INTERNATIONAL STANDARD

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# Solid biofuels — Determination of bulk density

*Biocombustibles solides — Détermination de la masse volumique apparente*

Reference number
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# Foreword

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The committee responsible for this document is ISO/TC 238, *Solid biofuels*.

# Introduction

Bulk density is an important parameter for fuel deliveries on volume basis, and together with the net calorific value, it determines the energy density. It also facilitates the estimation of space requirements for transport and storage. This International Standard describes the determination of the bulk density of pourable solid biofuels, which can be conveyed in a continuous material flow.

For practical reasons, two standard measuring containers with a volume of 5 l or 50 l were chosen for the determination. Due to the limited volume of these containers, some fuels are therefore excluded from the scope of this International Standard. This, for example, applies for chunk wood, non-comminuted bark, baled material and larger briquettes. The bulk density of such fuels can be calculated from their mass and the volume of the container or lorry used for transportation.

To decide on the actual storage volume requirement of a solid biofuel the different storage conditions, which usually differ largely from the conditions of sample analysis (e.g. height of heap versus volume of the standard measuring container, moisture content) also have to be taken into account.

The described method herein includes a defined shock exposure of the bulk material for several reasons. A shock leads to a certain volume reduction, which accounts for compaction effects occurring during the production chain. These compaction effects are mainly due the fact, that the fuel is usually transported and/or stored in containers or silos that are much larger than the measuring container as chosen for the described method. Thus, in practice, the higher mass load leads to an increased load pressure and to settling of the material, which can also be additionally enhanced by the vibrations during transportation. Furthermore, filling or unloading operations in practice usually apply a higher falling depth than the one chosen for the performed test. This will also result in a respectively higher compaction due to the increased kinetic energy of the particles falling. A procedure which applies a controlled shock to the sample was thus believed to reflect the practically prevailing bulk density in a better way than a method without shock. This is particularly true when the mass of a delivered fuel has to be estimated from the volume load of a transporting vehicle, which is a common procedure in many countries. For a rough estimation on how susceptible the different solid biofuels are towards the shock exposure, some research data are given in Annex A. The data show a compaction effect between 6 % and 18 % for biomass fuels.

# Solid biofuels — Determination of bulk density

## 1 Scope

This International Standard defines a method of determining bulk density of solid biofuels by the use of a standard measuring container. This method is applicable to all pourable solid biofuels with a nominal top size of maximum 100 mm.

Bulk density is not an absolute value; therefore, conditions for its determination have to be standardized in order to gain comparative measuring results.

NOTE Bulk density of solid biofuels is subject to variation due to several factors such as vibration, shock, pressure, biodegradation, drying, and wetting. Measured bulk density can therefore deviate from actual conditions during transportation, storage, or transhipment.

## 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.

ISO 14780, *Solid biofuels — Sample preparation*[1)]

ISO 16559, *Solid biofuels — Terminology, definitions and descriptions*

ISO 18134-1, *Solid biofuels — Determination of moisture content — Oven dry method, Part 1: Total moisture — Reference method*

ISO 18134-2, *Solid biofuels — Determination of moisture content — Oven dry method, Part 2: Total moisture — Simplified procedure*

ISO 18135, *Solid biofuels — Sampling*[1)]

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16559 apply.

## 4 Principle

A standard container is filled with the test portion of a given size and shape, densified by defined shock exposure and weighed afterwards. The bulk density is calculated from the net weight per standard volume and reported with the determined moisture content.

## 5 Apparatus

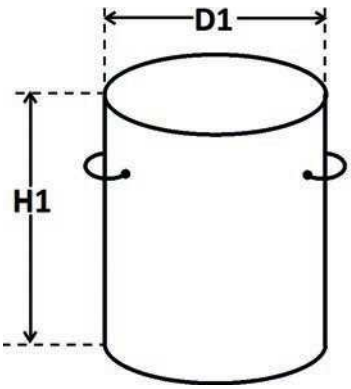
### 5.1 Measuring containers

#### 5.1.1 General

The container shall be cylindrically shaped and manufactured of a shock resistant, smooth-surfaced material. The container shall be resistant to deformation in order to prevent any variation in shape

1) In preparation.

and volume. The container has to be waterproof. For easier handling, grips can be fixed externally. The height-diameter-ratio shall be within 1,25 and 1,50.

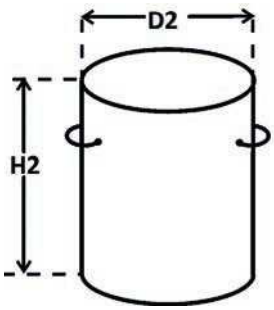



**Key**

D1 = 360 mm

H1 = 491 mm

**Figure 1 — Large measuring container**




**Key**

D2 = 167 mm

H2 = 228 mm

**Figure 2 — Small measuring container**

### 5.1.2 Large container

The large measuring container (see Figure 1) has a filling volume of 50 l (0,05 $m^3$) volume. The volume can deviate by 1 l (= 2 %). It shall have an effective (inner) diameter of 360 mm and an effective (inner) height of 491 mm (see Figure 1). Deviations from these dimensions are tolerable, if the height-diameter-ratio remains as given in 5.1.1.

### 5.1.3 Small container

The small measuring container (see Figure 2) has a filling volume of 5 l (0,005 $m^3$) volume. The volume can deviate by 0,1 l (= 2 %). It shall have an effective (inner) diameter of 167 mm and an effective (inner) height of 228 mm (see Figure 2). Deviations from these dimensions are tolerable, if the height-diameter-ratio remains as given in 5.1.1.

### 5.2 Balances

#### 5.2.1 Balance 1

A balance shall be capable of reading to the nearest 10 g. This balance shall be used for measurements with the large container.

#### 5.2.2 Balance 2

A balance shall be capable of reading to the nearest 1 g. This balance shall be used for measurements with the small container.

### 5.3 Scantlings

A rigid scantling with a length exceeding the diameter of the container in 5.1.1 shall be used for levelling the material in the measuring container by lateral movements of the scantling across the rim of the measuring container.

NOTE It is advisable to use a second scantling or other device for spacing the dropping height of 150 mm between the measuring container and the wooden board in 5.4.

### 5.4 Wooden board

A flat wooden board [e.g. oriented strand board (OSB)] with a thickness of approximately 15 mm and sufficient in size for dropping the container during shock exposure.

## 6 Sample preparation

Sampling shall be carried out in accordance with ISO 18135. If necessary, the sample can be divided in to test portions in accordance with ISO 14780. The test portion volume shall exceed the volume of the container measures by minimum of 30 %.

NOTE Precautions should be taken to ensure that the moisture is evenly distributed within the sample.

## 7 Procedure

### 7.1 Determination of the container volume

Before use, the mass and filling volume of the container shall be determined. Weigh the empty, clean, and dry container on the balance (5.2.1 or 5.2.2). Then fill the container with water and a few drops of wetting agent (e.g. liquid soap) until maximum capacity; then weigh it again. The water should be at a temperature between 10 °C and 20 °C. Calculate the volume (V) of the container from the net weight of water and the density of the water (1 kg/dm$^3$) and record the result rounded to the nearest 0,01 l (0,000 01 m$^3$) for the large container or 0,001 l (0,000 001 m$^3$) for the small container.

NOTE 1 The effect of temperature on the density of water is negligible.

NOTE 2 The container should be cleaned regularly and its volume should be checked regularly.

### 7.2 Container selection

The large container (5.2.1) can be used for larger materials within the scope of this International Standard. For materials with a nominal top size up to 12 mm and for pellets with a diameter equal or below 12 mm the small container (5.2.2) can be used (optional).

### 7.3 Measurement procedure

a) Fill the container by pouring the sample material from a height of 200 mm to 300 mm above the upper rim until a cone of maximum possible height is formed.

NOTE Make sure that the container is dry and clean before being (re)filled.

b) The filled container is then shock exposed to allow settling. This shall be done by dropping it freely from 150 mm height onto a wooden board (5.4). Before shock exposure, remove particles from the wooden board within the dropping area. Make sure that the container hits the board in a vertical position. Repeat the shock exposure two more times to apply a total of three shock exposures. Then refill the resulting empty space at the top of the container in accordance with 7.3 a).

NOTE The second scantling or device referred to in 5.3 can be used for spacing of the distance between the measuring container and the wooden board before dropping. Also, other mechanisms to create a comparable shock impact can be suitable.

c) Remove surplus material by using a scantling (5.3), which is shuffled over the container's edge in oscillating movements. When the test portion contains coarse material, all particles preventing the free passage of the scantling have to be removed by hand. If the removal of larger particles tears bigger holes into the leveled surface, the cavities shall be refilled and the removal procedure is repeated.

d) Weigh the container with the remaining sample material.

e) Unify the used sample material with the unused sample material and repeat the procedure from 7.3 a) to 7.3 d) at least once in order to get duplicate determinations.

f) Determine moisture content of the test sample material as received according to ISO 18134-1 or ISO 18134-2 immediately after bulk density determination.

# 8 Calculation

## 8.1 Calculation of bulk density as received

Calculate the bulk density of the sample as received ($BD_{ar}$) according to Formula (1):

$$BD_{ar} = \frac{(m_2 - m_1)}{V} \quad (1)$$

where

$BD_{ar}$ is the bulk density as received in kg/m$^3$;

$BD_d$ is the bulk density of the sample on dry basis in kg/m$^3$;

$m_1$ is the mass of the empty container in kg;

$m_2$ is the mass of the filled container in kg;

$V$ is the net volume of the measuring container in m$^3$.

The result for each individual determination shall be calculated to 0,1 decimal place and for reporting purposes the mean value of the individual results shall be calculated and rounded to the nearest 10 kg/m$^3$.

### 8.2 Calculation of bulk density on dry basis

Calculate the bulk density of the test portion mass on dry basis ($BD_d$) in accordance with Formula (2):

$$BD_d = BD_{ar} \times \frac{(100 - M_{ar})}{100} \quad (2)$$

NOTE Formula (2) in 8.2 disregards shrinkage or expansion, which usually causes significant deviations when the test portion is measured at different drying stages. For wood fuels, these phenomena usually occur at a moisture content below the fibre saturation point, which is at around 25 % moisture content, depending on the wood species. A true comparison between material samples is therefore only possible when bulk density is measured at similar moisture contents. If material samples with different moisture content shall be compared and at least one sample is below the fibre saturation point, the usual effect of swelling or shrinkage is in the order of around 0,7 % volume change per percentage point of moisture difference below the fibre saturation point (see Reference [1]). For a comparison of measurements based on materials with similar moisture content, the application of this correction factor can be useful.

## 9 Performance characteristics

### 9.1 General

**Table 1 — Repeatability and reproducibility limits**

| Bulk density | Maximum acceptable differences between results obtained | |
|---|---|---|
| | Repeatability limits | Reproducibility limits |
| Bulk density below 300 kg/m$^3$ | 3,0 % | 6,0 % |
| Bulk density equal or above 300 kg/m$^3$ | 2,0 % | 4,0 % |

### 9.2 Repeatability

The results obtained for bulk density as received ($BD_{ar}$) of the duplicate determinations (see 7.3), performed within a short period of time by the same operator using the same apparatus in the same laboratory shall not differ by more than the values in Table 1 (see Reference [2]).

### 9.3 Reproducibility

The mean values of the results of duplicate determinations (see 7.3) for bulk density as received ($BD_{ar}$), performed in each of two different laboratories on representative test portions taken from the same sample material shall not differ by more than the values in Table 1 (see Reference [2]).

## 10 Test report

The test report shall include at least the following information:

a) identification of laboratory performing the test and the date of the test;

b) identification of the product (or sample) tested;

c) a reference to this International Standard, i.e. ISO 17828;

d) specification of the applied container size;

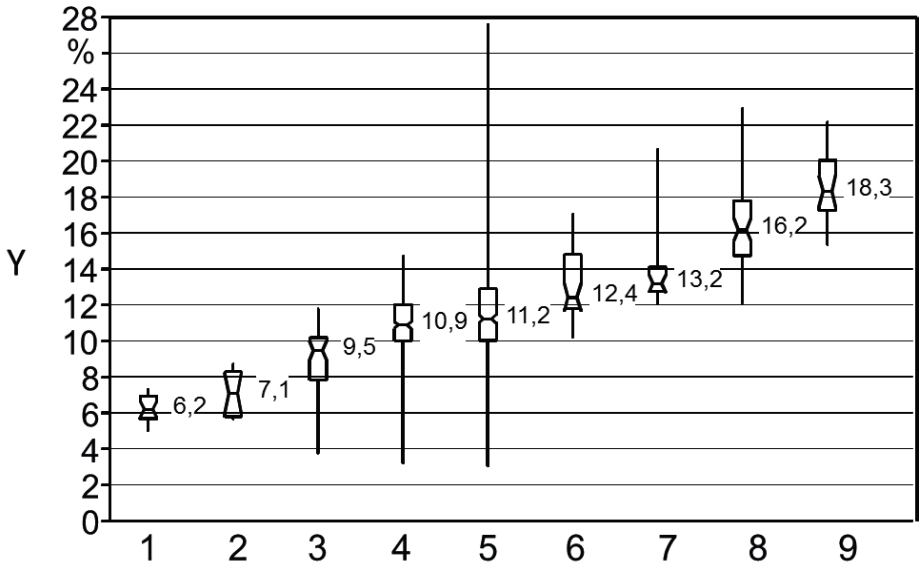
e) result of the test at moisture content as received according to 8.1 (required) or according to 8.2 (optional), expressed with relevant symbols;

f) any unusual features noted during the determination, which can affect the result;

g) any deviation from this International Standard or operations regarded as optional.

# Annex A
(informative)

# Measuring differences of sample treatment with and without shock impact




| | | |
|---|---|---|
| **Legend** | | Maximum |
| Y Relative deviation in % to non-shock application | | |
| | Number of replications | 75th percentile |
| 1 Wood pellets | 21 | |
| 2 Grain kernels | 12 | Median |
| 3 Herbaceous pellets | 42 | |
| 4 High density wood chips | 312 | 25th percentile |
| 5 Low density wood chips | 492 | |
| 6 Sawdust | 39 | Minimum |
| 7 Peat | 18 | |
| 8 Bark | 63 | |
| 9 Chopped miscanthus | 24 | |

**Figure A.1**

Representation of the relative effect of shock impact compared to a non-shock application for bulk density determination, here given for the 50-l-container dropped three times before re-filling, surface levelling and weighing. The boundary value for high or low bulk density grouping of wood chips was 180 kg/m$^3$ (see Reference [1]).

# Bibliography

[1] Hartmann H., Böhm T., Daugbjerg Jensen P. Temmerman, M.; Rabier, F.; Jirjis, R. Hersener, J.-L.; Rathbauer, J.: Methods for Bulk Density Determination of Solid Biofuels. In: Van Swaaij, W. P. M.; Fjällström, T.; Helm, P.; Grassi, A. (Eds.): 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection, Rome, 10-14 May 2004, pp. 662-665

[2] Böhm T., & Hartmann H. Guidelines for bulk density determination – European project "Pre-normative work on sampling and testing of solid biofuels for the development of quality assurance systems" (BioNorm) ENK6-CT-2001-00556, Deliverable D4 Part 2, Technology and Support Centre of Renewable Raw Materials. TFZ, Straubing, Germany, 2004

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