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Second edition
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Solid biofuels — Determination of particle density of pellets and briquettes

Biocombustibles solides — Détermination de la masse volumique unitaire des granulés et des briquettes

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Foreword

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This document was prepared by Technical Committee ISO/TC 238, *Solid biofuels*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 335, *Solid biofuels*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 18847:2016), which has been technically revised.

The main changes are as follows:

— editorial changes made;

— ISO 21945 inserted as a normative reference;

— method for the determination of particle density is specified in more detail;

— informative Annex B on a liquid displacement method to estimate the particle density of pellets added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Particle density is a fuel parameter of pellets and briquettes which is often considered when describing the degree of compaction of the raw material used. Particle density can be highly specific for the respective type or species of biomass and thus, it also characterizes the material's general ability to be compacted. High particle density is often associated with high resistance to abrasion or low susceptibility towards fracturing during handling and storage. A high particle density also generally leads to reduced storage volume demands and to a lower filling level in a combustion chamber at constant fuel mass flow. Particle density can also affect the heat transfer rate within the fuel and thus, it can have an impact on fuel ignition and on the dynamics of gasification.

Apart from the buoyancy method which is described in this document as a reference method, larger particles (briquettes) are sometimes easier tested by simple stereometric means. For internal laboratory practices, such a procedure is also presented in Annex A. For small particles (pellets), this procedure is not recommended.

For pellets, a simplified method using the displacement of a liquid by the pellets is available, which can be used as an on-site method, and is described in Annex B.

Pellets disintegrate in water relatively fast, but with the buoyancy method the particle density is sufficiently stable for about 30 s (see [3]). To improve reproducibility, the reading of the results is fixed at 5 s. This also ensures synchronization with the results of the estimation method by liquid displacement.

For the determination of particle density, several other methods are available. Normally the results show only minor deviations.

Solid biofuels — Determination of particle density of pellets and briquettes

1 Scope

This document specifies a method for determining the particle density of compressed fuels such as pellets or briquettes. Particle density is not an absolute value and conditions for its determination have to be standardized to enable comparative determinations to be made.

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.

ISO 14780, *Solid biofuels — Sample preparation*

ISO 16559, *Solid biofuels — Vocabulary*

ISO 18135, *Solid Biofuels — Sampling*

ISO 21945, *Solid biofuels — Simplified sampling method for small scale applications*

3 Terms and definitions

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

ISO and IEC maintain terminology 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 Principle

Both mass and volume of an individual particle or a group of particles are determined. The volume is measured by determining the buoyancy in a liquid. This procedure follows the physical principle that the buoyancy is equal to the mass of the displaced volume of a liquid. The apparent loss in weight between a measurement in air and a subsequent measurement in liquid marks its buoyancy. The volume of the test portion body is calculated via the density of the applied liquid.

NOTE 1 The particle density of briquettes can alternatively be estimated by stereometric means (see Annex A).

NOTE 2 As an on-site method the particle density of pellets can be estimated by a displacement method (see Annex B).

5 Reagents

5.1 Water, with a conductivity < 1 000 µS/cm (e.g. typical drinking water quality) in a temperature range of 10 °C to 30 °C.

5.2 Detergent. A non-ionic surfactant detergent named O-[4-(1,1,3,3-Tetramethylbutyl)-phenyl]-deca(oxyethylen), Octylphenoldecaethylen-glycolether, Polyethylenglycol-mono-[p-(1,1,3,3-tetramethylbutyl)-phenyl]-ether. Alternatively, a non-ionic surfactant with similar properties may be used, e. g. Ethylene oxide-propylene oxide copolymer mono(2-ethylhexyl) ether.

Using an alternative detergent, the density of the liquid used for the determination (water with 1, 5 g/l detergent) shall be determined to the nearest 0,001 g/l and used for calculations instead of the value given in Clause 9.

NOTE The exclusive use of a specific detergent with given characteristics allows to apply a fixed value for the density of the liquid (mixture with water) and ensures constant properties as wetting agent. As an example, the detergent available under the name Triton® X-100[1)] can be used. The density at +20 °C is 1,07 g/ml. According to health and/or environmental regulations, the use of an alternative detergent can be necessary.

5.3 Paraffin, with a melting point of 52 °C to 54 °C.

6 Apparatus

6.1 General apparatus requirements

A thermometer capable of reading to the nearest 1 °C.

6.2 Apparatus for pellet testing

6.2.1 Balance, shall be capable of reading to the nearest 0,001 g.

6.2.2 Glass beaker, a transparent glass beaker with a filling volume of about 200 ml.

6.2.3 Density determination rig. The density determination rig consists of a bridge and a submergence rig.

The bridge overstretches the weighing plate of the balance in order to prevent the balance from being loaded. The bridge is capable of carrying the *glass beaker* (6.2.2).

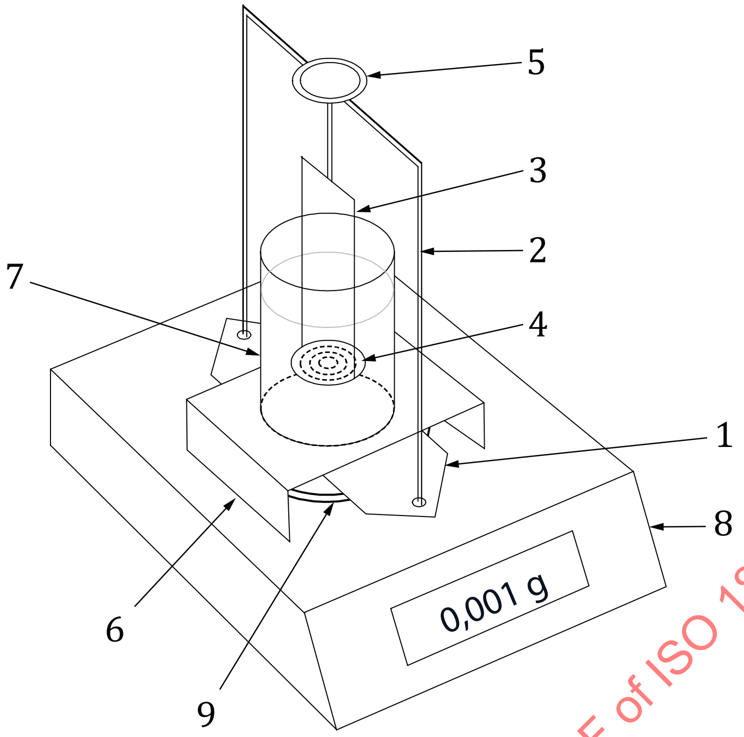
The submergence rig consists of a supporting frame and a submergence unit (submergence bracket with a submergence dish), which is hung into the *glass beaker* (6.2.2) to weigh the pellets in liquid (see Figure 1). The submergence dish shall be able to accommodate at least four pellets at once.

The submergence rig is directly placed on the balance plate.

Through the submergence bracket the submergence depth is always kept constant. The bottom of the submergence dish is perforated by openings, which are smaller in diameter than the diameter of the pellets. The perforation allows the liquid to fill the dish from underneath when it is submerged. If material of low density is tested (below 1,0 g/cm^3) a modified suspension having an inverted submergence dish is required; this is to force the pellets underneath the liquid surface and prevent them from floating on top of the liquid.

For the determination of the mass in air, a weighing dish shall be fixed on top of the suspension rig (Figure 1).

1) Triton® X-100 is the trademark of a product supplied by Dow. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.



Key

1	submergence rig	6	bridge
2	supporting frame	7	glass beaker
3	submergence bracket	8	balance
4	submergence dish	9	weighing plate of balance
5	weighing dish		

NOTE Submergence dish for pellets with density below 1,0 g/m^3 is not shown in this figure.

Figure 1 — Density determination rig on a balance (method for pellets)

6.3 Apparatus for briquette testing

6.3.1 General

Figure 2 shows the set up for measuring density of large particles (briquettes)

6.3.2 Balance, shall be capable of reading to the nearest 0,01 g.

If briquettes of more than 500 g each are tested, the balance shall be capable of reading to the nearest 0,1 g.

The balance shall have a connecting point for hanging a weight to its load cell.

6.3.3 Transparent container for liquid, having a sufficient filling volume to accommodate the liquid and the submerged briquette.

A sufficient filling volume is usually achieved when the container's cross section is about eight times larger than the cross section of the briquette. In this case, any effects by level changes of the liquid caused by submersion of the briquette are negligible. Such error would be due to a larger part of the holding steel string (6.3.4) being submerged.

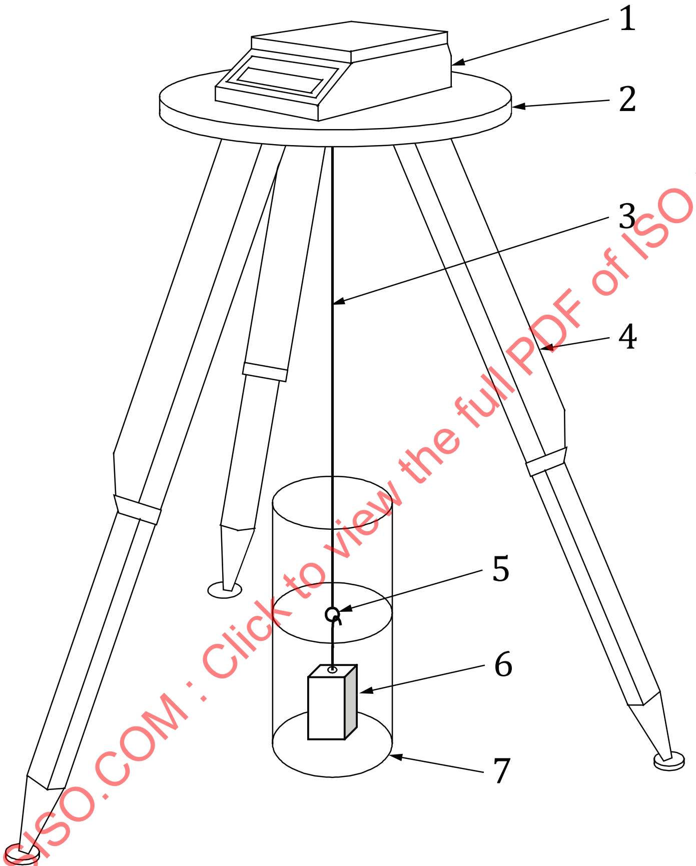
6.3.4 Non-absorbent thin steel string, which can be hung to the connecting point of the balance.

The end of the string is equipped with a hook or a ring, which allows an easy appending of the briquette.

6.3.5 Tripod, on which a balance can be placed. The tripod should have a plate with an opening which allows the string to pass through unhindered to the balance (Figure 2) while hanging.

6.3.6 Steel loop or any other steel support device, to which the briquette can be fixed while freely hanging and which allows to be fixed to the lower connecting point (Figure 2) of the steel string.

6.3.7 Removable weight, required if material of low density is tested (below 1,0 g/cm^3), which is positioned onto the briquette in a way which prevents the briquette from floating on top of the liquid.



Key

1 balance
2 carrying plate with opening
3 steel string
4 tripod
5 connection ring or hook
6 test piece (briquette)
7 transparent container

Figure 2 — Buoyancy determination rig using a hanging load to a balance (method for briquettes)

7 Sample preparation

7.1 General apparatus requirements

A laboratory sample shall be obtained in accordance with ISO 18135 or ISO 21945 and a test sample shall be prepared in accordance to ISO 14780.

A total test sample mass of 500 g (pellets with a diameter ≤ 12 mm) or 1 000 g for pellets with a diameter > 12 mm or a minimum of 15 briquettes is required.

From the test sample, a test portion of minimum 40 pellets or 10 briquettes is selected and stored in a sealed container to retain the moisture content as received.

For low density and coarse textured briquettes, a rapid disintegration after submergence in the liquid can happen, thus the reading can be difficult to take. In this case the briquettes may be coated by submerging in liquid paraffin (5.3), preferably at a temperature of 90 °C, before performing the test.

NOTE When using a coating, the additional volume reduces the measured particle density slightly.

8 Procedures

8.1 Procedure for pellets

a) Fill the glass beaker with water to a filling level which ensures that full submersion of all pellets on the submergence dish can be achieved.

b) Add 1,5 g/l of the detergent (5.2) to the water in the glass beaker and stir until full homogeneity of the liquid is achieved. Position the glass beaker with the liquid onto the bridge.

   At 1,5 g/l of the above detergent, the critical micelle concentration in water (xCMC = 0,15 g/l) is exceeded by ten times. A magnetic stirring device should be used for better homogeneity.

c) Check the temperature of the liquid to ensure that the requirements in 5.1 are met.

d) Place the density determination rig (submergence rig and bridge) and the filled glass beaker on the balance as given in Figure 1. The submergence bracket and the submergence dish shall not touch the bottom or walls of the glass beaker.

e) Tare the balance to zero while the empty submergence dish is below liquid surface at maximum depth.

f) Determine the total mass of a group of at least four pellets in air and record the measurement to the nearest 0,001 g.

g) Place the same pellets as measured in f) in the submergence dish. This can be done after removing the submergence rig. Fill in the pellets and replace the submergence rig carefully. The pellets can also be place in the mounted submergence rig.

   If pellets of low density are tested (below 1,0 g/cm^3), they can float on top of the detergent solution. In this case, use the inverted submergence dish (6.2.3) to force the pellets underneath the liquid surface. If pellets do not behave uniformly, i.e. some migrate to the top and some migrate to the bottom, it can be necessary to perform the test on the individual pellets instead of submerging all pellets in a group.

h) While the group of pellets is submerged in the liquid, read the total mass from the balance and record to the nearest 0,001 g. The reading of the mass in liquid shall be done (5 ± 1) seconds after submerging the pellets in order to prevent them from up taking any liquid or from decomposition.

NOTE It is useful to apply a manually triggered electronic data logging from the balance to a computer in order to facilitate the reading, particularly if the displayed value remains relatively inconstant.

i) Remove the pellets from the liquid immediately after recording in order to avoid liquid contamination by dissolving pellets.

j) Repeat the procedure e) to i) nine times to achieve ten replications in total. Replace the detergent solution at minimum after ten replications.

8.2 Procedure for briquettes

a) Fill the liquid container with water to a filling level which ensures that full submersion of all briquettes can be achieved.

b) Add 1,5 g/l of the detergent (5.2) to the water in the container and stir until full homogeneity of the liquid is achieved.

c) Check the temperature of the liquid to ensure that the requirements in 5.1 are met.

d) Determine the total mass of a sample briquette in air and record the measurement to the nearest 0,01 g. If briquettes each of more than 500 g are tested, record to the nearest 0,1 g.

e) Fix the empty steel loop or any other briquette mounting armature to the connection ring of the string and submerge this empty armature to maximum depth. The armature shall not be in contact with either the walls or the bottom of the container.

f) Tare the balance to zero while the empty mounting armature is below liquid surface.

g) Remove the mounting armature from the container and fix the same sample briquette as measured in step d) to the mounting equipment. Fix it to the connecting ring and carefully submerge the total load into the liquid.

h) While the briquette is submerged in the liquid, read the total mass from the balance and record it to the nearest 0,01 g. If briquettes with a total mass each of more than 500 g are tested, record to the nearest 0,1 g. If a sample with a density lower than 1,0 g/cm^3 is tested, an extra weight shall be fixed to the load to prevent it from floating on top of the liquid. In this case, the taring of the balance to zero (step f) has to include the same extra weight. The load shall not be in contact with either the walls or the bottom of the container. The reading of the mass in liquid shall be done (5 ± 1) seconds after submerging the briquette in order to prevent it from up taking any liquid or from decay.

i) Remove the briquette from the liquid immediately after recording in order to avoid liquid contamination by dissolving briquette.

j) Repeat the procedure d) to i) nine times to achieve ten replications in total. Replace the detergent solution at minimum after ten replications.

9 Calculation

The density of the liquid (water and reagent) when properly prepared is 0,995 8 g/cm^3. Apply this value for the calculation below or use a density which was determined individually.

Calculate the particle density of each group of pellets or of each briquette according to Formula (1):

$$\rho_M = \frac{m_a}{m_a - m_l} \rho_l \tag{1}$$

where

ρ_M is the density of either the group of pellets or the individual briquette at the as received moisture content M, in g/cm^3;

m_a is the mass of the test portion in air (including test portion moisture) as recorded in 8.1 f) or in 8.2 d), respectively, in g;

m_l is the mass of the test portion in liquid (including test portion moisture) as recorded in 8.1 h) or in 8.2 h), respectively, in g;

ρ_l is the density of the applied liquid (0,995 8 g/cm^3), in g/cm^3.

As a matter of principle, the rise of the liquid surface in the liquid containment, which is caused by the displacement through the test portion (pellets) or test piece (briquettes), increases the buoyancy because a larger share of the suspension is now submerged, too. However, this effect can be neglected.

Calculate the arithmetic mean value of the total number of replications as defined in 8.1 j) (for pellets) or in 8.2 j) (for briquettes) and report it as the mean particle density to the nearest 0,01 g/cm^3.

10 Performance characteristics

10.1 General

Table 1 — Maximum acceptable differences between measured results

	Repeatability limit	Reproducibility limit
Pellets	5 %	7 %
Briquettes	5 %	7 %

10.2 Repeatability

The results calculated according to Clause 9 (performed within a short period of time, but not simultaneously) in the same laboratory by the same operator using the same apparatus on two representative test portions taken from the same test sample, shall not differ by more than the values given in Table 1[4].

10.3 Reproducibility

The results calculated according to Clause 9, performed in each of two different laboratories on representative test portions taken from the same test sample shall not differ by more than the values given in Table 1[4].

11 Test report

The test report shall include at least the following information:

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

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

c) a reference to this document, i.e. ISO 18847:2024;

d) the result of the particle density as mean value according to Clause 9;

e) any unusual features noted during the determination, which may affect the result;

f) any deviation from this document, or operations regarded as optional.

Annex A
(informative)

Stereometric volume estimation

A.1 Volume estimation procedure for regular shaped cylindrical briquettes

A.1.1 General

The particle density of regular shaped cylindrical briquettes can be estimated by a stereometric measurement. Different formulae have to be used for briquettes with or without a central hole.

The minimum number of briquette to be determined is six.

The briquette shall be cut to achieve a regular formed cylinder (see Figure A.1 and Figure A.2).

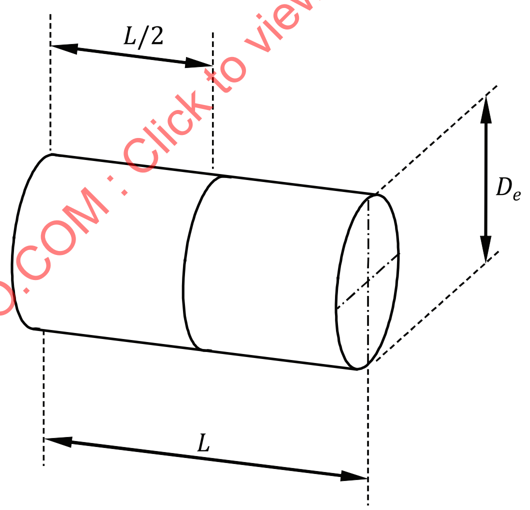
All measurements with a calliper should be made with a reading accuracy of 0,1 mm.

A.1.2 Cylindrical briquettes without a central hole

Calliper measurements:

— Length (L): two measurements per briquette, each with 90° offset;

— External diameter (D_e): six measurements per briquette (twice at both ends and in the middle at ½ L).



Key

L length

D_e external diameter

Figure A.1 — Measurement points at a briquette without central hole

Calculation:

$$V_b = \frac{D_{em}^2 * \pi * L_m}{4} \quad (A.1)$$

where

V_b is the volume of the briquette, in cm^3;

L_m is the mean length of the two measurements for L, in cm;

D_{em} is the mean value of the six measurements for D_e, in cm.

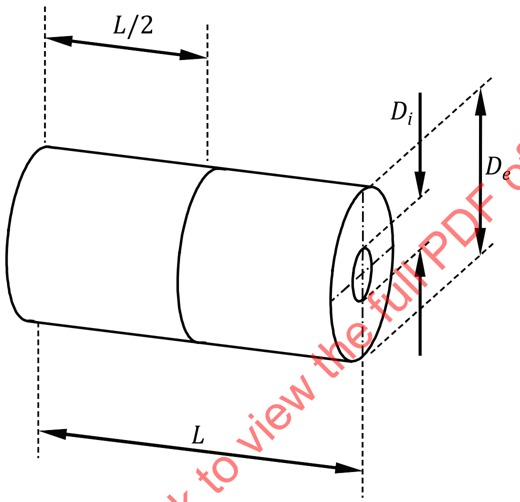
A.1.3 Cylindrical briquettes with a central hole

Calliper measurements:

— Length (L): two measurements per briquette, each with 90° offset;

— External diameter (D_e): six measurements per briquette (twice at both ends and in the middle at ½ L).

— Internal diameter (D_i): four measurements per briquette, twice at both ends.



Key

L length

D_e external diameter

D_i internal diameter

Figure A.2 — Measurement points at a briquette with a central hole

Calculation:

$$V_b = V_e - V_i \tag{A.2}$$

with

$$V_e = \frac{D_{em}{}^2 * \pi * L_m}{4} \tag{A.3}$$

and

$$V_i = \frac{D_{im}{}^2 * \pi * L_m}{4} \tag{A.4}$$

where

V_b is the volume of the briquette, in cm^3;

V_e is the external volume of the particle, in cm^3;

V_i is the volume of the hole, in cm^3;

L_m is the mean length of the two measurements for L, in cm;

D_{em} is the mean value of the six measurements for D_e, in cm;

D_{im} is the mean value of the four measurements for D_i, in cm.

A.2 Alternative volume estimation procedure for briquettes (also suitable for irregularly shaped briquettes)

The volume of non-cylindrical or irregular shaped briquettes can be estimated by the following procedure:

— Weigh a paper sheet with a precision of 1 mg (M_s in g) and measure its dimensions in cm at a precision of 0,1 cm. Calculate the surface A_s.

— Place the briquette standing upright on the base in the middle of the sheet.

— Use a sharp pencil (0,5 mm) to draw the circumferential line around the base of the briquette. The use of a special line marking equipment is advisable here.

— Cut out the area precisely on the line using a pair of scissors.

— Weigh the cut out piece of paper (M_p in g) with an accuracy of 1 mg.

— Apply calliper measurement (twice) for the length of the briquette (L_b) in cm (two measurements) and if applicable the diameter of any central hole (D_i in cm) (four measurements: two at both ends of the briquette, each with an offset of 90°).

A minimum number of six briquettes should be determined.

Calculation:

The surface of the briquette's base is (without hole) as given by Formula (A.5):

$$A_b = \frac{A_S * M_p}{M_s} \quad \text{(A.5)}$$

where

A_b is the base surface, in cm^2;

A_s is the surface of the original uncut paper sheet, in cm^2;

M_p is the mass of the cut piece of paper, in g;

M_s is the mass of the original uncut paper sheet, in g.

In case of any central hole in the briquette, reduce the surface of the base accordingly.

The briquette volume is as given by Formula (A.6):

$$V_b = A_b * L_b \quad \text{(A.6)}$$

where

V_b is the volume of the briquette, in cm^3;

A_b is the surface of the briquette, in cm^2;

L_b is the length of the briquette, in cm.