INTERNATIONAL STANDARD

ISO 17892-12

First edition
2018-06

Geotechnical investigation and testing — Laboratory testing of soil —

Part 12: Determination of liquid and plastic limits

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

Partie 12: Détermination des limites de liquidité et de plasticité

Reference number
ISO 17892-12:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Apparatus **2**
4.1 General 2
4.2 Fall cone method 3
4.3 Casagrande method 5
4.4 Plastic limit equipment 6
5 Test procedure **7**
5.1 Choice of liquid limit method 7
5.2 Specimen preparation 7
5.3 Determination of liquid limit by the fall cone method 8
5.4 Determination of liquid limit by the Casagrande method 10
5.5 Determination of plastic limit 12
6 Test results **13**
6.1 Proportion of sample smaller than 0,4 mm 13
6.2 Liquid limit by the fall cone method 13
6.3 Liquid limit by the Casagrande method 15
6.4 Plastic limit 15
6.5 Plasticity index 16
7 Test report **16**
7.1 Mandatory reporting 16
7.2 Optional reporting 16
Annex A (normative) **Calibration, maintenance and checks** **18**
Annex B (normative) **Additional parameters** **25**
Bibliography **27**

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 voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 341 *Geotechnical investigation and testing*, in collaboration with ISO Technical Committee TC 182, *Geotechnics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 17892-12 cancels and replaces ISO/TS 17892-12:2004, which has been technically revised. It also incorporates ISO/TS 17892-12:2004/Cor.1:2006.

A list of all the parts in the ISO 17892 series can be found on the ISO website.

Introduction

This document covers areas in the international field of geotechnical engineering never previously standardised internationally. It is intended that this document 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 12: Determination of liquid and plastic limits

1 Scope

This document specifies methods for the determination of the liquid and plastic limits of a soil. These comprise two of the Atterberg limits for soils.

The liquid limit is the water content at which a soil changes from the liquid to the plastic state.

This document describes the determination of the liquid limit of a specimen of natural soil, or of a specimen of soil from which material larger than about 0,4 mm has been removed. This document describes two methods: the fall cone method and the Casagrande method.

NOTE The fall cone method in this document should not be confused with that of ISO 17892-6.

The plastic limit of a soil is the water content at which a soil ceases to be plastic when dried further.

The determination of the plastic limit is normally made in conjunction with the determination of the liquid limit. It is recognized that the results of the test are subject to the judgement of the operator, and that some variability in results will occur.

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

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

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
liquid limit
w_L
water content at which a soil passes from the liquid to the plastic state, as determined by the liquid limit test

3.2
plastic limit
w_P
water content at which a specimen ceases to be plastic when dried further, as determined by the plastic limit test

3.3
plasticity index
I_P
numerical difference between the liquid limit and the plastic limit of a soil

3.4
non plastic soil
soil which has a plasticity index of zero or one for which the plastic limit cannot be determined

4 Apparatus

4.1 General

See also Annex A for more manufacturing tolerances (where appropriate), calibration, maintenance and checks on the equipment.

4.1.1 Balance.

The balance shall have an accuracy of 0,01 g or 0,1 % of the weighed mass whichever value is the greater.

4.1.2 Test specimen containers.

Test specimen containers shall be made of a material that does not change mass as a result of repeated drying cycles. Glass, porcelain and corrosion-resistant metals have been found to be suitable. Containers shall have a capacity large enough to hold the mass of sample to be dried without spillage, but should not be so large that the mass of the empty container is significantly in excess of that of the specimen. Containers used for plastic limit determinations shall have close fitting lids.

4.1.3 Water.

Water should be distilled, de-ionized or demineralized. Where distilled is referred to in this document, the terms are interchangeable.

4.1.4 Ancillary apparatus.

4.1.4.1 Spatulas.

4.1.4.2 Spray bottle (preferably of plastic).

4.1.4.3 Evaporating dishes.

4.1.4.4 Sieves complying with ISO 3310-1.

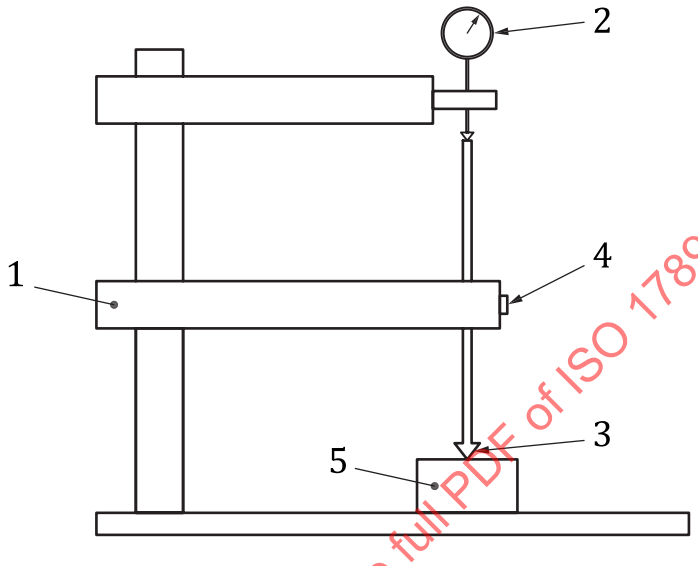
4.1.4.5 Flat mixing plate, for example glass.

4.1.4.6 Metal straightedge about 100 mm long.

4.2 Fall cone method

4.2.1 Fall cone apparatus.

4.2.1.1 The fall cone apparatus is shown schematically in Figure 1. It shall permit the cone to be held firmly initially and to be released instantaneously to fall freely in a vertical direction into the soil specimen.



Key

1 vertical adjustment mechanism
2 penetration measurement device
3 fall cone
4 lock/release button
5 specimen cup

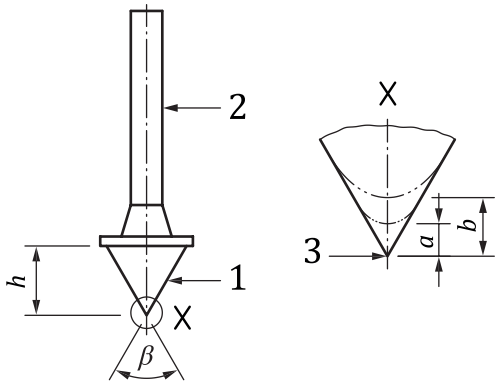
Figure 1 — Schematic of a fall cone apparatus

4.2.1.2 The fall cone apparatus shall have a vertical adjustment mechanism which allows the cone to be raised or lowered and adjusted so that the tip of the cone just touches the surface of the specimen before the cone is released.

4.2.1.3 The fall cone apparatus shall be equipped with a method of measuring the penetration of the cone into the specimen after release to a resolution of 0,1 mm (or better), within the range 5 mm to 20 mm if the 60 g/60° cone is used, or within the range 10 mm to 30 mm if the 80 g/30° cone is used.

4.2.2 Cones.

4.2.2.1 A typical cone is shown schematically in Figure 2.



Key

1 cone
2 shaft
3 cone tip
a deviation from the geometrical tip at manufacturing
b maximum tip wear
h height of the conical tip
β tip angle

Figure 2 — Example of liquid limit fall cone penetrometer (60° cone)

4.2.2.2 Either a 60 g/60° cone or a 80 g/30° cone complying with the requirements of Table 1 may be used as it has been shown that both cones give essentially the same value for the liquid limit. Other cone devices may be adopted provided they can be shown to give comparable results to those obtained from the tests described herein.

Table 1 — Set of fall cones — Typical manufacturing specifications for masses and dimensions

Mass of cone plus shaft	g	60 ± 0,06	80 ± 0,08
Tip angle *β*	°	60 ± 0,2	30 ± 0,2
Height of the cone tip *h*	mm	≥20	≥30
The deviation a from the geometrical tip at manufacturing	mm	<0,1	<0,1

4.2.2.3 The cone shall be manufactured of or coated with a corrosion resistant material such as stainless steel or chromium, and should have smooth polished surfaces with an average roughness Ra of less than 0,8 µm as a manufacturing specification. The cone surface has to remain smooth with use, and should be replaced if the smooth surface is noticeably damaged.

4.2.2.4 The maximum wear *b* shall be less than 0,3 mm (see Figure 2).

4.2.3 Sample cup.

The sample cup shall be made of non-corrodible and rigid material, spherical or cylindrical in shape. If cylindrical, it shall have a base parallel to the rim with a diameter of at least 50 mm and a depth of at least 25 mm if the 60 g/60° cone is used and a depth of at least 40 mm if the 80 g/30° cone is used.

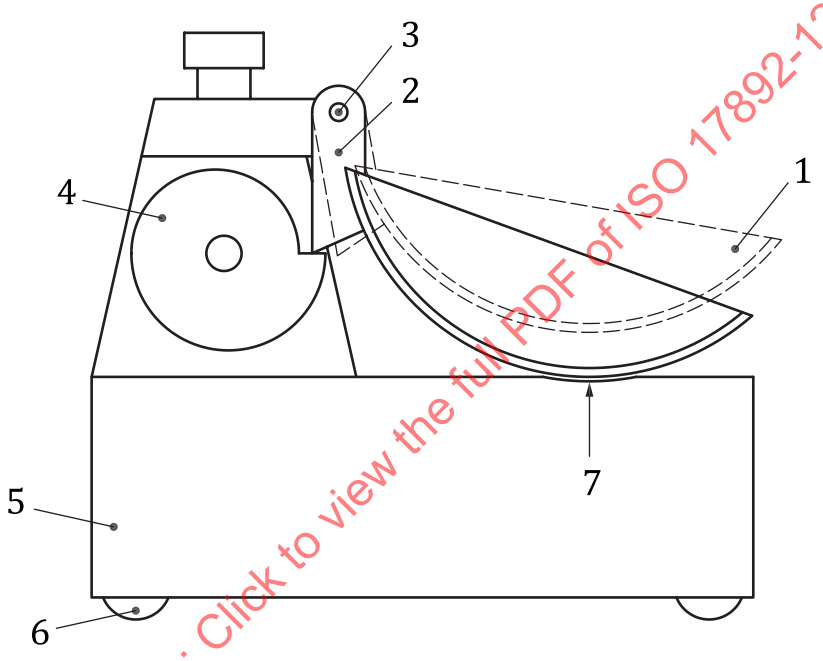
4.2.4 Timing device.

A clock or stop-watch, or similar, capable of being read to the nearest 1 s.

4.3 Casagrande method

4.3.1 Casagrande apparatus.

The Casagrande apparatus is shown schematically in Figure 3. The apparatus consists of a specimen cup which is raised by a cam and then dropped a specified distance onto a base. The device may be operated by either a hand crank or electric motor. Dimensions, manufacturing specifications and tolerances are included in Annex A. A Casagrande apparatus and grooving tool in accordance with other specifications may be adopted provided it can be shown to give comparable results.



Key

1 specimen cup (= bowl)
2 hanger
3 carriage with pin
4 cam (turned by handle or motor)
5 base
6 rubber feet
7 point of contact

Figure 3 — Schematic of the Casagrande apparatus

4.3.2 Base and rubber feet.

The base and feet shall be made of rubber complying with the requirements of Table 2. The feet supporting the base, are designed to provide isolation of the base from the work surface.

Table 2 — Base and feet — Rubber requirements

Hardness of the feet	Hardness of the base	Resilience of the base
Shore A value between 62 and 65	Shore D value of at least 80	Resilience (rebound value) between S = 0,80 and S = 0,90

Measurement of hardness (Shore A and Shore D) and resilience S is defined in A.3.7.5.

4.3.3 **Specimen Cup**.

The specimen cup should be made of brass or stainless steel. The shape of the cup shall be a segment of a sphere. Dimensions, manufacturing specifications and tolerances are included in Annex A.

The cup should not be polished. The surface has to remain smooth with use, and should be replaced if the smooth surface is noticeably damaged.

4.3.4 **Cam**.

The cam shall raise the cup smoothly and continuously to its maximum height, by increasing the radius of the cam over at least 180° of cam rotation. The final portion of the cam shall be shaped so that the cup does not develop an upward or downward velocity when the cam follower leaves the cam. A logarithmic spiral design has been found to be satisfactory.

4.3.5 **Carriage**.

The carriage is constructed in a way that allows convenient but secure adjustment of the 10 mm height-of-drop of the cup.

4.3.6 **Motor drive** (optional).

The apparatus may be equipped with a motor to turn the cam and if used shall operate at 2 ± 0,25 revolutions per second. The motor shall be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus.

4.3.7 **Grooving tool**.

A flat or curved tool made of plastic or non-corroding-metal. The grooving tool shall have a bevelled tip (see Annex A). The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not incorporate the gauge for adjusting the height-of-drop of the liquid limit device.

4.4 Plastic limit equipment

4.4.1 **Mixing plate**.

The mixing plate shall be flat, clean and smooth, and should be free from significant scratches which affect the behaviour during rolling of the threads. A glass plate of about 10 mm thick and 300 mm square has been found to be convenient.

4.4.2 **Rod or gauge**.

Either a rod with a diameter between 3 mm and 3,5 mm, or a gauge with an opening of the same size, shall be used.

5 Test procedure

5.1 Choice of liquid limit method

Two independent test methods are included in this document for the determination of the liquid limit. The fall cone method provides results with higher repeatability, and is the preferred method. However, there is a long history of use of the Casagrande method and its use is equally permitted.

NOTE 1 The two methods are known to give a difference in results. Experience has shown that the liquid limit determined by the fall cone and the Casagrande apparatus are in general agreement at a w_L of around 30 % to 40 %. At higher values of w_L, the Casagrande apparatus generally gives slightly greater values of liquid limit. At lower values of w_L, the Casagrande apparatus generally gives slightly smaller values of liquid limit.

For both liquid limit methods either a four-point test, or a one-point test, may be used. The four-point test is described here and is preferred. However the one-point method may be appropriate in soils whose plasticity is well understood and for which robust correlation factors have been established.

NOTE 2 In the four point liquid limit method the test is carried out at four different water contents whereas in the one point method the test is carried out at a single water content.

The choice of test method to be used shall be agreed with the client and reported.

5.2 Specimen preparation

5.2.1 Whenever possible the tests shall be carried out on soil from its natural state. About 200 g of soil finer than 0,4 mm is required for the determination of the liquid limit by either method. Sieves with an aperture of 0,425 mm or an aperture of 0,400 mm are acceptable for removing the coarser material.

NOTE Where, further in this document, a 0,4 mm or nearest sieve is mentioned, sieves with an aperture of 0,425 mm or an aperture of 0,400 mm, are acceptable.

Soils should not normally be oven-dried before testing, but if this is necessary it shall be reported. For soils that are susceptible to oxidation when exposed to air, the tests should either be determined immediately after extrusion, or if done at a later time, the specimen shall be sealed until the test is performed.

5.2.2 If the sample does not include material larger than about 0,4 mm, go to 5.2.8.

5.2.3 If the sample includes material larger than about 0,4 mm, this coarser fraction should be removed as in 5.2.4 to 5.2.7.

5.2.4 Determine the water content (w) of a representative specimen of the original sample according to ISO 17892-1.

5.2.5 Weigh a representative specimen of undried soil that will give at least 200 g of soil passing a 0,4 mm or nearest sieve. Weigh this representative specimen of undried soil to 0,1 % of its mass or 0,01 g, whichever is the greater (m_1).

5.2.6 If the fraction larger than 0,4 mm consists of a small number of discrete coarse particles, these may be removed by hand, dried at 105 °C to 110 °C and weighed (m_r).

5.2.7 If the coarse fraction cannot readily be removed by hand, the particles shall be removed using the wet separation method as follows.

5.2.7.1 Place the specimen in a container and add just enough distilled water to cover it, and then stir until it forms a slurry.

5.2.7.2 Pour the slurry through a 0,4 mm or nearest sieve. A larger aperture guard sieve may be used to protect this sieve. Wash the material retained on the sieve with a minimum amount of distilled water until the water passing the 0,4 mm or nearest sieve is virtually clear. Retain all material passing the 0,4 mm or nearest sieve.

5.2.7.3 Dry the material retained on the 0,4 mm or nearest sieve and any guard sieve used at 105 °C to 110 °C. Weigh this dried material with an accuracy equal to 0,1 % of its mass or 0,01 g, whichever is the greater (m_r).

5.2.7.4 Allow the collected washings to settle and pour off any clear water.

5.2.7.5 The remaining suspension may be partially dried in a current of warm air, or in an oven at not more than 50 °C, until it becomes a firm paste. Local drying shall be prevented at the surface or edges by repeated stirring.

5.2.8 Remould the specimen of natural soil, hand-picked soil or sieved soil thoroughly to break down the structure of the soil, adding or removing water as necessary to adjust the consistency of the resulting remoulded paste to bring it into the range required of the test.

5.2.9 Remoulding should be carried out by hand using spatulas to mix the sample on the mixing plate, and should be continued until the consistency of the specimen ceases to change. This may take up to 40 min. Avoid air bubbles being mixed into the specimen while remoulding it.

5.2.10 If a significant quantity of water needs to be added to the specimen to achieve the desired consistency of remoulded paste, allow the specimen to equilibrate with the water for a minimum of 4 h (taking care not to let the specimen dry in air). High plasticity soils may require up to 24 h.

5.2.11 If a significant quantity of water needs to be removed from the specimen to achieve the desired consistency of remoulded paste, spread the whole specimen on a plate or evaporating dish and allow it to slowly air dry, or to dry under a gentle stream of warm air. Localized drying shall be avoided by repeated remixing of the soil.

5.2.12 The liquid limit should be determined as soon as possible after remoulding.

5.3 Determination of liquid limit by the fall cone method

5.3.1 Place portions of the prepared remoulded paste into a clean and dry cup with a spatula, taking care not to trap air. Strike off excess soil with a straightedge to give a smooth level surface.

NOTE The liquid limit is influenced by trapping of air bubbles when remoulding or placing the paste into the cup, or insufficient remoulding.

5.3.2 Lock the penetration cone in the raised position. Lower the supporting assembly so that the tip of the cone just touches the surface of the soil. When the cone is in the correct position a slight movement of the cup will just mark the soil surface.

5.3.3 Lock the penetration cone in position and either zero the depth penetration measuring device, or record the initial position of the cone shaft to the nearest 0,1 mm.

5.3.4 Release the penetration cone and let it settle for a period of 5 s ± 1 s. If the apparatus is not fitted with a locking device, care shall be taken not to jerk the apparatus during this operation.

5.3.5 Record the depth of penetration of the cone after 5 s ± 1 s to the nearest 0,1 mm.

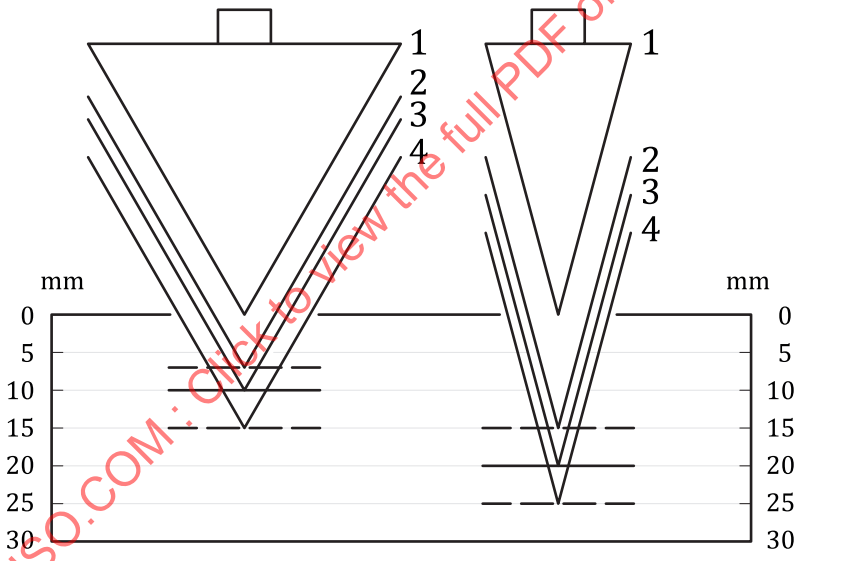
5.3.6 Calculate the depth of penetration of the cone as the difference between the initial and final position of the cone shaft. Check that the depth of penetration is within the required range for the type of cone in use as given in Table 3 and as shown in Figure 4. If the penetration is outside the required range, repeat from 5.2.8 adding or removing a little water as necessary to adjust the consistency of the remoulded paste.

5.3.7 If the depth of penetration is within the required range, lift the cone out and clean it, being careful to avoid scratching its surface.

5.3.8 Add a little more remoulded paste to the cup, taking care not to trap air, level the surface as in 5.3.1 and repeat 5.3.2 to 5.3.7 until the difference between two successive readings is less than the value in Table 3.

Table 3 — Cone penetration requirements

Type of cone	60 g/60°	80 g/30°
Allowable cone penetration range	7 mm to 15 mm	15 mm to 25 mm
Liquid limit (w_L) determined at a penetration depth of	10 mm	20 mm
Maximum difference between two successive readings	0,4 mm	0,5 mm



a) 60 g/60° cone **b) 80 g/30° cone**

Key

1 initial position before fall
2 minimum penetration
3 penetration corresponding to w_L
4 maximum penetration

Figure 4 — Penetration range in a liquid limit fall cone test

5.3.9 Remove a specimen of minimum mass of 15 g of the remoulded paste from the zone penetrated by the cone, and determine the water content according to ISO 17892-1 (allowing a smaller mass to be used).

5.3.10 Remove the remaining remoulded paste from the cup and add it to the rest of the remoulded paste on the plate. Adjust the water content by a small amount, and thoroughly remix the sample with the spatula to ensure uniform distribution of the water.

5.3.11 Repeat 5.3.1 to 5.3.10 to give at least four test points at different water contents. The four points shall all be within the range specified in Table 3, and with at least one point above and at least one point below the penetration depth corresponding to the liquid limit. The four or more test points should be roughly evenly spaced across the penetration range in Table 3.

5.3.12 The water content of the specimen should not be alternately increased and reduced but either increased or reduced in stages.

NOTE It is normally more practicable to carry out the test going from the drier condition to the wetter condition in continuously increasing water contents although going from the wetter to the drier condition is also acceptable.

5.3.13 If at any time during the above procedure the soil has to be left for a while it shall be covered with the evaporating dish or a damp cloth to prevent it from drying out.

5.3.14 If the one-point method is used, the penetration shall be repeated at least once. The cone penetration measurements shall be within the allowable range and the repeated penetrations shall be consistent in accordance with Table 3. A separate water content determination shall be made for each penetration. If these measured water contents differ by more than 5 relative percent, the test shall be repeated.

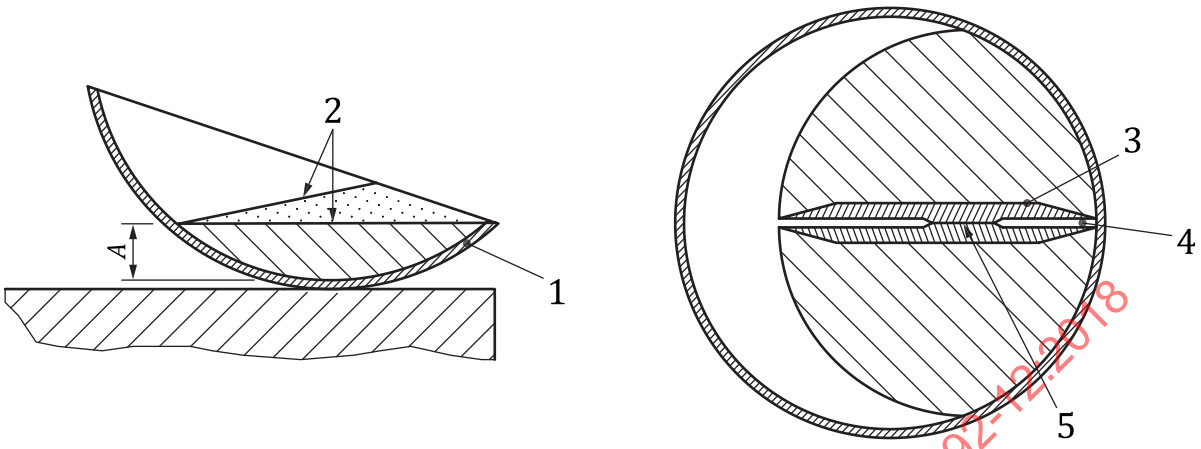
5.4 Determination of liquid limit by the Casagrande method

5.4.1 Place the Casagrande apparatus on a solid and level surface.

5.4.2 Add the remoulded paste to the cup with a spatula, taking care not to trap air. Press the soil down and spread it out into the cup to a depth of at least 10 mm at its deepest point.

NOTE The liquid limit is influenced by trapping of air bubbles when remoulding or placing the paste into the cup, or insufficient remoulding.

5.4.3 Strike off excess soil with a spatula, using as few strokes as possible, to give a smooth surface of 10 mm depth at its deepest point, tapering to form an approximately horizontal surface. This is shown schematically in Figure 5a) in cross section and Figure 5b) in plan.



a) Cross section **b) Plan**

Key

1 cup
2 surface level for test
3 principle sketch of profiled side of groove as cut
4 base of cup exposed by groove as cut
5 10 mm closure of groove at end point of test
A 10 mm

Figure 5 — a) Filling the cup with soil, b) cup at the end of the test

5.4.4 Use the grooving tool to cut a groove in the soil paste, exposing the face of the cup at the base of the groove. The grooving tool shall be clean and dry, and shall be kept perpendicular to the inner surface of the cup with the bevelled edge facing the direction of movement.

5.4.5 If the specimen is clay, the groove should be cut in a single stroke. If the specimen is silt, several cuts may be required, taking away a small amount of the specimen with each stroke. While cutting the groove, ensure that the specimen does not slide across the face of the cup, nor crack.

5.4.6 Lift and drop the cup onto the base by rotating the cam at about 2 revolutions per second. Do not hold the base while rotating the cam.

5.4.7 Count the number of rotations while carefully observing the groove cut in the soil. The gap should close by soil flowing, rather than by soil sliding across the surface of the cup.

5.4.8 Stop rotating the cam as soon as the groove has closed over a length of 10 mm (Figure 5b). Record the number of rotations.

5.4.9 Check that the number of rotations is within the required range as given in Table 4. If the number is outside the required range, repeat 5.2.8 to 5.2.12, adding or removing a little water as necessary to adjust the consistency of the remoulded paste, and then repeat the measurement from 5.4.1.

Table 4 — Casagrande test requirements

	Number of rotations
Range of number of rotations	15 to 40
Number of rotations to determine liquid limit (w_L)	25
Maximum difference between two successive readings for a one-point test	2

5.4.10 Remove a specimen of at least 15 g of the remoulded paste from the zone where the groove has closed, and determine the water content according to ISO 17892-1 (allowing a smaller mass to be used).

5.4.11 Remove the remaining remoulded paste from the cup and add it to the rest of the remoulded paste on the plate. Adjust the water content by a small amount, and thoroughly remix the sample with the spatula to ensure uniform distribution of the water.

5.4.12 Repeat 5.4.1 to 5.4.11 to give at least four test points at different water contents, cleaning and thoroughly drying the cup between each. The four points shall all be within the range specified in Table 4, and with at least one point above and at least one point below 25 rotations. The four or more test points should be roughly evenly spaced across the rotation count range in Table 4.

5.4.13 The water content of the specimen should not be alternately increased and reduced but either increased or reduced in stages.

NOTE It is normally more practical to carry out the test going from the drier condition to the wetter condition in continuously increasing water contents although going from the wetter to the drier condition is also acceptable.

5.4.14 If at any time during the above procedure the soil has to be left for a while it shall be covered with the evaporating dish or a damp cloth to prevent it from drying out.

5.4.15 If the one-point method is used, the counting of the number of rotations for the closure of the groove over a length of 10 mm shall be repeated at least once. The specimen shall be removed from the cup and remoulded between tests. The rotation counts for the two or more determinations shall comply with the range of values given in Table 4, and the repeated results shall be consistent as also specified in Table 4. If the water contents measured in the separate determinations differ by more than 5 relative percent, the test shall be repeated.

5.5 Determination of plastic limit

5.5.1 Take a specimen of about 15 g to 20 g of the soil paste prepared according to 5.2, and place it on the mixing plate.

NOTE It is often convenient to carry out the test on a portion of the material prepared for one of the liquid limit tests procedures.

5.5.2 Allow the remoulded paste to partially dry on the plate until it becomes plastic enough to be shaped into a ball. The specimen may be air-dried, or dried under a gentle stream of warm air.

5.5.3 Mould the ball of partially dried paste between the fingers and roll it between the palms of the hands until the heat of the hands has dried the soil sufficiently for slight cracks to appear on its surface. Divide the ball into two portions of about equal mass.

5.5.4 Divide one portion into 3 sub-portions.

5.5.5 One sub-portion at a time, mould each into a thread about 6 mm diameter between the first finger and thumb of each hand.

5.5.6 Place the thread on the mixing plate and roll it backwards and forwards with an even motion of the hand. Rolling between the fingers of one hand, from finger-tip to the second joint has proven to be good practice. Maintain a gentle uniform downwards pressure and roll the thread in such way that the whole thread gets an even thickness, until its diameter approaches 3 mm. If required, use the 3 mm rod or gauge to assess the diameter of the thread.

5.5.7 Repeat 5.5.5 to 5.5.6 until the thread crumbles when it has been rolled to 3 mm diameter. The correct end-point of the test is when the threads just begin to break apart, rather than when they begin to crack.

5.5.8 Place the crumbled pieces of thread into a suitable container and place a lid on it.

5.5.9 Repeat 5.5.5 to 5.5.7 on the other two sub-portions of partially dried remoulded paste, placing all the crumbled pieces of thread from all three sub-portions into the same container. Determine the water content of the crumbled threads according to ISO 17892-1.

5.5.10 Repeat 5.5.4 to 5.5.9 on the second portion of partially dried remoulded paste at 5.5.3, placing the crumbled threads from these three sub-portions into a second container, and determine the water content of the crumbled threads according to ISO 17892-1.

5.5.11 Some soils have very low plasticity, and it can be difficult to assess the precise crumbling condition. If it is not possible to roll 3 mm threads, the sample should be reported as non-plastic.

6 Test results

6.1 Proportion of sample smaller than 0,4 mm

If particles have been removed from the specimen, estimate the percentage of material smaller than 0,4 mm (K) from Formula (1):

$$K = \frac{\left[\left(\frac{100 \times m_1}{100 + w}\right) - m_r\right]}{\left(\frac{100 \times m_1}{100 + w}\right)} \times 100\,\% \qquad (1)$$

where

w is the water content of the separate representative specimen, in per cent;

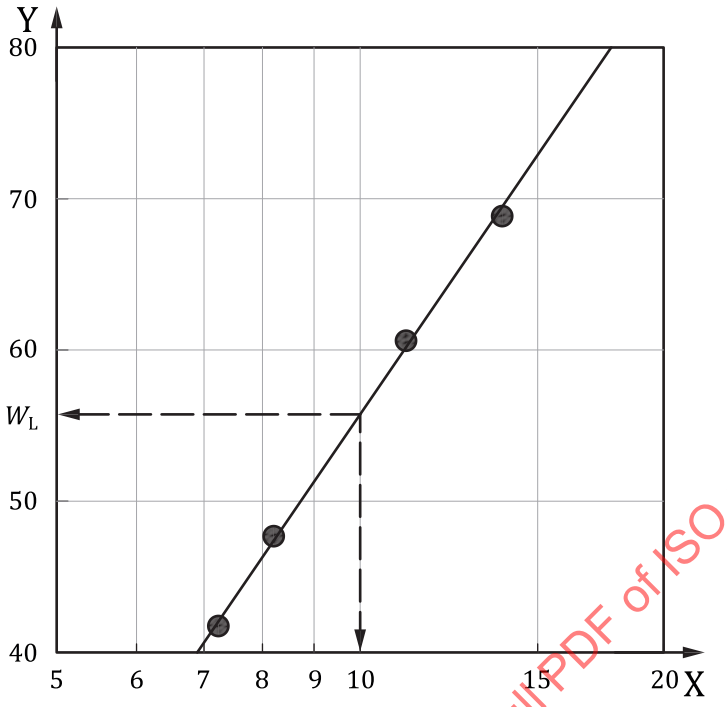
m_1 is the mass of undried soil (g);

m_r is the dry mass of coarse particles greater than 0,4 mm removed (g).

6.2 Liquid limit by the fall cone method

6.2.1 Plot the measured water contents as ordinate on a linear scale, and the corresponding cone penetrations as abscissa on a log10 scale if using the 60 g/60° cone. If using the 80 g/30° cone, plot both

water content and cone penetration on linear scales. An example plot for a 60 g/60° cone is shown in Figure 6.



Key

X cone penetration (mm)

Y water content (%)

Figure 6 — Example of a liquid limit test result from a fall cone test with the 60 g cone

6.2.2 Draw the best straight-line fit through the plotted points. If one of the measured water contents differs by more than 5 relative percent in water content from the line, this test-point may be omitted from the regression. If the remaining three points do not give a satisfactory linear relationship, the test should be repeated.

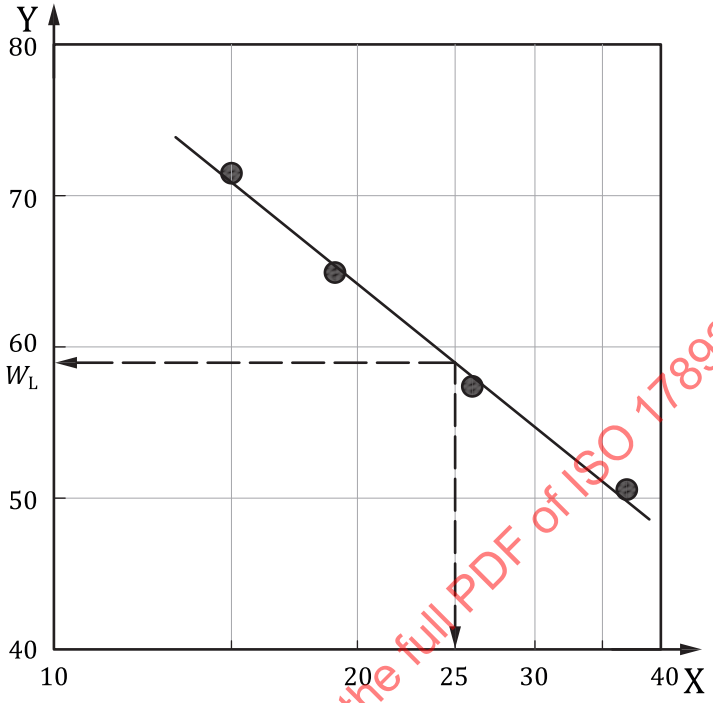
6.2.3 Read off the liquid limit (w_L) being the water content corresponding to 10 mm penetration for the 60 g/60° cone, or the water content corresponding to 20 mm penetration for the 80 g/30° cone.

NOTE Other penetration criteria have been used to define liquid limit, for example 17 mm has been adopted in some countries and local correlations can be used to compare previous data with the method defined in this document.

6.2.4 In using a one-point method, calculate the average water content and average cone penetration of the repeated determinations. The average measured water content shall be corrected by pre-determined correlation factors in order to reference the answer to the standard 10 mm penetration for the 60 g/60° cone, or to 20 mm standard penetration if using to 80 g/30° cone, to give the value of the liquid limit (w_L).

6.3 Liquid limit by the Casagrande method

6.3.1 Plot the measured water contents as ordinate on a linear scale and the corresponding number of rotations as abscissa on a log10 scale. An example plot is shown in Figure 7.



Key

X number of rotations N

Y water content (%)

Figure 7 — Example of a liquid limit test result from a Casagrande test

6.3.2 Draw the best straight-line fit through the plotted points. If one of the measured water contents differs by more than 5 relative percent in water content from the line, this test-point may be omitted from the regression. If the remaining three points do not give a clear indication of the liquid limit, the test should be repeated.

6.3.3 Read off the liquid limit (w_L) being the water content corresponding to 25 rotations.

6.3.4 In using the one-point method, calculate the average water content and average number of rotations of the repeated determinations. The average measured water content shall be corrected by pre-determined correlation factors in order to reference the answer to the standard 25 rotations, to give the value of the liquid limit (w_L).

6.4 Plastic limit

6.4.1 If the two plastic limit water content results differ by more than 2 % absolute for values of w_P less than or equal to 40 %, or by more than 5 % relative for values of w_P greater than 40 %, the plastic limit test shall be repeated. Calculate the plastic limit (w_P) as the average water content from the two plastic limit water content determinations.

6.5 Plasticity index

The plasticity index (I_P) shall be calculated according to Formula (2):

$$I_P = w_L - w_P \quad (2)$$

where

w_L is the liquid limit;

w_P is the plastic limit.

7 Test report

7.1 Mandatory reporting

The test report shall affirm that the test was carried out in accordance with this document, and shall contain the following information:

a) method used to obtain the liquid limit, i.e. either fall cone or Casagrande, and whether four-point or one-point, and whether with increasing or decreasing water content;

b) if using the fall cone liquid limit method, the type of cone used;

c) if using a one-point liquid limit method, the test readings and the correlation factors used.

d) an identification of the sample (test specimen) being tested, e.g. by borehole number, sample number, test number, sample depth, etc.;

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

f) history of the sample, e.g. whether tested in the natural state or after wet sieving or after any other preparation process;

g) proportion of material passing the 0,4 mm or nearest sieve, when determined, and whether this was estimated by hand-picking or measured by wet-sieving;

h) the water content of the specimen before removal of particles prior to determination of liquid or plastic limits, if measured.

i) value of the liquid limit to the nearest one percent;

j) value of the plastic limit to the nearest one percent, or if it was not possible to determine the plastic limit, report it as non-plastic;

k) value of the plasticity index, to the nearest one percent, when determined;

7.2 Optional reporting

The following additional information may also be reported (see Annex B):

a) liquidity index;

b) consistency index;

c) activity index;

d) the calculated water content ($w_{<0,4}$) of the portion of the sample passing 0,4 mm or nearest sieve;

e) individual plots from which w_L has been derived;

f) plasticity chart.

Annex A
(normative)

Calibration, maintenance and checks

A.1 General requirements

All measurement equipment used in this document shall be calibrated periodically, its performance shall be checked where required at intervals, and it shall be operated in a controlled environment if so specified. This Annex defines 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 of an accuracy at least that of 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.

Notwithstanding 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.

A.3 Apparatus

A.3.1 Ovens

The set temperature at the mid-point 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 complying with ISO 386 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 thereafter at least once a year.

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 4.1.1, the balance shall be taken out of service until remedial action is complete.

A.3.4 Separation sieves

Each sieve shall be separately identified. Checks on sieves shall be carried out in accordance with the following procedures.

All sieves shall be checked by the operator before each use. The visual checks shall identify any damage or blockage which is likely to affect the performance of the sieve. If any doubt exists, a measurement or performance check, as appropriate, shall be carried out before further use.

Test sieves which fail visual checks shall be clearly marked as such, and be either discarded or used as guard sieves where appropriate.

A.3.5 Timers

Timing devices, such as clocks and stop watches, shall be checked at least once per year to 1 s in a 600 s recorded period.

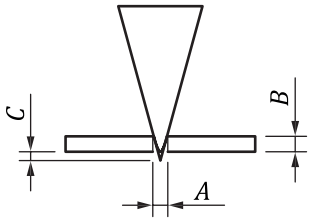
A.3.6 Fall cone liquid limit device

A.3.6.1 Cone

Before the first use on each day of use, check the sharpness of the cone tip, the surface finish on the cone and the free fall of the cone.

To ensure that the point remains sufficiently sharp for the purposes of the test, the cone should be replaced if the point can no longer be felt when brushed lightly with the tip of the finger when the tip is pushed through a hole (1,50 ± 0,02) mm in diameter, drilled through a metal plate (2,50 ± 0,02) mm thick for a 30° cone or a (1,00 ± 0,02) mm thick metal plate for a 60° cone. This is shown schematically in Figure A.1.

Other gauge dimensions may be used providing the ratios of its thickness to the diameters of the holes are maintained. The maximum permitted degree of wear of the cone tip (4.2.2) corresponds to the worn tip being flush with the bottom of the metal plate.



Key

A hole diameter 1,50 (±0,02) mm

B plate thickness 2,50 (±0,02) mm
for a 30° cone, or 1,00 (±0,02) mm
for a 60° cone

C maximum tip wear 0,3 mm

Figure A.1 — Cone tip sharpness check gauge

The surface finish of the cones shall be visually checked before use on each day of use to ensure no significant scratches or corrosion is visible.

The cone mass, dimensions and total tip wear shall be verified at least annually to ensure the requirements of Table 1 and 4.2.2.4 are met.

A.3.6.2 Penetration measurement device

The device used to measure the fall of the cone shall be calibrated against reference gauge blocks or another reference device at least every year, to meet the requirements (4.2.1.3) within an accuracy of 0,1 mm. Reference gauge blocks and other reference devices shall be calibrated at least every five years.

A.3.7 Casagrande liquid limit device

A.3.7.1 Dimensions

The dimensions of the apparatus (see Figure A.2) shall be in accordance with those given in Tables A.1 to A.3. Dimensions and specifications marked with an (*) are checked as in A.3.7.5. The other dimensions of the apparatus are manufacturing specifications.

The design of the apparatus and the materials used in its construction should ensure compatibility between all parts and ensure a stable and robust apparatus.

The rubber for the base and feet should meet the requirements of Table 2, 4.3.2.

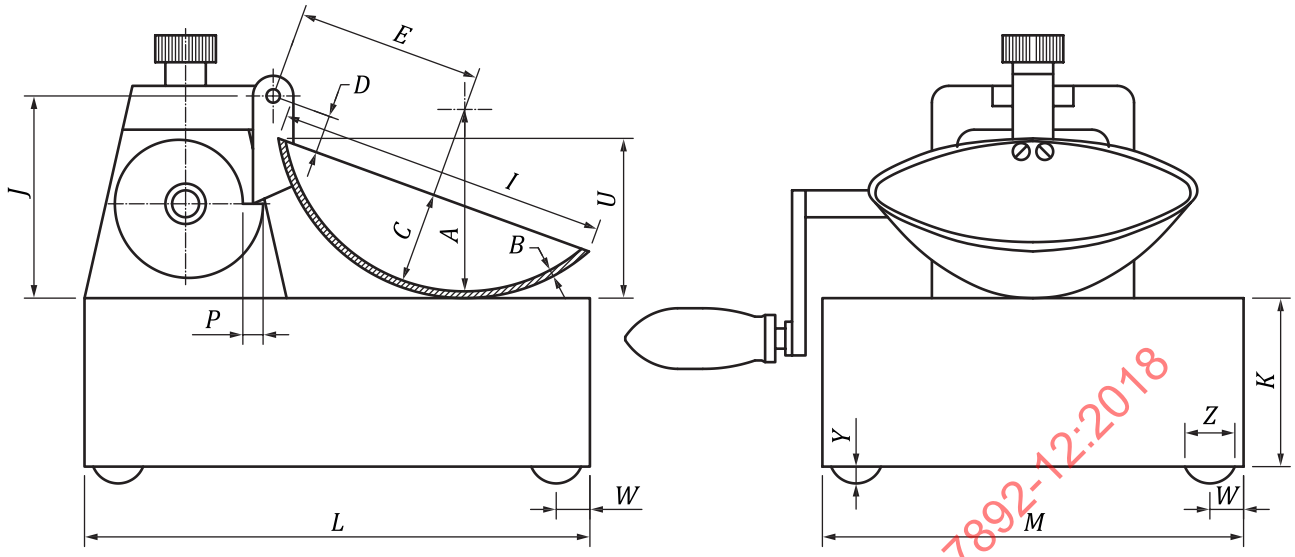


Figure A.2 — Casagrande liquid limit device — Dimensions

Table A.1 — Manufactured dimensions of the base and feet

Dimension	K*	L*	M*	W	Y	Z
Length (mm)	50	150	125	13	5	14,5
Tolerance (mm)	±2	±2	±2	±1	±0,5	±1,5

Table A.2 — Manufactured dimensions of the cup and cup hanger

Dimension	A (radius)	B*	C*	D	E	I*	J*	U*	P
Length (mm)	54	2	27	12	57	93,5	60	46	6
Tolerance (mm)	±0,5	±0,25	±0,5	±0,5	±1,0	±0,5	±1	±1	±0,5

Table A.3 — Mass of the cup and hanger

	Mass of cup*	Mass of hanger*
Mass when manufactured (g)	173	27
Manufacturing tolerance (g)	±3	±0,5
Minimum mass in use (g)	170	26

A.3.7.2 Dimensions of the cam

The cam should either be a spiral, with the radius increasing smoothly from a minimum of 18 mm to a maximum of 24 mm, or may be designed with one semi-circle of radius 19 mm and a second semi-circle of radius 22 mm with a 3 mm separation between the centres of the radii, so that in both cases the step in the cam causing the cup to drop is 6 mm. The final portion of the cam shall be shaped so that the cup does not develop an upward or downward velocity when the cam follower leaves the cam.

A.3.7.3 Grooving tools

The dimensions of the grooving tools (Figure A.3) shall be in accordance with Table A.4 for the flat tool and with Table A.5 for the curved tool. Dimensions and specifications marked with an (*) are checked as in A.3.7.5. The other dimensions of the grooving tools are manufacturing specifications.