INTERNATIONAL STANDARD

ISO 17892-3

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Corrected version
2015-12-15

Geotechnical investigation and testing — Laboratory testing of soil —

Part 3:
Determination of particle density

Reconnaissance et essais géotechniques — Essais de laboratoire sur les sols —

Partie 3: Détermination de la masse volumique des grains

Reference number
ISO 17892-3:2015(E)

International Organization for Standardization

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Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

ISO 17892-3 was prepared by the European Committee for standardization (CEN) TC 341 *Geotechnical investigation and testing*, in collaboration with ISO/TC 182 *Geotechnics*, Subcommittee SC 1 *Geotechnical investigation and testing*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This International Standard cancels and replaces ISO/TS 17892-3:2004, which has been technically revised. It also incorporates the Technical Corrigendum ISO/TS 17892-3:2004/Cor.1:2006.

ISO 17892 consists of the following parts, under the general title *Geotechnical investigation and testing — Laboratory testing of soil*:

- *Part 1: Determination of water content*
- *Part 2: Determination of bulk density*
- *Part 3: Determination of particle density*
- *Part 4: Determination of particle size distribution*
- *Part 5: Incremental loading oedometer test*
- *Part 6: Fall cone test*
- *Part 7: Unconfined compression test*
- *Part 8: Unconsolidated undrained triaxial test*
- *Part 9: Consolidated triaxial compression tests*
- *Part 10: Direct shear tests*
- *Part 11: Permeability tests*
- *Part 12: Determination of liquid and plastic limits*

This corrected version of ISO 17892-3:2015 incorporates the following corrections plus other minor editorial modifications.

Foreword: It has been clarified that this is a first edition of an International Standard that is replacing a Technical Specification.

3.1: The word ‘dry’ has been added to the definition.

4.3.2: A temperature range has been specified.

Figure 2: Labels V_s and V_r have been removed.

5.2.4.3: An alternative method to determine the volume of the specimen has been added.

6.1.2: A temperature has been specified for $\rho_{L.}$

6.2.2: A note has been added.

Formula (7): Formula has been modified with a factor of 10^{-6} instead of 10^{6}.

Introduction

This part of ISO 17892 covers areas in the international field of geotechnical engineering never previously standardized internationally. It is intended that this part of ISO 17892 presents broad good practice and significant differences with national documents is not anticipated. It is based on international practice (see Reference [1]).

Geotechnical investigation and testing — Laboratory testing of soil —

Part 3:
Determination of particle density

1 Scope

This part of ISO 17892 specifies methods for the determination of the particle density of soils.

This part of ISO 17892 is applicable to the laboratory determination of the particle density of soil within the scope of geotechnical investigations, and describes two methods, a pycnometer method by fluid displacement and a pycnometer method by gas displacement.

The fluid pycnometer method described in this part of ISO 17892 applies to soil types with particle sizes under about 4 mm, or soils crushed to meet this requirement. Larger pycnometers are used for coarser materials. The particle size of soils suitable for testing in the gas pycnometer is limited by the dimensions of the specimen container of the particular gas pycnometer being used.

NOTE 1 This part of ISO 17892 fulfils the requirements of the determination of particle density of soils for geotechnical investigation and testing in accordance with EN 1997-1 and EN 1997-2.

NOTE 2 The presence of dissolved salts in the pore water can affect the results of these tests. Techniques for compensating for dissolved salts are available but are beyond the scope of this standard.

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 17892–1, *Geotechnical investigation and testing — Laboratory testing of soil — Part 1: Determination of water content*

ISO 14688–1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
density of solid particles
ρ_S
dry mass of the particles divided by their volume

4 Apparatus

4.1 Calibration requirements

See Annex A for calibration requirements of the following equipment.

4.2 General

4.2.1 Balance, shall have an accuracy of 0,01 g or 0,1 % of the weighed soil mass, whichever is greater.

4.2.2 Dessicator, shall be of suitable size and contain dry, self-indicating desiccant such as silica gel. It is not required if test specimen containers with close-fitting lids are used.

NOTE The purpose of the desiccator is to prevent absorption of moisture from air.

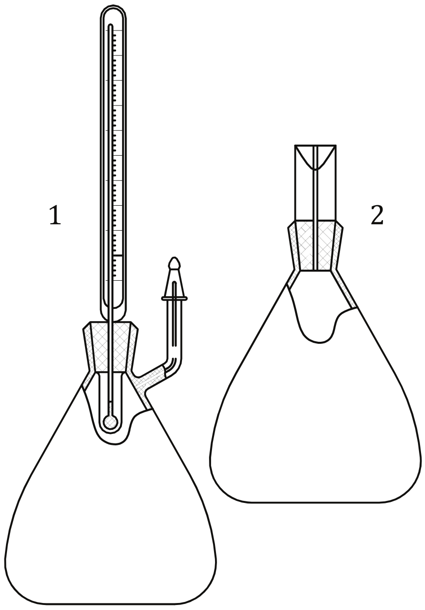
4.2.3 Riffle box, should be used to obtain a representative part of the specimen. Distribution by hand (quartering) is also acceptable if this results in a representative part of the specimen.

4.2.4 Drying oven, of the forced-draught type and shall be capable of maintaining a uniform temperature throughout the drying chamber. Any air circulation shall not be so strong that any transport of particles can take place.

4.2.5 Sample crushing equipment, a mortar and soft-ended pestle (e.g. a pestle with a rubber or wooden tip) shall be used to break up dried soil specimens. More substantial sample crushing equipment may be required to crush gravel sized rock particles.

4.3 Fluid displacement equipment

4.3.1 Fluid pycnometer, shall have a volume of at least 50 ml, a glass stopper which has been ground to fit precisely, and a capillary rising tube (see Figure 1).



Key

1 pycnometer with capillary and thermometer

2 pycnometer with capillary

Figure 1 — Examples of fluid pycnometers

4.3.2 Water bath or temperature-controlled enclosure or cabinet, thermostatically-controlled water bath, or a temperature-controlled room or cabinet, operating in the range 10 to 30 °C and with temperature variation not exceeding ±0,5 °C during the test shall be used.

4.3.3 Temperature measurement, temperature measuring device accurate to 0,1 °C shall be used.

The temperature measuring device should preferably be included in the glass stopper of the pycnometer. Alternatively, a temperature measuring device may be placed in the water bath or in the temperature-controlled enclosure/room, as close to the pycnometer as possible.

4.3.4 Apparatus to remove trapped air, vacuum pump or water aspirator that is capable of producing a partial vacuum should be used to remove air from the sample during the test.

4.3.5 Control liquid, of known or measured density is required to fill the pycnometer bottle. Distilled, demineralized, or deionized water is often the most suitable liquid. Alternatively, a suitable organic solvent such as hexane or kerosene may be used. Control liquids with a surface tension lower than that of water might be found to be preferable to rapidly saturate fine soils.

NOTE Use of liquids other than water can cause health or safety hazards, or contravene national laws.

4.4 Gas displacement equipment

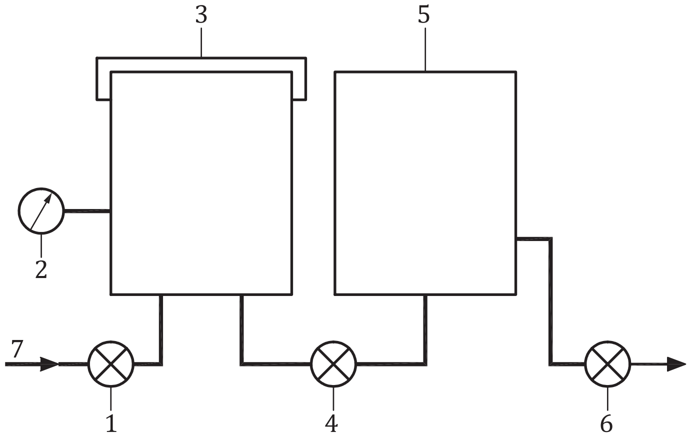
4.4.1 Gas pycnometer, with sample and expansion chambers, isolation valves and a pressure gauge shall be used (see Figure 2).

4.4.1.1 Other equipment arrangements are permitted, with pressure measurement being on either chamber. The pressure in the specimen chamber may either be increased or decreased on opening the isolation valve.

4.4.1.2 The chambers and valves shall be pressure-tight at the instrument's working pressures.

4.4.1.3 The system shall be fitted with a pressure gauge with an accuracy of 0,1 kPa or 0,1 % of the working pressure of the gas pycnometer, whichever value is greater.

4.4.1.4 For improved accuracy, the sample chamber should have a volume not more than two times that of the sample, and the volumes of the sample and expansion chambers should not differ by more than a factor of three.



Key

1	fill valve	5	expansion chamber
2	pressure indicator	6	vent valve
3	sample chamber	7	gas inlet
4	isolation valve		

Figure 2 — Schematic diagram of a typical gas pycnometer

4.4.2 Compressed gas

Helium is preferred as the measurement gas. Other gasses that give good diffusion into soil pores may be used, but this should be stated in the report. Unless otherwise specified as being acceptable by the gas pycnometer equipment manufacturer, research grade (>99,5 % purity) helium should be used in conjunction with the instrument.

5 Test procedures

5.1 Fluid pycnometer method

5.1.1 General

The fluid pycnometer method is based on the determination of the difference in the volume of liquid required to fill the pycnometer with and without the sample being present. The density of solid particles is calculated from the dry mass of the soil particles and the volume difference.

5.1.2 Reference measurements

5.1.2.1 Determine the dry mass of the clean and dry pycnometer to the nearest 0,01 g or 0,1 % of the weighed soil mass, whichever is the greater (m_0).

5.1.2.2 Fill the pycnometer with the control fluid so that no air shall be left in the pycnometer or capillary tube.

5.1.2.3 Place the pycnometer in the water bath, or in the temperature-controlled room or cabinet. Record the temperature. If using a water bath, only the neck, the stopper, and the capillary rising tube of the pycnometer should emerge above the surface of the water in the bath. Leave the pycnometer in the water bath until the control fluid temperature is equal to that of the water bath, a minimum of 1 h should be allowed. If a temperature-controlled room or cabinet is used, a much longer period will be required for temperature equilibration, a minimum of 16 h should be allowed.

5.1.2.4 Check the level of the control fluid in the pycnometer and add or remove fluid when necessary. Depending on the type of pycnometer, the level of the fluid should be at the top of the capillary.

5.1.2.5 If using a water bath, take the pycnometer out and immediately dry its external surfaces.

5.1.2.6 Without delay, determine the total mass of the pycnometer filled with control fluid, to the nearest 0,01 g or 0,1 % of the weighed soil mass, whichever is greater (m_1).

NOTE Excessive time delay or excessive handling once the pycnometer is removed from the temperature-controlled environment can result in a significant loss of fluid due to thermal expansion.

5.1.3 Specimen requirements

5.1.3.1 The specimen may be oven-dried or tested moist. If oven-dried, the sample should be dried in accordance with ISO 17892-1.

5.1.3.2 The selected specimen shall be representative of the soil, shall have a dry mass of at least 10 g and shall pass through a 4 mm sieve (or nearest equivalent) if using a 50 ml pycnometer. If larger particles are present, they may be crushed to meet the 4 mm limit, or a larger capacity pycnometer shall be used with a correspondingly larger sample. In either case, care should be taken to break down aggregations of oven dried fine soils with the mortar and pestle to release individual particles before testing.

5.1.3.3 In materials with enclosed voids, the measured density of the particles might underestimate the true density of the minerals present. This is a consequence of the volume of air in the enclosed voids being included in the volume of the particles. If the true density of the solid particles is to be determined, the sample should be crushed to remove enclosed voids.

5.1.3.4 Tests on predominantly organic material should be performed using a pycnometer with a nominal volume of 100 ml or greater and it should be filled with a volume of sample of at least 75 % of the volume of the pycnometer.

NOTE Tests on organic soils are prone to significant error because the organic component will often have a density below 1 Mg/m^3, and great care is required to obtain reliable results.

5.1.4 Test execution

For both oven-dried and moist specimens, at least two determinations shall be made. If the results do not agree to within 0,03 Mg/m^3, the tests shall be repeated.

5.1.4.1 Oven-dried specimens (method A)

5.1.4.1.1 Ensure that the pycnometer is clean and dry. Place the dry specimen in the pycnometer and determine the total mass to the nearest 0,01 g or 0,1 % of the weighed soil mass, whichever is greater (m_2).

5.1.4.1.2 Add control fluid to the pycnometer until the specimen is covered with 10 mm to 20 mm of fluid. Ensure that any trapped air in the specimen is removed, for example by mechanical agitation, by gentle heating or by the application of vacuum. While mechanical agitation alone can be sufficient to remove air from coarse specimens, the use of either heat or vacuum is recommended for all fine specimens. Pre-soaking of the specimen can be beneficial. In all cases take care not to lose any sample from the pycnometer.

5.1.4.1.3 Fill the pycnometer with control fluid and proceed in accordance with 5.1.2.2 to 5.1.2.5.

5.1.4.1.4 Without delay, determine the mass of the pycnometer completely filled with the saturated specimen and control fluid to the nearest 0,01 g or 0,1 % of the weighed soil mass, whichever is greater (m_3).

5.1.4.2 Moist specimens (method B)

5.1.4.2.1 Ensure that the pycnometer is clean and dry. Place the moist specimen in the pycnometer.

5.1.4.2.2 Add control fluid to the pycnometer until the specimen is covered with 10 mm to 20 mm of fluid. Ensure that any trapped air in the specimen is removed, e.g. by mechanical agitation, by gentle heating or by the gentle application of vacuum. While mechanical agitation alone can be sufficient to remove air from coarse specimens, the use of either heat or vacuum is recommended for all fine specimens. Pre-soaking of the specimen can be beneficial. In all cases, take care not to lose any sample from the pycnometer.

5.1.4.2.3 Fill the pycnometer with control fluid and proceed in accordance with 5.1.2.2 to 5.1.2.5.

5.1.4.2.4 Without delay, determine the mass of the pycnometer completely filled with the saturated specimen and control fluid to the nearest 0,01 g or 0,1 % of the weighed soil mass, whichever is greater (m_3).

5.1.4.2.5 Remove the specimen from the pycnometer and dry it to a constant mass in accordance with ISO 17892-1 (m_4). Alternatively, the moist mass of the specimen and the water content of a separate specimen determined in accordance with ISO 17892-1 may be used to calculate the dry mass of the test specimen.

5.2 Gas pycnometer method

5.2.1 General

The gas pycnometer method is based on the determination of the difference in the change in gas pressure, within the apparatus, between tests with the sample present and a reference test without a sample. The pressure difference is converted to a volume difference using Boyle's Law. The density of the particles is calculated from the dry mass of the sample and the volume difference.

NOTE The term "gas jar" has been used in some countries to describe a method for testing gravel-sized samples using a glass vessel that is not a pycnometer, and water as the fluid. The gas pycnometer method described here is not the same as the "gas jar" method, but the two are easily confused.

5.2.2 Reference measurements

5.2.2.1 Using appropriate pressure readings, determine the volume of the sample chamber, in accordance with the equipment manufacturer's instructions, using the chosen sample container (see 5.2.4.2) in the absence of any sample (V_c). Similarly, determine the volume of the expansion chamber (V_r).

5.2.3 Specimen requirements

The specimen shall be oven dried in accordance with ISO 17892-1.

5.2.3.1 The selected specimen shall be representative of the soil and shall have a dry mass of at least 10 g. If the specimen contains coarse material, it should be crushed prior to testing if required.

5.2.3.2 Care should be taken to break down aggregations of oven dried fine soils with the mortar and pestle before testing.

5.2.3.3 In materials with enclosed voids, the measured density of the particles might underestimate the true density of the minerals present. This is a consequence of the volume of air in the enclosed voids being included in the volume of the particles. If the true density of the solid particles is to be determined, the sample should be crushed to remove enclosed voids.

5.2.4 Test execution

5.2.4.1 Determine the mass of the specimen to the nearest 0,01 g or 0,1 % of the weighed soil mass whichever is the greater (m_4).

5.2.4.2 Transfer the specimen to a suitable container and place it in the test chamber. The specimen container should be chosen so that it is at least 75 % full. Alternatively, a known reference volume can be added to the specimen to fill the container almost completely.

5.2.4.3 Determine the volume of the specimen, in accordance with the equipment manufacturer's instructions or in accordance with Formula (6) (V_s).

5.2.4.4 Perform the test at least three times on each specimen. If the results do not agree to within 0,03 Mg/m^3, the tests shall be repeated.

6 Test results

6.1 Fluid pycnometer method

6.1.1 Dry mass of specimen

For oven dried specimens (method A), the dry mass m_4 shall be determined from Formula (1):

$$m_4 = m_2 - m_0 \tag{1}$$

For moist specimens (method B), the value of m_2 shall be determined from Formula (2):

$$m_2 = m_4 + m_0 \tag{2}$$

6.1.2 Density of solid particles

The density of the solid particles shall be determined from Formula (3):

$$\rho_s = \frac{m_4}{\left(m_1 - m_0\right) - \left(m_3 - m_2\right)} \cdot \rho_L \tag{3}$$

where

ρ_s is the density of the soil particles, in Mg/m^3;

m_0 is the mass of the dry pycnometer, in g;

m_1 is the mass of the pycnometer filled with the control fluid, in g;

m_2 is the mass of the pycnometer with the dry specimen, in g;

m_3 is the mass of the pycnometer with the specimen and filled with the control fluid, in g;

m_4 is the dry mass of test specimen, in g;

ρ_L is the density of the control fluid at the test temperature (see Table 1 if the fluid is de-aired and distilled water), in Mg/m^3.

If m_1 and m_3 are determined at different temperatures, Formula (3) becomes Formula (4):

$$\rho_s = \frac{m_4}{\left[\left(m_1 - m_0\right)/\rho_{L1}\right] - \left[\left(m_3 - m_2\right)/\rho_{L3}\right]} \tag{4}$$

where

ρ_{L1} is the density of the control fluid at the temperature at which m_1 is determined;

ρ_{L3} is the density of the control fluid at the temperature at which m_3 is determined.

Table 1 — Density of de-aired and distilled water at various temperatures, corrected for uplift in air

Temperature T (°C)	**Density** ρ_w (Mg/m^3)	**Temperature** T (°C)	**Density** ρ_w (Mg/m^3)
10	0,999 73	21	0,998 02
11	0,999 63	22	0,997 80
12	0,999 53	23	0,997 57
13	0,999 41	24	0,997 33
14	0,999 27	25	0,997 08
15	0,999 13	26	0,996 81
16	0,998 97	27	0,996 54
17	0,998 80	28	0,996 26
18	0,998 62	29	0,995 98
19	0,998 42	30	0,995 68
20	0,998 23		

The tabulated values can also be determined from Formula (5) from which intermediate or values for other temperatures can be calculated:

$$\rho_w = \frac{1}{\left(1+\left(\left(2{,}31\cdot T-2\right)^2-182\right)\cdot 10^{-6}\right)} \qquad (5)$$

where

ρ_w is the density of de-aired and distilled water, in Mg/m^3;

T is the temperature, in °C.

NOTE If the soil contains components that are soluble in the control fluid (e.g. salt in saline soils), the density of the control fluid and of the specimen can alter as a result.

6.2 Gas pycnometer method

6.2.1 Dry mass of specimen

The dry mass of the specimen is obtained directly from measured mass m_4.

6.2.2 Volume of the specimen

The volume of the sample is calculated from Formula (6):

$$V_s = V_c + \frac{V_r}{1-\left[\left(P_1-P_0\right)/\left(P_2-P_0\right)\right]} \qquad (6)$$

where

V_s is the volume of the specimen, in m^3;

V_c is the volume of the sample chamber, in m^3;

V_r is the volume of the reference or expansion chamber, in m^3;

P_0 is the initial pressure in the equipment, which can be atmospheric pressure, in kPa;

P_1 is the pressure in the system before opening the isolation valve, in kPa;

P_2 is the pressure in the system after opening the isolation valve, in kPa.

NOTE Formula (6) only applies to equipment of the same design as Figure 2.

6.2.3 Density of solid particles

The density of the solid particles is determined from Formula (7):

$$\rho_s = \frac{m_4}{V_s} \cdot 10^{-6} \qquad (7)$$

where

ρ_s is the density of the soil particles, in Mg/m^3;

m_4 is the dry mass of test specimen, in g;

V_s is the volume of the specimen, in m^3.

7 Test report

The test report shall affirm that the test was carried out in accordance with this part of ISO 17892-3 and shall contain the following information:

a) method of test used;

b) if using the fluid pycnometer method, the volume of the pycnometer if it is not 50 ml;

c) if using the gas pycnometer method, the identity of the gas used if it is not helium;

d) identification of the specimen tested, e.g. by borehole number, sample number and sample depth and any other relevant details required, e.g. depth of specimen within a sample, method of sample selection, if relevant;

e) visual description of the specimen including any observed features noted after testing, following the principles in ISO 14688-1;

f) mean value for the particle density in Mg/m^3 to two decimal places;

g) any deviation from the specified test procedure, and any other information that could be important for interpreting the test results, e.g. crushing the sample.

Annex A
(normative)

Calibration, maintenance, and checks

A.1 General requirements

All measurement equipment used in this part of ISO 17892 shall be calibrated periodically, its performance shall be checked where required at intervals, and it shall be operated in a controlled environment if required by this part of ISO 17892. This Annex specifies these requirements for this method.

If calibration of measurement equipment is carried out by a third party, it shall be carried out by an accredited calibration laboratory. The certification shall show traceability to recognized national or international standards of measurement.

Where calibration of test measuring equipment is carried out in house, the laboratory shall hold appropriate reference standards or instruments that are used solely for calibration purposes. These should be calibrated by an accredited calibration laboratory with certification requirements as above. When not in use, reference measurement equipment should be retained securely in a suitable environment separate from working standards or instruments. Reference standards and instruments shall be at least as accurate as the working device so that the desired accuracy of test measurement is achieved.

In-house calibration procedures shall be documented, shall only be performed by approved persons and records of such calibrations, and of performance checks, shall be retained on file.

Regardless of the required calibration or check intervals in this Annex, whenever any item of reference equipment or test measurement equipment has been mishandled, repaired, dismantled, adjusted or overhauled, it shall be recalibrated before further use.

All calibrated equipment shall be used only within the range for which it has been calibrated.

A.2 Environmental conditions

There are no specific environmental conditions applicable to the execution of this test method if a water bath is used. However, for the fluid pycnometer method, the temperature of the test room or cabinet shall be maintained constant within ±0,5 °C if no water bath is used.

A.3 Equipment

A.3.1 Ovens

The set temperature close to the centre of the usable oven space of an empty oven shall be checked by means of a calibrated temperature measuring device at least once a year.

The temperature distribution of an empty oven shall be checked before first use and after any major repair or replacement of heater elements and/or thermostat. If any of the individual temperature points is found to be outside the specified range of the set temperature, remedial action shall be taken.

A.3.2 Thermometers

Reference thermometers shall be calibrated or replaced at intervals not exceeding five years. All other liquid-in-glass thermometers shall be calibrated before first use and shall be re-calibrated or replaced at intervals not exceeding five years.

An ice point or another appropriate single point check of working thermometers shall be carried out six months after first being brought into use, then annually in addition to the five year calibration interval requirement.

If thermocouples are used for verifying oven temperatures, they shall be calibrated against a reference thermocouple, reference platinum resistance thermometer or reference liquid-in-glass thermometer before first use and at least once a year after that.

A.3.3 Balances

Balances shall be calibrated over their working range for the location of use, using certified reference weights, at least once a year. Reference weights shall be appropriate to the category of balance being calibrated, and shall have a tolerance (maximum permissible error) better than the resolution of the balance to be calibrated. Reference weights shall be calibrated when first brought into use and thereafter at least every two years.

Balances shall be checked on each day of use to confirm the zero point and to confirm the mass of a test item of known mass. The test item should not corrode or otherwise change mass with time, and should have a mass within the range 50 % to 80 % of the working range of the balance. The results of these checks shall be recorded. If the balance cannot be zeroed or the mass of the test weight is found to be outside the tolerance specified in 4.2.1, the balance shall be taken out of service until remedial action is complete.

A.3.4 Fluid pycnometer

Unless the pycnometer volume is determined in accordance with 5.1.1 during the execution of each test, the fluid pycnometer volume shall be checked at least once a year.

A.3.5 Gas pycnometer

The gas pycnometer pressure indicator shall be checked for accuracy at pressures close to the normal working pressures of the system (i.e. at pressures indicative of both P_0 and P_1), at least every six months, by comparison with a reference pressure indicator.

The specimen chamber and the reference or expansion chamber volumes shall be checked at least every six months.

The performance of the whole system shall be checked at least every six months by the use of a reference object of known volume or a specimen with known particle density. Such reference objects will usually be supplied with the equipment. If a reference object is used, the determined volume should fall within 0,05 cm^3 or 0,2 % of the object volume, whichever is greater. If a reference specimen is used, the determined particle density should fall within 0,01 Mg/m^3 of the reference particle density.

Bibliography

[1] DIN. ISSMGE (Eds.) (1998), *Recommendations of the ISSMGE for geotechnical laboratory testing*, (in English, German and French), Beuth Verlag, Berlin

[2] EN 1997-1, *Eurocode 7 – Geotechnical design — Part 1: General rules*

[3] EN 1997-2, *Eurocode 7 – Geotechnical Design — Part 2: Ground investigation and testing*

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