MS, using the balance (6.3);

d) sieve the laboratory sample at LDF with the circular mesh sieve (6.4); (to make the sieving easier, the coarsest fractions may be removed manually, ensuring that they do not contain any fines);

e) weigh the undersized material with the balance (6.3), i.e. the *MF* fine pieces small enough to pass through the *LDF* sieve;

f) the elements not passing through the sieve shall be used to determine the maximum lengths as follows:

Place each element not passing through the sieve on the flat image acquisition area of the optical measurement system. Place the pieces so that the largest area is in contact with the flat surface. Any foreign body identified during this step shall be reported with a warning that it cannot be representative since the sampling plan is not designed for such foreign bodies;

g) ensure that the pieces are completely separated, especially that the filaments of each piece are completely separated from the filaments of the other pieces. Ensure that they are all within the acquisition area;

h) capture the image of the arranged pieces;

i) repeat the operation until all the pieces in the sample are dealt with;

j) start to process the images with the measurement equipment to determine the largest projected length of each of the *TNF* pieces in the sample and to determine the filaments in each piece of the sample;

k) obtain the total mass of any elements consisting solely of metal wires released from the pieces of end-of-life tyre (and which are not counted in the TNF pieces), MLM;

l) calculate the mass percentage of the loose metal wires, $MPM = 100 \times MLM/MS$;

m) calculate the mass percentage of the fine pieces, $MPF = 100 \times MF/MS$;

n) from the projected lengths excluding filaments, calculate the numerical percentages per class (and optionally the mass percentages);

NOTE 2 The histogram traced from these percentages gives an overview of the distribution of the maximum projected dimensions excluding filaments.

o) calculate the number percentage of large pieces, NPL (and optionally the mass percentage, MPL) corresponding to the piece larger than the higher dimension of the *HDF* format;

p) calculate the number percentage, *NPC* (and optionally the mass percentage, *MPC*) of the pieces in the *NCC* central classes amongst the *NCR* classes between the lower and higher dimensions of the format (*LDF* and *HDF*);

q) calculate *ANPF*, the average number per piece of filaments longer than *MLF1*;

r) calculate *NPF*, the number percentage of pieces having at least one filament longer than *MLF2*.

8 Precision

The method specified in this document has not yet been validated and therefore data on robustness, repeatability and reproducibility are currently unavailable.

9 Test report

The test report shall include at least the following information:

a) General information:

   1) address of the sampling establishment and of the testing laboratory,

   2) establishment responsible for the whole testing (sampling establishment or quantification establishment),

   3) date of the test,

   4) a reference to this European Standard, i.e. EN 15415-3,

   5) any deviation from this European Standard;

b) Information concerning sampling plan, taking of the field sample and producing the laboratory sample(s):

   1) name of the sampler,

   2) place where the sample(s) were taken, possibly with photograph,

   3) date/hour of increment taking,

   4) size of population and lot,

   5) weighing results at the different sampling steps,

   6) storage conditions;

c) Information concerning preparation of the test portion from the laboratory sample:

   1) mass of the laboratory sample (*MS*, in kilograms),

   2) report on any eventual observed foreign body;

NOTE Presently there is no systematic test method available for foreign bodies especially for efficient sampling procedures.

d) Information concerning measurement of the lengths and statistical assessment:

1) name(s) of the person(s) performing the measurement,

2) mass of the fine pieces (*MF*, in kilograms),

3) results of the measurement of the projected lengths excluding filaments (in millimetres),

4) results of the measurement of the filaments,

5) mass of the loose metal parts (*MLM*, in kilograms),

6) mass percentage of the loose metal wires (*MPM*, in percent),

7) mass percentage of the fine pieces (*PMF*, in percent),

8) number percentage of large pieces (*PNG*, in percent), corresponding to the piece larger than the higher dimension of the *HDF* format,

9) number percentage (*NPC*, in percent), of the fractions in the number of central classes (*NCC*) amongst the number of classes between the lower and higher dimensions of the *LDF* and *HDF* format (*NCR*),

10) average number per piece of filaments (*ANPF*), longer than *MLF1*,

11) number percentage of pieces having at least one filament (*NPF*), longer than *MLF2*.

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AFNOR XP T47-757, *End-of-life tyres (ELT) — Determination of the format of products from primary shredding — Method of evaluation of filaments*

AFNOR NF X11-696:1989, *Particle size analysis through image analysis*

CEN/TS 14243, *Materials produced from end of life tyres — Specification of categories based on their dimension(s) and impurities and methods for determining their dimension(s) and impurities*

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ISO 3310-2, *Test sieves — Technical requirements and testing — Part 2: Test sieves of perforated metal plate*

ISO 13320, *Particle size analysis — Laser diffraction methods*

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