
**Geotechnical investigation and testing —
Sampling methods and groundwater
measurements —**

**Part 1:
Technical principles for execution**

*Reconnaissance et essais géotechniques — Méthodes de prélèvement
et mesurages piézométriques —*

Partie 1: Principes techniques des travaux



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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 22475-1 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical investigation and testing*, in collaboration with Technical Committee 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).

ISO 22475-1 consists of the following parts, under the general title *Geotechnical investigation and testing — Sampling methods and groundwater measurements*:

- *Part 1: Technical principles for execution*
- *Part 2: Qualification criteria for enterprises and personnel*
- *Part 3: Conformity assessment of enterprises and personnel by third party*

Introduction

ISO 22475-1 specifies the technical principles for the execution of sampling and groundwater measurements for geotechnical purposes.

The quality of these services can be proven by:

- a) a declaration of conformity by a contractor (first party control);
- b) a declaration of conformity by a client (second party control);
- c) a declaration of conformity by a conformity assessment body (third party control).

Every enterprise or individual may decide, if and how they will prove the fulfilment of the technically related criteria: by first, second or third party control because no part of ISO 22475 requires such a declaration.

ISO/TS 22475-2 specifies the qualification criteria for enterprises and personnel that perform sampling and groundwater measurements according to ISO 22475-1.

The conformity assessment by third party control can be made according to the technical principles for execution of sampling and groundwater measurements specified in ISO 22475-1, as indicated in ISO/TS 22475-2, and in the conformity assessment procedure given in ISO/TS 22475-3.

Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for execution

1 Scope

This part of ISO 22475 deals with the technical principles of sampling of soil, rock and groundwater, and with groundwater measurements, in the context of geotechnical investigation and testing, as described in EN 1997-1 and EN 1997-2.

The aims of such ground investigations are:

- a) to recover soil and rock samples of a quality sufficient to assess the general suitability of a site for geotechnical engineering purposes and to determine the required soil and rock characteristics in the laboratory;
- b) to obtain information on the sequence, thickness and orientation of strata and joint system and faults;
- c) to establish the type, composition and condition of strata;
- d) to obtain information on groundwater conditions and recover water samples for assessment of the interaction of groundwater, soil, rock and construction material.

The quality of a sample is influenced by the geological and hydrogeological conditions, the choice and execution of the drilling and/or the sampling method, handling, transport and storage of the samples.

This part of ISO 22475 does not cover soil sampling for the purposes of agricultural and environmental soil investigation.

NOTE 1 Soil sampling for these purposes is to be found in ISO 10381.

Water sampling for the purposes of quality control, quality characterisation, and identification of sources of pollution of water, including bottom deposits and sludges is not covered.

NOTE 2 Water sampling for these purposes is to be found in ISO 5667.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 791, *Drill rigs — Safety*

EN 996, *Piling equipment — Safety requirement*

EN 1997-1, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 1997-2, *Eurocode 7: Geotechnical design — Part 2: Design assisted by laboratory testing*

ISO 22476-3, *Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test*

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

ISO 14689-1, *Geotechnical investigation and testing — Identification and classification of rock — Part 1: Identification and description*

ISO 3551-1, *Rotary core diamond drilling equipment — System A — Part 1: Metric units*

ISO 3552-1, *Rotary core diamond drilling equipment — System B — Part 1: Metric units*

GUM: *Guide to the expression of uncertainty in measurement*, BIPM/IEC/IFCC/ISO/OIML/IUPAC/IUPAP

ISO 10097-1, *Wireline diamond core drilling equipment — System A — Part 1: Metric units*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1997-1, EN 1997-2, ISO 14688-1 and ISO 14689-1 and the following apply.

NOTE Additional terms and definitions can be found in the books and literature listed in the Bibliography.

3.1 Site investigation methods

3.1.1

trial pit

open excavation constructed to examine the ground conditions *in situ*, recover samples or carry out field testing

3.1.2

shaft

open vertical or steeply inclined excavation, typically more than 5 m deep, constructed to examine the ground conditions *in situ*, recover samples or carry out field testing

3.1.3

heading

adit

small tunnel driven horizontally or with a slight inclination from a shaft or into sloping ground to examine the ground conditions *in situ*, recover samples and carry out field testing

3.1.4

borehole

hole of any predetermined diameter and length formed in any geological formation or man-made material by drilling

NOTE Investigations carried out in such a hole can be to recover rock, soil or water samples from a specified depth or to carry out *in situ* tests and measurements.

3.1.5

drilling

process by which a borehole is produced in any geological formation by rotary, rotary percussive, percussive or thrust methods and in any predetermined direction in relation to the drill rig

3.1.6

small diameter drilling

drilling in the soil with a diameter greater than 30 mm but less than 80 mm

3.1.7**drilling method**

technique employed to create and stabilise the borehole

3.2 Drilling rigs and equipment**3.2.1****drilling tool**

device attached to, or forming an integral part of, the drill string, used as a cutting tool for penetrating the geological formation

3.2.2**drill bit**

device attached to, or forming an integral part of, the drill string, used as a cutting tool to penetrate the formation being drilled by the drilling method employed

3.2.3**drill rig**

device which carries out the drilling function

3.2.4**casing**

tubing temporarily or permanently inserted into a borehole

NOTE Casing is used, e.g. to stabilise the borehole, to prevent the loss of flushing medium to the surrounding formation, or to prevent cross flow between different groundwater horizons

3.2.5**flushing medium**

liquid or gaseous medium used to move cuttings and/or samples and to lubricate and cool the drilling tool from the borehole

3.2.6**flushing additive**

substance added to the flushing medium in order to affect or change its properties to improve its functioning

3.2.7**core lifter**

split, internally slotted or serrated conical spring steel ring, grooves, flexible spring fingers, hinged wedge-shaped fingers or hinged flaps mounted in a carrier ring, to retain the core sample whilst the corebarrel is being hoisted from the borehole

3.2.8**sample retainer**

cylindrical retainer fitted with a split-ring core lifter; it is mounted at the lower end of the sampler tube and used to retain the sample in the tube as the sampler is being lifted from the ground

3.3 Sampling**3.3.1****sampling by drilling
continuous sampling**

process by which samples are obtained by the drilling tools as the borehole proceeds

NOTE The drilling process is designed to obtain complete samples of the length of the borehole. The drilling tools are used as sampling tools.

3.3.2

sampling by using sampler

process by which samples are obtained by samplers from trial pits, headings, shafts or borehole bottom at selected positions

3.3.3

soil sampling by small diameter drilling

sampling by drilling in soils, using drilling tools with a diameter greater than 30 mm but less than 80 mm

3.3.4

sample

defined amount of rock, soil or groundwater recovered from recorded depth

3.3.5

core, core sample

cylindrical sample of soil or rock obtained from a borehole from recorded depth

3.3.6

block sample

sample of soil or rock cut out by special techniques

3.3.7

cuttings

particles of geological formations formed in the borehole by the cutting action of the drilling tool

3.3.8

suspended matter

abraded ground material in the flushing medium generated by drilling, in which the individual particle size cannot be recognised with the naked eye

3.3.9

core run

length of the core drilling between the start and the finish for the removal of the sample

3.3.10

core loss

difference between a core run and the length of the core recovered

3.3.11

area ratio

C_a

ratio of the area of soil displaced by the sampler tube in proportion to the area of the sample

$$C_a = \frac{D_2^2 - D_1^2}{D_1^2} \cdot 100$$

See Figure 1.

NOTE 1 The area ratio is expressed in per cent.

NOTE 2 One of the factors that determines the mechanical disturbance of the soil.

3.3.12

inside clearance ratio

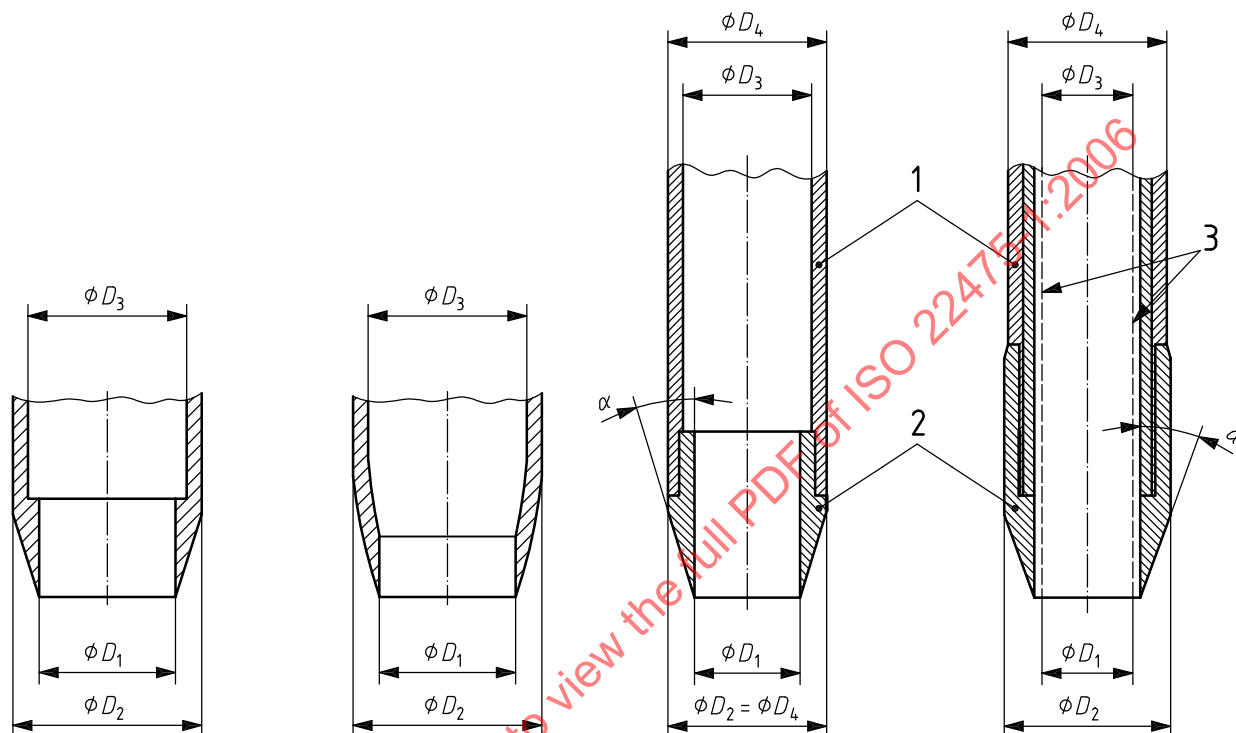
C_i

$$C_i = \frac{D_3 - D_1}{D_1} \cdot 100$$

See Figure 1.

NOTE 1 The inside clearance ratio is expressed in percent.

NOTE 2 One of the factors that determines the mechanical disturbance of the sample caused by the friction on the inside wall of sample tube or of the liner.



Key

D_1 inside diameter of the cutting shoe
 D_2 greatest outside diameter of the cutting shoe
 D_3 inside diameter of the sample tube or liner
 D_4 outside diameter of the sample tube

α taper angle
1 sample tube
2 cutting shoe
3 liner (optional)

Figure 1 — Definitions of the diameters D_1 , D_2 , D_3 and D_4

3.3.13 outside clearance ratio

C_o

$$C_o = \frac{D_2 - D_4}{D_4} \cdot 100$$

See Figure 1.

NOTE The outside clearance ratio is expressed in percent.

3.3.14 Fracture state terms

3.3.14.1

total core recovery in rock

TCR

total length of core sample recovered (solid and non-intact), expressed as a percentage of the length of the core run

See Figure 2.

3.3.14.2

rock quality designation

RQD

sum length of all core pieces with at least one full diameter that are 100 mm or longer between natural fractures, measured along the centre line of the core, expressed as a percentage of the length of the core run

See Figure 2.

3.3.14.3

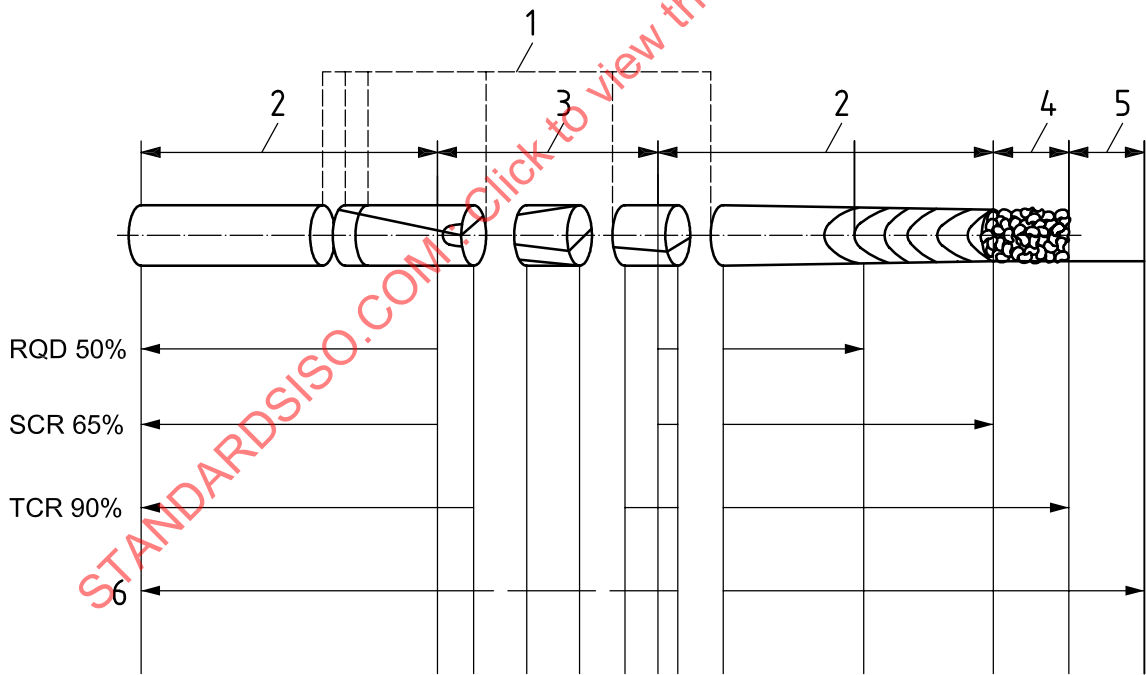
solid core recovery

SCR

length of core recovered as solid cylinders, expressed as a percentage of the length of the core run

See Figure 2.

NOTE A solid core has a full diameter, uninterrupted by natural discontinuities, but not necessarily a full circumference, and is commonly measured along the core axis or other scan line.



NOTE All features shown are natural discontinuities unless stated otherwise.

Key

- 1 drilling-induced fractures
- 2 at least one full diameter
- 3 no single full diameter
- 4 non-intact
- 5 no recovery
- 6 core run

Description of fracture state of rock cores:

- RQD rock quality designation
- SCR solid core recovery
- TCR total core recovery

Figure 2 — Application of fracture state terms for rock cores

3.3.15**sample recovery ratio in soil****TC**

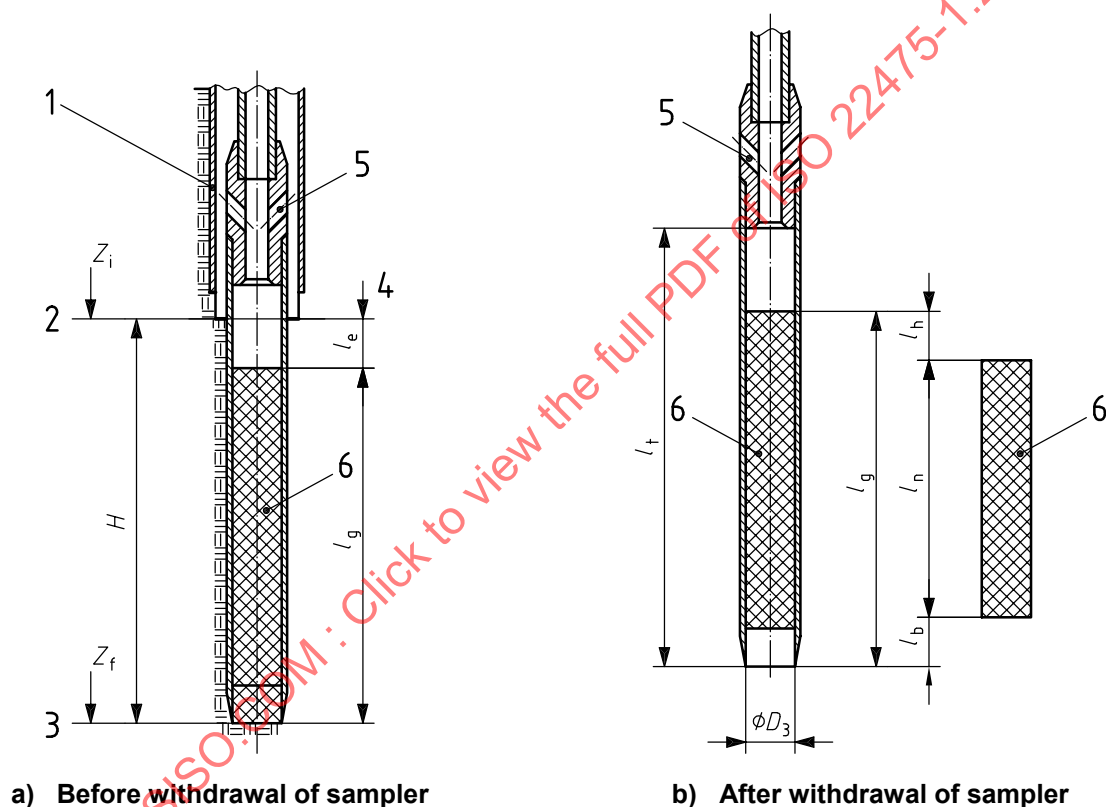
ratio of the length of the sample, l_g , to the length of the sample run, H

See Figure 3.

3.3.16**net sample recovery ratio****IC**

ratio of the net length of the sample, l_n , to the length of the sample run, H

See Figure 3

**Key**

- | | |
|---|--|
| 1 casing | l_b length of the lower part of the sample, which was remoulded or lost |
| 2 beginning of coring | l_e difference between the sample run and the actual length of the sample |
| 3 end of coring | l_g total length of the sample after withdrawal of the sampler, measured from the top of the sample to the cutter edge, including the remoulded or lost parts at both ends of the sample |
| 4 bottom of predrilled borehole | l_h length of the remoulded or polluted upper part of the sample |
| 5 vent-hole | l_n net length of the sample, before its conditioning |
| 6 sample | l_t effective (useful) length of the sampling tube |
| D_3 inside diameter of the sample tube or liner | |
| H length of the sample run | |
| Z_f depth, under the natural ground level, of the lower end of the sampler after sampling and before withdrawing the sampler | |
| Z_i depth, under the natural ground level, of the borehole bottom before sampling, and before the beginning of the following core run | |

Figure 3 — Lengths of core run and sample

3.3.17

thin-walled sampler

soil sampler with a low area ratio and a low taper angle and thin edge

3.3.18

thick-walled sampler

soil sampler that has an area ratio, taper angle and/or edge larger than that of thin-walled sampler

3.4 Groundwater measurements

3.4.1

piezometric head

sum of pressure head and elevation

3.4.2

groundwater surface

upper boundary surface of the groundwater

3.4.3

aquifer

body of permeable rock or soil mass suitable for containing and transmitting groundwater

3.4.4

aquitard

confining layer that retards, but does not prevent, the flow of water to or from an adjacent aquifer

3.4.5

aquiclude

body of soil or rock with extremely low transmissivity, which effectively prevents the flow of water through the ground

3.4.6

confined aquifer

aquifer which is bounded above and below by aquicludes

3.4.7

unconfined aquifer

aquifer in which the groundwater surface forms the upper boundary

3.4.8

pore pressure

pressure of the fluid that fills the voids of a soil or rock mass

3.4.9

permeability

capacity of soil or rock for transmitting water

3.4.10

filter

water permeable section of a piezometer retaining the soil

3.4.11

filter pack

water permeable backfilling around the filter and retaining the soil

3.4.12

open filter area

opening percentage of the filter surface

3.4.13

groundwater measurement

measurement of the groundwater surface or pore pressure

3.4.14

groundwater measuring station

place where groundwater measuring equipment is installed or groundwater measurement is carried out

3.4.15

groundwater fluctuations

variations of groundwater surface and/or pore pressure

3.4.16

groundwater pressure

the pressure in pores, voids and fissures in the ground at a certain point and time

3.4.17

piezometer

equipment for the determination of the groundwater or the piezometric head, including both open and closed systems

3.4.18

open system

measuring system in which the groundwater is in direct contact with the atmosphere and in which the groundwater surface at the filter level is measured

3.4.19

closed system

measuring system in which the groundwater is not in direct contact with the atmosphere and in which the pore pressure at the filter level is measured hydraulically, pneumatically or electrically

3.4.20

hydraulic system

closed system in which the water pressure in the filter tip is transmitted to a measuring unit on or close to the ground surface through a liquid-filled pressure tube

3.4.21

pneumatic system

closed system in which the water pressure acts on a membrane located behind the filter of the filter tip and which is balanced by gas pressure on the membrane's reverse side by a pressure tube from the ground surface

3.4.22

electrical system

closed system in which the water pressure effects the membrane located behind the filter of the filter tip and where the water pressure is converted into an electrical signal

3.4.23

pick-up system

electrical transducer system, in which the transducer can be added to and removed from the filter tip installed in the ground

3.4.24

filter tip

tip for piezometers provided with a filter to prevent soil particles from entering the equipment

3.4.25

high air entry filter

filter with small pores giving a high resistance to air entry when water saturated

3.4.26

time lag

time lapse between a change in pore pressure in the ground and its total recording by the measuring system

4 Drilling rigs and ancillary equipment

4.1 General

The drilling and sampling equipment selected shall be of the appropriate size and type in order to produce the required quality.

If applicable, the drilling and sampling equipment shall be in accordance with ISO 3351-1, ISO 3352-1 and ISO 10097-1.

4.2 Requirements for the drilling rigs and equipment

Drilling rigs with appropriate stability, power and equipment such as drill rods, casing, corebarrels and bits shall be selected in order that the required sampling and borehole tests can be carried out to the required depth of the borehole and sampling categories.

NOTE Annex C gives a selection of equipment which is currently used.

4.3 Equipment scope

The drilling rig and equipment shall allow all drilling functions to be adjusted accurately. When specified, the following drilling parameters should be measured and recorded against depth:

- drill head rotational torque (Nm)
- drill head rotational speed (min^{-1});
- feed thrust and pulling force (kN);
- penetration rate (m/min);
- depth of hammering intervals (on/off);
- topographical depth (m);
- azimuth and inclination when inclined drilling (degree);
- drilled length when inclined drilling (m);
- flushing medium pressure at the output of the pump (kPa);
- flushing medium circulation rate (input) (l/min);
- flushing medium recovery rate (l/min).

5 General requirements prior to sampling and groundwater measurements

5.1 General

The type and extent of sample recovery and groundwater measurements shall be specified in advance according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing (see EN 1997-2).

5.2 Selection of techniques and methods

5.2.1 The techniques and methods for sampling and groundwater measurements shall be selected according to the purpose of the investigations in relation to the expected geological and hydrogeological conditions.

5.2.2 Sampling techniques, sample transportation and storage procedures shall be selected on the basis of the required

- sample quality class according to EN 1997-2,
- sample mass, and
- sample diameter,

depending on the type of laboratory tests to be carried out.

5.2.3 A specific sampling category shall be selected in order to achieve a required sample quality class according to EN 1997-2 (see 6.2).

5.2.4 Different disturbance of sample can be expected when using different sampling methods. The quality class of a sample taken with the same sampler can vary depending on, e.g. the soil type to be sampled, the presence of groundwater and the sampling operation. The following sample disturbance can be generated by the drilling and sampling methods:

- mechanical sample disturbance due to compression, shearing, flushing or vibration during drilling or excavation;
- sample disturbance due to release of *in situ* stresses and related rebound;
- changes in material and chemical constituents such as water content and gases.

5.2.5 The sample diameter for soils containing large particles should be chosen with respect to the size of the largest particles of the sampled material.

5.2.6 If investigation below the groundwater surface or to greater depths is necessary, stable or stabilized boreholes are required.

5.2.7 Trial pits, headings and shafts give the possibility to investigate the ground in a larger scale e.g. to get information on the composition, sequence, structure and orientation of strata and possible rock surface. Without groundwater lowering, the depth is often limited to shallow depth above the groundwater surface. Large samples can be taken in order to analyse boulder content, bearing capacity, compactibility and permeability. At the same time, the excavability could be assessed and photographic documentation made.

5.3 Requirements for ground investigation sites and points

5.3.1 Site investigation points on land shall be marked on the site before the investigation process commences. Their location and elevation shall be surveyed and entered in a site plan on completion of the investigation.

5.3.2 Investigation sites shall be checked with respect to relevant hazards, underground utilities and unexpected, unexploded ordnance and, if necessary, appropriate actions have to be taken. Investigation locations on contaminated ground have to be dealt with by special procedures.

5.3.3 Trial pits should be situated outside the planned foundation area as the excavation can loosen the ground. There should have a distance between the nearest excavation wall and the planned foundation edge of at least 0,5 m plus half the intended excavation depth below the foundation level.

5.3.4 Trial pits (with or without access), headings and shafts shall be constructed in accordance with appropriate national or international standards and national safety regulations. They shall be sufficiently large to permit inspection, sampling and testing to be carried out *in situ*. Where necessary, they shall be protected against the effects of disturbance and weathering.

5.3.5 If visual logging, photographic evidence of the soil strata, sampling and *in situ* tests are to be carried out, this has to be done immediately after excavation.

5.3.6 The environmental impact of drilling and sampling shall be considered. Special principles have to be applied in water supply areas.

5.4 Preliminary information needed before starting sampling and groundwater measurements

At least the following preliminary information shall be available at the site before the sampling and/or groundwater measurements can start (see e.g. Annex A):

- a) objective of the sampling and groundwater measurements;
- b) location of the planned boreholes or excavations or groundwater measurements;
- c) orientation, inclination and acceptable deviations in boreholes;
- d) surveying requirements, and expected geological and hydrogeological conditions;
- e) required accuracy and uncertainty of measurements in accordance with the *Guide to the expression of uncertainty in measurement*;
- f) frequency of measurements;
- g) environmental and safety risks associated with, e.g. flushing media or suspensions intended to be used as well as regulations for their use;
- h) possible risks, e.g. underground and overhead services, traffic, unexpected and unexploded ordnance, contamination;
- i) identification and planned depths of boreholes and/or excavations;
- j) sampling method and sampling category intended;
- k) requirements on numbering of boreholes, excavations or samples;
- l) sample handling, storage and transport intended;
- m) *in situ* tests intended;
- n) borehole or excavation completion method and site reinstatement (backfilling or grouting);
- o) environmental care;
- p) emergency arrangements;
- q) name of contact person;
- r) the planned flow of information.

5.5 Backfilling and site abandonment

5.5.1 When sampling is completed it is of the utmost importance that the site is restored and no hazards are left which would be of potential harm to the public, the environment or animals. The backfilling shall be carried out in accordance with national regulations, technical or authority requirements, and take into consideration the strata, contamination of the ground and its bearing capacity.

5.5.2 Every borehole and excavation shall be fenced or temporarily capped in a safe manner until the borehole and excavation is finally and permanently capped or backfilled.

5.5.3 Unless a borehole is required to be kept open for a specific purpose, it should be infilled, consolidated and capped in such a manner that there will be no subsequent depression at ground level due to the settlement to the infill material.

5.5.4 Boreholes shall normally be filled with materials of equal or less permeability than the surrounding ground, e.g. in order to prevent contamination and connections between aquifers. If mixed grout is used, it should be placed by means of a tremie lowered to the base of the borehole. The tremie shall be slowly raised as the grout is placed. If there is an influence on future projects, special technical requirements for backfilling shall be specified in advance, e.g. for tunnel projects. Voids shall not occur during the placement of the filling material in the borehole.

5.5.5 The site should be left in a safe, clean and tidy state.

5.6 Safety and special requirements

5.6.1 Regarding safety on the site and safety of the working practices, the respective national standards, specifications or statutory requirements for execution of boreholes, trial pits, heading and shafts shall be applied, as long as respective international standards are not available.

Drill rigs shall be in accordance with EN 791 and EN 996.

5.6.2 Regarding nuisance and environmental protection, for each particular situation, as long as respective international standards are not available, the national requirements and the local requirements shall be applied.

6 Soil sampling methods

6.1 General

6.1.1 Techniques for obtaining soil samples can generally be divided into the following groups:

- a) sampling by drilling (continuous sampling);
- b) sampling using samplers;
- c) block sampling.

6.1.2 Combinations of these sampling methods are possible and sometimes required due to the geological conditions and the purpose of the investigation.

6.2 Categories of soil sampling methods

6.2.1 There are three categories A, B and C of sampling methods. For given ground conditions, they are related to the best obtainable laboratory quality class of soil samples (defined in EN 1997-2) as shown in Table 1 and Table 2, column 9:

- category A sampling methods: samples of quality classes 1 to 5 can be obtained;
- category B sampling methods: samples of quality classes 3 to 5 can be obtained;
- category C sampling methods: only samples of quality class 5 can be obtained.

6.2.2 Samples of quality class 1 or 2 can only be obtained by using category A sampling methods. The intention is to obtain samples in which no or only slight disturbance of the soil structure has occurred during the sampling procedure or in handling of the samples. The water content and the void ratio of the soil correspond to that *in situ*. No change in constituents or in the chemical composition of the soil has occurred. Certain unforeseen circumstances, such as varying of geological strata, can lead to lower sample quality classes being obtained.

6.2.3 By using category B sampling methods, this will preclude achieving sampling quality class better than 3. The intention is to obtain samples containing all the constituents of the *in situ* soil in their original proportions and the soil has retained its natural water content. The general arrangement of the different soil layers or components can be identified. The structure of the soil has been disturbed. Certain unforeseen circumstances, such as varying of geological strata, can lead to lower sample quality classes being obtained.

6.2.4 By using category C sampling methods, this will preclude achieving sampling quality class better than 5. The soil's structure in the sample has been totally changed. The general arrangement of the different soil layers or components has been changed so that the *in situ* layers cannot be identified accurately. The water content of the sample may not represent the natural water content of the soil layer sampled.

Table 1 — Quality classes of soil samples for laboratory testing and sampling categories to be used

Quality classes of soil samples for laboratory testing	1	2	3	4	5
Sampling categories	A				
			B		
					C

6.3 Sampling by drilling (continuous sampling)

6.3.1 General

6.3.1.1 This sampling method allows

- the identification and description of the soil at the site penetrated by the borehole;
- the differentiation of distinct soil layers and changes of soil material;
- the sampling as well as the investigation and testing of samples of all strata and depths.

NOTE Continuous sampling, combined with a sampling method according to category A (see Table 2), normally gives the most valuable information on the ground conditions out of all the ground investigation methods by drilling. Sampling by drilling is therefore the preferred sampling method for heterogeneously-layered soils.

6.3.1.2 Drilling methods and equipment shall be selected as a function of the required sampling category (see Table 2 and Table 4), tests and/or groundwater measurements to be carried out in the borehole.

6.3.1.3 Boreholes shall be stabilised, usually by casing, as drilling proceeds to prevent collapse of the borehole and caving.

6.3.1.4 When drilling below groundwater surface, the diameters of borehole casings and tools and the water level in the casing pipe shall be selected as to preclude the inflow of soil into the pipe. To prevent the drilling and cleaning tools from creating hydraulic failure in the soil, they shall be selected with sufficient annular clearance and withdrawn slowly. An adequate water pressure shall be maintained in the borehole.

6.3.2 Sampling by rotary drilling

6.3.2.1 Sampling by rotary dry core drilling

6.3.2.1.1 In sampling by rotary dry core drilling, a tube system fitted with a bit at its lower end is rotated and fed into the soil by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool can be single tube with a preferred borehole diameter of 100 mm to 200 mm or a hollow stem auger with a preferred borehole diameter of 100 mm to 300 mm. No flushing medium is used.

6.3.2.1.2 This technique is used for clay, silt and fine sand. If a hollow stem auger is used as a sampling tool, it will also be suitable for medium and coarse sand as well as organic soils. Sampling by rotary dry core drilling is generally unsuitable for sampling coarse gravel, cobbles and boulders.

6.3.2.2 Sampling by rotary core drilling

6.3.2.2.1 In sampling by rotary core drilling, a tube system fitted with a bit at its lower end is rotated and fed into the soil by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool can be single tube, double tube or triple tube. The preferred borehole diameter is between 100 mm and 200 mm. Flushing medium is used.

6.3.2.2.2 The single-tube corebarrel consists of a core tube with a bit at its lower end and a corebarrel head that attaches to the drill rods at its upper end. A core lifter can be fitted between the bit and the core tube or directly within the bit. The flushing medium passes between the inside of the core tube and the recovered soil core, continuously washing the length of the recovered sample.

6.3.2.2.3 The double-tube corebarrel consists of two concentric tubes and a bearing arrangement in the corebarrel head which allows the inner tube to remain stationary whilst the outer tube is rotated by the drill string. A core lifter is generally fitted between the core bit and the inner tube. The flushing medium passes through the annulus between the inner and outer tubes thus protecting the recovered core sample from damage. The double-tube corebarrel can be fitted with an optional additional plastic lining tube within the inner tube. When such a liner is fitted, the standard core bit and core lifter shall be replaced by a core bit and core lifter with a reduced inner gauge. The fitting of such a plastic liner will assist in improving core recovery in certain soil types and contain and protect the sample during transport. The double-tube corebarrel can also be fitted with an extension to the inner tube that passes through and protrudes just ahead of the core bit for use in very soft soil types.

6.3.2.2.4 The triple-tube corebarrel is similar in construction to the double-tube design but is fitted with an additional third tube within the inner tube as standard. This third tube is generally a thin wall steel tube split in half longitudinally so that, when it is removed from the inner tube, the top half can be removed to view the core sample. In some cases, the split inner tube can be replaced by a plastic liner. The triple-tube corebarrel can also be fitted with an extension to the inner tube that passes through and protrudes just ahead of the core bit for use in very soft soil types.

6.3.2.2.5 Sampling by rotary core drilling is generally suitable for clay, clayey and cemented composite soils and boulders; it is unsuitable for all non-cohesive soils.

6.3.2.2.7 After recovery of the corebarrel to the surface, the recovered core shall be handled in such a way that it as far as possible maintains its natural state. Extraction shall be made horizontally with a suitable extruder and in the same direction as it entered the barrel.

6.3.2.3 Sampling by flight auger drilling

6.3.2.3.1 In sampling by flight auger drilling, an auger consisting of a spiral flight, wound round a solid centre stem and fitted with a cutter head, is drilled into the ground. Two sampling methods can be used:

- continuous sampling method;
- non-continuous sampling method.

Table 2 — Sampling by drilling in soils

Column	1	2	3	4	5	6
Line	Drilling method				Equipment	
	Soil cutting technique ^b	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm
1	Rotary drilling	No	Drilling tool	Rotary dry core drilling ^c	Single-tube corebarrel	100 to 200
					Hollow stem auger	100 to 300
2		Yes	Drilling tool	Rotary core drilling	Single-tube corebarrel	100 to 200
					Double-tube corebarrel ^a	
					Triple-tube corebarrel ^a	
3		Yes	Drilling tool	Rotary core drilling	Double/triple-tube corebarrel with extended inner tube	100 to 200
4	Hammer driving	No	Drilling tool	Auger drilling	Drill rods with shell or flight auger; hollow stem auger	100 to 2 000
5		Yes	Reverse flow of flushing medium	Reverse circulation drilling	Drill rods with hollow chisel	150 to 1 300
6		No	Drilling tool	Auger drilling with light equipment	Shell auger or spiral flight auger	40 to 80
7	Rotary hammer driving	No	Drilling tool	Percussive core drilling	Percussion clay cutter with cutting edge inside; also with sleeve (or hollow stem auger) ^b	80 to 200
8		No	Drilling tool	Percussive drilling	Percussive clay cutter with cutting edge outside ^b	150 to 300
9		No	Drilling tool	Small diameter hammer driving	Hammer driving linkage with tube sampler	30 to 80
10	Rotary hammer driving	Yes	Drilling tool	Rotary percussive drilling	Single- or double-tube corebarrel	100 to 200
11	Vibration drilling with an optional slow rotation	No (only for lowering casing)	Drilling tool	Resonance drilling	Thick wall sampler or single tube corebarrel with optional plastic lining tube	80 to 200
12	Percussion	No	Drilling tool	Cable percussion drilling	Cable with percussion shell auger	150 to 500
13		No	Drilling tool	Cable percussion drilling	Cable with valve auger	100 to 1 000
14	Pneumatic/continuous thrust	No	Drilling tool	Small diameter pneumatic/continuous thrust drilling	Pneumatic/continuous thrust linkage, with tube sampler	30 to 80
15	Grabbing	No	Drilling tool	Grab drilling	Cable with grab	400 to 1 500

^a Conventional or wireline corebarrel.

^b Using the hammer driving technique, the drilling tool will be driven by a special driving tool. Using the percussion technique, the drilling tool will be driven by its repetitive lifting and falling.

^c Rotary dry core drilling is commonly used if the observation of the groundwater surface is the most important aim of the ground investigation.

Table 2 (continued)

7	8	9	10	11	Column
Guideline for application and limitations ^d		Achievable sampling categories ^e	Achievable quality class ^e	Remarks	Line
Unsuitable for ^d	Preferred method for ^d				
coarse gravel, cobbles, boulders	clay, silt, fine sand, silt	B (A)	4 (2-3)	Good interior, outside dried out	1
	clay, silt, sand, organic soils	B (A)	3 (1-2)	—	
non-cohesive soils	clay, clayey and cemented composite soils, boulders	B (A)	4 (2-3)	—	2
		B (A)	3 (1-2)		
		A	1		
gravel, cobbles, boulders	clay, silt	A	2 (1)	—	3
boulders larger than $D_e/3$	all soils above water surface, all cohesive soils below water surface	B	4 (3)	—	4
—	all soils	C (B)	5 (4)	—	5
coarse gravel with a particle size larger than $D_e/3$, dense soils, cohesion-less soils beneath groundwater surface	clay to medium gravel above water surface; cohesive soils below water surface	C ^f	5	Only to be used for small depths	6
soils with a particle size larger than $D_e/3$ laminated soil, e.g. varve	clay, silt and soils with a particle size up to $D_e/3$	cohesive soil: A	2 (1)	Plotting of driving chart on the basis of number of impacts	7
		non-cohesive soil: B (A)	3 (2)		
soils with a particle size larger than $D_e/3$	gravel and soils with a particle size up to $D_e/3$	B	4		8
soils with a particle size larger than $D_e/2$	soils with a particle size up to $D_e/5$	C ^f	5	Only to be used for small depths	9
composite and pure sands with a particle size larger than 2,0 mm, gravel, firm and stiff clays	clay, silt, fine sand	cohesive soil: A	2 (1)	—	10
		non-cohesive soil: B	4 (3)		
—	—	cohesive soil: B	4	—	11
		non-cohesive soil: C	5		
gravel above water surface, silt, sand and gravel below water surface	clay and silt above water surface, clay below water surface	C (B)	4 (3)	—	12
recovery above water surface	gravel and sand in water	C (B)	5 (4)	Can also be used in cohesive soils if water is added	13
dense and coarse-grained soils	clay, silt, fine sand	C ^f	5	Only to be used for small depths	14
firm, cohesive soils, boulders of size larger than $D_e/2$	gravel, boulders of size less than $D_e/2$, cobbles	above water surface: B	4	—	15
		below water surface: C	5		

^d D_e is the internal diameter of the sampling tool.

^e The sampling categories and quality classes given in parentheses can only be achieved in particularly favourable ground conditions, which shall be explained in such cases.

^f Sampling category B is sometimes possible in light cohesive soils.

NOTE Straight flush drilling is not covered because the sample quality class that can be achieved is generally worse than class 5.

6.3.2.3.2 With the continuous sampling method, the flights act as a screw conveyor and continuously bring the cuttings to the surface. Additional sections of auger can be added until the required depth is reached. At the mouth of the borehole, the obtained samples are remoulded.

6.3.2.3.3 With the non-continuous sampling method, the flight auger is screwed into the soil with the penetration rate suitable for the auger rotational speed and the pitch of the flight auger. The sampling length into the soil shall not exceed the maximum length of the flight auger. During the screwing of the flight auger, the vertical displacement of the soil between the flights shall be minimised. After the screwing, the drilling tool shall be completely removed from the borehole without rotation of the auger and the samples shall be taken from the material adhering to the auger flights.

6.3.2.3.4 With the non-continuous sampling method, flight auger drilling shall be only used if the borehole is stable or if stabilized with an auxiliary casing.

6.3.2.3.5 Sampling by flight auger drilling is suitable for cohesive soils and soils above the groundwater surface.

6.3.2.4 Sampling by reverse circulation drilling

6.3.2.4.1 In sampling by reverse circulation drilling, the flushing fluid passes down the outside of the drill rods over the cutting face of the bit then, carrying the cuttings, passes through a central orifice in the bit and up through the drill rods to the surface.

6.3.2.4.2 The borehole diameter is usually between 150 mm and 1 300 mm.

6.3.2.4.3 This sampling technique is suitable for all soils.

6.3.2.5 Sampling by shell auger drilling

6.3.2.5.1 In sampling by shell auger drilling, a shell auger is used as the sampling tool. Single-edge shell augers shall be used for cohesive soils and double-edge shell augers for non-cohesive soils. Double-edge shell augers with an internal clack are sometimes used for non-cohesive soils. The sampling length into the soil shall not exceed the maximum length of the shell auger. During the penetration of the shell auger, the vertical displacement of the soil in the shell auger shall be minimised. After the screwing, the drilling tool shall be completely removed from the borehole and the sample shall be extracted from the auger.

6.3.2.5.2 Sampling by shell auger drilling shall be only used if the borehole is stable or with a casing.

6.3.3 Sampling by use of hammer driving methods

6.3.3.1 Sampling by percussive drilling

In sampling by percussive drilling, a clay cutter tube device with an internal cutting edge at the lower end is driven into the soil by hammer blows transmitted to it via appropriate drill rods. It is generally suitable for clay, silt and soils with a particle size up to $D_e/3$ ¹⁾ and with a borehole diameter up to 300 mm. The sample is retained within the clay cutter by a suitable retainer.

6.3.3.2 Sampling by rotary percussive drilling

In sampling by rotary percussive drilling, a clay cutter tube device with a cutting shoe fitted to the lower end is driven into the soil by hammer blows and the supporting drill rods slowly rotated. It is generally suitable for clays, silt and soils with a particle size up to $D_e/3$ and a borehole diameter up to 300 mm. The sample is retained within the clay cutter tube.

¹⁾ D_e is the internal diameter of the sampling tool.

6.3.4 Sampling by cable percussion drilling

6.3.4.1 In sampling by cable percussion drilling, appropriate percussive sampling, drilling and bailing tools are suspended on a cable, which is raised and free lowered by a winch so allowing the mass of the equipment to drive the tools into the soil. Boreholes up to 500 mm can be bored and sampled using this method.

6.3.4.2 Sampling by cable percussion drilling can be used in all soils by the selection of the appropriate equipment.

6.3.5 Sampling by hollow stem auger drilling

6.3.5.1 In sampling by hollow stem auger drilling, the hollow stem auger, which consists of a spiral flight wound round a hollow central tube and fitted with an appropriate cutting head, is drilled into the soil in a similar manner to the flight auger (see 6.3.2.3). Additional sections of hollow stem auger are added till the required depth is reached.

6.3.5.2 Once the required depth is reached, a sampling system or corebarrel can be lowered through the centre tube of the hollow stem auger to take samples from the bottom of the hole, without removing the hollow stem auger string.

6.3.6 Sampling by grab drilling

6.3.6.1 In sampling by grab drilling, the sampling tool is a cable with grab.

6.3.6.2 The borehole diameter should be between 400 mm and 1 500 mm.

6.3.6.3 This sampling technique is the preferred method for gravel, cobbles and boulders with a size less than $D_e/2$. It is unsuitable for firm, cohesive soils and boulders larger than $D_e/2$.

6.3.7 Soil sampling by small diameter drilling

6.3.7.1 Small diameter drilling refers to all drilling with a hole diameter between 30 mm and 80 mm. In principle, the same drilling methods and equipment described in Table 2 can be used.

6.3.7.2 Sampling by small diameter drilling is only suitable in sands and fine-grained soils.

When employing small diameter drilling methods, it should be noted that the samples recovered are sufficient in size and mass, suitable for the scheduled laboratory testing.

6.3.7.3 Generally the quality of a core sample obtained by small diameter drilling is lower than if larger diameter drilling with the same drilling method is used.

6.3.8 Sampling by resonance drilling

In sampling by resonance drilling, a tube fitted with a bit at its lower end is fed into the soil or soft rock by vibration of a frequency variable from 30 Hz to 150 Hz. The frequency is adjusted after each addition of extension rod in order to obtain a resonance.

When the penetration rate is too low, the sampler or corebarrel can be rotated (1 to 5 rotations per metre). The sampler or corebarrel can be equipped with a plastic lining tube.

6.4 Sampling using samplers

6.4.1 General

6.4.1.1 Sampling using samplers can be used in combination with many drilling methods. The drilling diameter shall be chosen so that the sampler can be lowered to the borehole bottom without hindrances.

6.4.1.2 Depending on the soil conditions, different samplers can be used (see Table 3). Usually sampling with samplers is used in combination with any drilling methods using drilling mud or a casing to support the borehole. The drilling method and technique shall be chosen in such a way that unacceptable disturbance of the soil samples is prevented.

6.4.1.3 The inside of the sampling tube or the liner shall be clean and smooth without any protruding edges or irregularities, which can cause disturbance of the sample.

6.4.1.4 Drilling of the casing with percussion is not allowed to the full depth in case of category A sampling. The percussion process shall be halted at least 0,25 m or 5 times the diameter of the borehole before reaching the sampling depth.

6.4.1.5 If a casing is used in sensitive clays, it shall not be brought closer than 2,5 times the outside diameter of the casing to the sampling depth to minimise disturbance. In other soils, the casing can be lowered to the borehole bottom. Samples shall be taken from the undisturbed soil below the casing in a pre-cased or slurry-supported borehole, slightly larger than the diameter of the sampler.

6.4.1.6 When drilling mud is used, its characteristics shall be chosen with respect to the drilling method, the soil and groundwater conditions to obtain a stable borehole.

6.4.1.7 Before taking undisturbed samples from borehole bottom, any loose or disturbed material shall be removed. In the case of cleaning the borehole bottom by circulating flushing medium, the rotary drill bit shall be advanced with utmost caution, and the fluid circulation reduced until the bit reaches the sampling depth. Remaining loose material shall be removed in a controlled manner.

Table 3 — Soil sampling using samplers

Column	1	2	3	4	5	6	7	8
Line	Type of sampler ^b	Preferred sample dimensions		Technique used	Applications and limitations		Sampling category for soils as in column 6 ^a	Achievable quality class ^a
		Diameter mm	Length mm		Unsuitable for	Recommended for use in		
1	thin-walled (OS-TW)	70 to 120	250 to 1 000	static or dynamic driving	gravel, loose sand below water surface, firm cohesive soils, soils including coarse particles	cohesive or organic soils of soft or stiff consistency (medium) dense sand below water surface cohesive or organic soils of stiff consistency	A B (A) A	1 3 (2) 2 (1)
2	thick-walled (OS-TKW)	>100	250 to 1 000	dynamic driving	gravel, sand below water surface, pasty and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of soft to stiff consistency, and including coarse particles	B (A)	3 (2)
3	thin-walled (PS-TW)	50 to 100	600 to 800	static driving	gravel, very loose and dense sands, semi-firm and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of pasty or stiff consistency, and sensitive soils sand above ground water	A B	1 3
4	thick-walled (PS-TKW)	50 to 100	600 to 1 000	static driving	gravel, sand below water surface, pasty and firm cohesive or organic soils, soils including coarse particles	cohesive or organic soils of soft to stiff consistency, and sensitive soils	B (A)	2 (1)
5	cylinder (LS)	250	350	static rotating	sand	clay; silt	A	1
6	cylinder (S-SPT)	35	450	dynamic driving	coarse gravel, blocks	sand, silt, clays	B	4
7	window	44 to 98	1 500 or 3 000	static or dynamic driving	sand, gravel	silt, clay	C	5

^a The sampling categories and achievable quality classes given in parentheses can only be achieved in particularly favourable soil conditions, which shall be explained in such cases.

^b OS-TW open-tube samplers, thin-walled
OS-TKW open-tube samplers, thick-walled
PS-TW piston samplers, thin-walled
PS-TKW piston samplers, thick-walled
LS large sampler
S-SPT SPT (standard penetration test) sampler

6.4.2 Sampling using open-tube or piston samplers

6.4.2.1 General

For recovering samples from boreholes in cohesive, sandy and organic soils, open-tube or piston samplers can be used. These samplers generally consist of a sampler tube with or without a piston and a sampler head with connection to the extension rods. The open-tube sampler (thin-walled and thick-walled) can be used in boreholes. The piston sampler can be pushed directly into soft to medium stiff soil.

6.4.2.2 General geometry

6.4.2.2.1 Tube inner diameters between 50 mm and 120 mm are common, but diameters up to 250 mm are used for special soil conditions. The lower end of the tube shall be shaped to form a cutting edge.

6.4.2.2.2 The sampling tube length should preferably be not greater than 20 times the sample diameter. An effective sampling length of 0,45 m to 1,00 m is considered sufficient for ordinary soil testing. Longer tubes can be used if friction reducing systems are applied.

6.4.2.3 Detailed geometry

6.4.2.3.1 The material of the sampling tube shall be rigid, resistant to corrosion and with a smooth surface. The thickness of the tube wall shall be chosen so that the tube resists distortion when pushed into the soil.

6.4.2.3.2 The thin-walled tube samplers used shall meet the following requirements, which apply by analogy to samplers with other internal diameters:

- a) the edge taper angle should not exceed 5 °;
- b) the area ratio, C_a (see 3.3.11), should be less than 15 %;
- c) taper angles between 5 ° and 15 ° and area ratios up to 25 % may only be used if it is demonstrated that the quality class is not affected;
- d) for tube samplers with C_a exceeding 15 %, the angle of the cutting edge shall decrease as the wall thickness increases;
- e) the tolerances on the cutting edge and the sample tube should be chosen to give a minimum inside clearance ratio, C_i (see 3.3.12), less than 0,5 %. When assessing the inside clearance, the worst case of manufacturing tolerances shall be applied.

6.4.2.4 Preparation of tubes

6.4.2.4.1 Prior to sampling, the sampler and its component parts should be carefully inspected, especially the cutting edge. Defective or damaged components should be replaced. In order to keep the sample as undisturbed as possible during extraction, transport and handling in the laboratory, samplers with rigid, low-friction liners are recommended.

6.4.2.4.2 The inside of the sampling tube or liner should be clean and smooth without any protruding edges or irregularities, which can cause disturbance of the sample. The tubes and liners shall have smooth walls to minimise friction in the soil. Tubes which are corroded on the inside, or have damaged cutting edge, shall not be used.

6.4.2.5 Field procedure

6.4.2.5.1 The sampler shall be pushed or driven into the soil (see column 4 of Table 3). If dynamic driving is used, the drop weight used shall impinge directly onto the sampler head, its mass being sufficient to effect the required penetration of the tube by a minimum number of blows from a small height.

6.4.2.5.2 Before sampling from the bottom of the borehole, any loose or disturbed material shall be removed. The sampler should be carefully lowered into a borehole as soon as practicable after the borehole bottom has been cleaned. The sampler tube shall be pushed down to at least 200 mm below any disturbed material at or below the base of the borehole. If a casing is used, samples shall be taken from the undisturbed soil below the casing.

6.4.2.5.3 The depth of the borehole and the position of the sampler shall be checked exactly when the sampler enters the borehole. The sampler shall not bear upon the soil at the bottom when the sampler reaches its full depth.

6.4.2.5.4 The sampler advance should be made in one continuous motion to the predetermined depth, and the length of advance should be measured. This length shall be assessed for each type of sampler. It is preferred to use not more than 90 % of the effective length. Advance in excess of the effective length is not allowed.

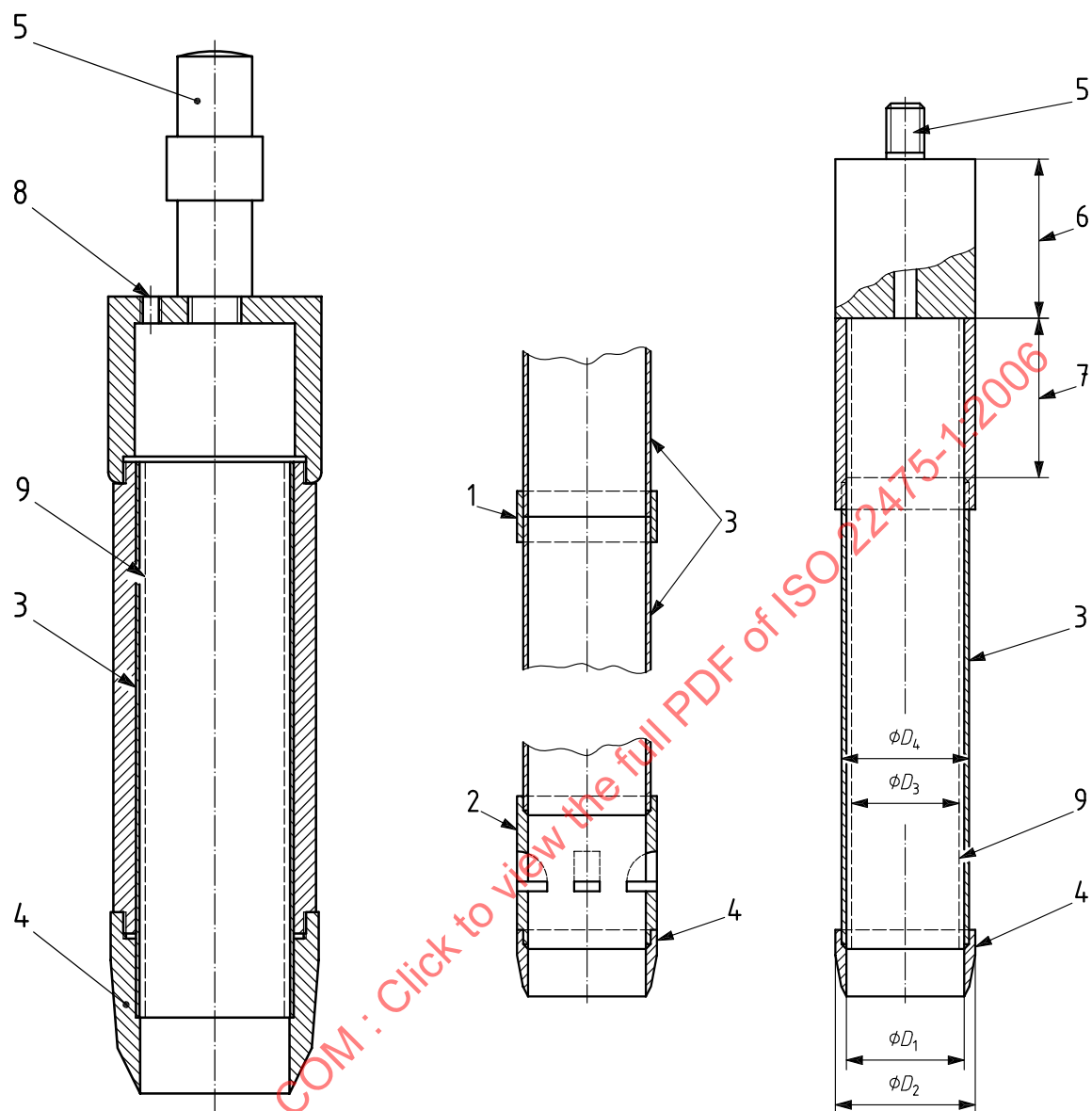
6.4.2.5.5 After driving, the sample shall be sheared off at the bottom edge of the sampler tube by rotating the rods or by slowly raising the sampler. The sampler should be carefully withdrawn without any vibrations or shocks in order to keep the sample undisturbed. It is often advisable to keep the sampler in position for a few minutes so that sufficient adhesion is developed between the sample and the sampling tube or liner.

6.4.2.5.6 After withdrawal the sampler should be disassembled and, if necessary, the samples carefully extracted without any bending or torsion of the sample. The sampling tube and the cutting edge should be checked for any deformations. Any such deformations should be noted in the sampling record. The occurrence of loosened soils or cuttings in the upper end shall also be checked and noted in the record.

6.4.2.5.7 The sampling process can disturb the soil underneath the sampler. This influence shall be considered.

6.4.2.6 Sampling using the open-tube sampler

6.4.2.6.1 In addition to the components mentioned in 6.4.2.3, open-tube samplers (OS) consist of a sampler tube with overdrive space and a sampler head with non-return valve tube. The sludge tube shall provide an overdrive space into which the softened material in the borehole can pass. The non-return valve ball and seat shall be adequately sized, so as to permit the free escape of the contained water and air when the sample enters the tube, and close tightly when the sampler is being withdrawn (see Figure 4). At its upper end, the sample tube is provided with a thread for connection to the sludge tube.



a) Schematic thick-walled open-tube sampler

b) Schematic thin-walled open-tube sampler

Key

D_1 inside diameter of the cutting shoe
 D_2 greatest outside diameter of the cutting shoe
 D_3 inside diameter of the sample tube or liner
 D_4 outside diameter of the sample tube

1 screw socket
 2 sample retainer

3 sample tube
 4 cutting shoe
 5 connection to drilling rods or sliding hammer
 6 non-return valve
 7 overdrive space
 8 valve
 9 liner (optional)

Figure 4 — Examples of open-tube samplers (OS) for recovering samples from boreholes

6.4.2.6.2 Sampling using the thin-walled open-tube sampler is usually regarded as either a category A or B sampling method, depending the soil conditions (see Table 3).

6.4.2.6.3 Thick-walled open-tube samplers are mostly suitable for stiff and dense soils and for soils containing coarse particles (see line 2 of Table 3). For soil types that are difficult to sample, sample-retaining or closure devices are necessary.

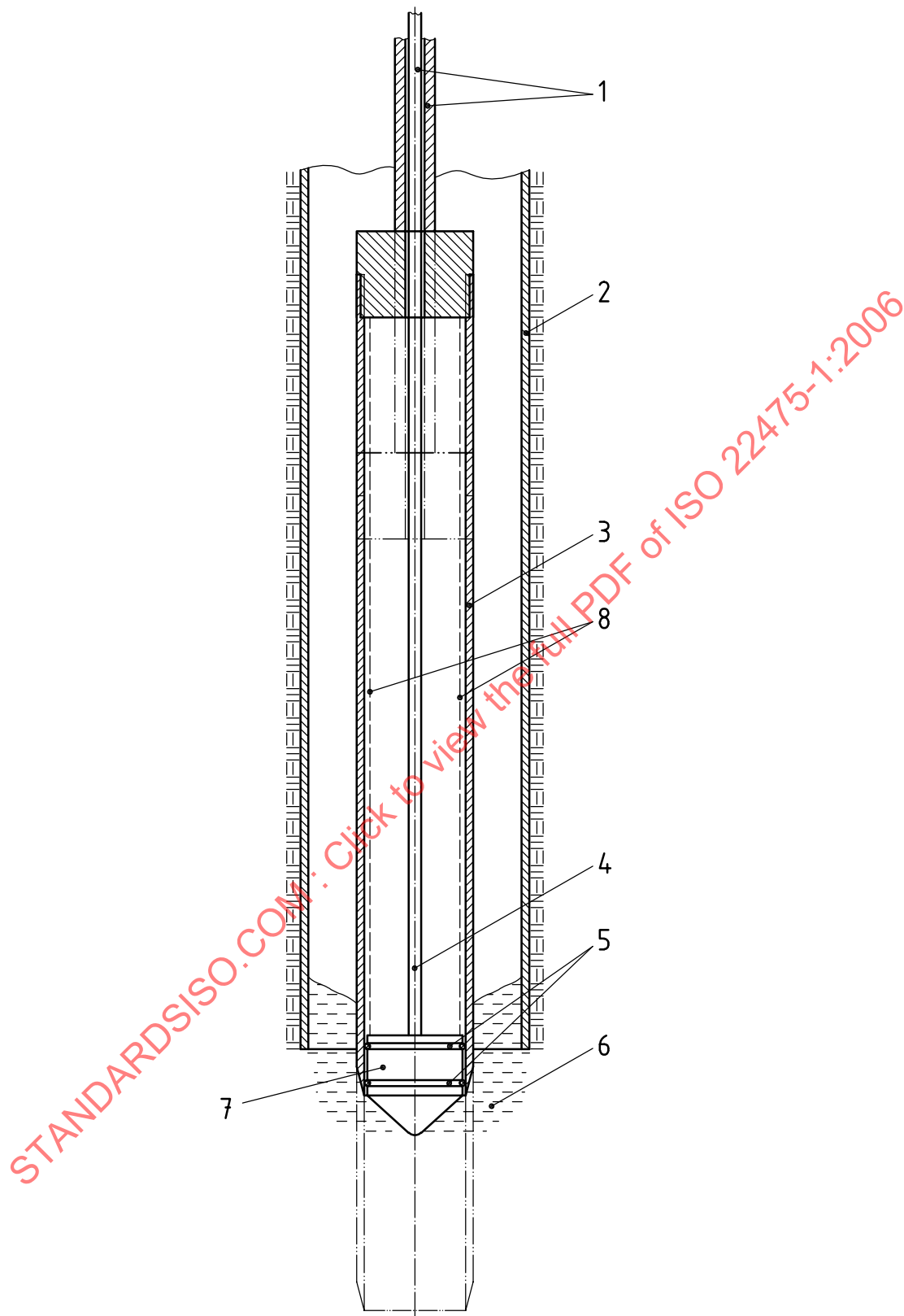
6.4.2.6.4 The thick-walled open-tube sampler is usually regarded as a category B sampling method.

6.4.2.7 Sampling using the piston sampler

6.4.2.7.1 The piston sampler can be used in low-strength fine soils such as silt and clay, including sensitive clays. It can be used either in boreholes or be pushed directly into the soil.

6.4.2.7.2 The piston sampler consists of a sample tube containing a close-fitting sliding piston, which is slightly coned at its lower face. The sample tube is fitted to the sampler head, whereas the piston is fixed to separate rods. This passes through a sliding joint in the sampler head and up inside the drill rods. Clamping devices, operated at ground level, enable the piston and sample tube to be locked together or the piston to be held stationary while the sample tube is driven down (see Figure 5). When shearing the sample, the piston shall be released or firmly fixed to the ground surface before further advance of the sampler is made. A movement of 1 % of the length of penetration in the piston rod due to tension is acceptable. The length of advance of the sampler shall not be more than the intended length of the sample to avoid compression of the sample.

6.4.2.7.3 Sampling using the piston sampler is usually regarded as a category A sampling method (see Table 3). In certain circumstances, the piston sampler can be used in sands by use of an appropriate core lifter. The sampling category in this case is usually regarded as a category B sampling method. For sampling in clay, a core lifter shall be avoided due to risk of disturbance. If used, it shall be noted in the sampling record.



Key

- | | |
|---|--------------------|
| 1 drill rod locking device above ground | 5 sealing ring |
| 2 casing | 6 disturbed soil |
| 3 sample tube | 7 piston |
| 4 vent | 8 liner (optional) |

Figure 5 — Schematic thin-walled stationary piston sampler (PS) for sampling from borehole bottom

6.4.3 Sampling using the standard penetration test sampler (SPT)

6.4.3.1 The standard penetration test sampler is mostly used in the standard penetration test according to ISO 22476-3. It takes samples 35 mm in diameter, 450 mm in length and has an area ratio, C_a , of about 100 %.

6.4.3.2 Sampling using the standard penetration test sampler is usually used as a category C sampling method (see Table 3). In certain homogenous fine-grained soils, it can also be used as a category B sampling method.

6.4.4 Sampling using the window sampler

6.4.4.1 A window sampler consists of a hollow tube with a longitudinal slot cut along part of its length (window) and fitted with a shoe having a sharp cutting edge at its lower end. Window samplers are used to take samples by the application of static thrust, by dynamic impact or by percussion. After driving and removal from the soil, the sample is removed from the window (see Figure C.23).

6.4.4.2 Sampling using the window sampler should only be done in the bottom of a borehole where the soil sample cannot be mixed with overlying soil layers, provided a shutter is not used.

6.4.4.3 Sampling using the window sampler is usually used as a category C sampling method (see Table 3).

6.5 Block sampling

6.5.1 Sampling from trial pits

6.5.1.1 In sampling from a trial pit, samplers with cutting procedure are used or block samples are recovered.

6.5.1.2 Block samples in cohesive soils can be cut by hand or by a handheld saw. The following precautions shall be taken:

- a) remoulded soil shall be carefully removed from the sampling spot;
- b) no extraneous water shall come into contact with the sample;
- c) the sample should be protected from sunshine, frost and winds;
- d) immediately after the sample has been cut, it shall be covered.

6.5.1.3 In soils with adequate cohesion, samples can be cut out by hand, care being taken to ensure that their dimensions are at least equal to those of the sampler tube shown in Figure C.31. Sampling from trial pits executed in such a way is usually used as category A or B sampling method.

6.5.1.4 In sampling from trial pits, samples are removed from the bottom, any slopes or walls of a trial pit using a sampling device as shown in Figure C.31. Sampler tubes according to Figure C.31 b) may only be used in soils with a maximum particle size up to 5 mm. The sampler tube shall be driven into the soil by hand or, where this is not possible, it shall be driven into the soil either by thrust or using a drop weight or sliding hammer and the sample recovered as shown in Figure C.31 c). In sampling dense sands, there is the possibility of losing sample material during extraction of the sampler tube. Such material shall be included in the sample to complete the sample.

6.5.2 Sampling using large samplers

6.5.2.1 The principles of sampling using a large sampler shall be as follows (see also C.15):

- a) Preparation of the borehole:

The preparation of a borehole for a large sampler requires the use of a solid auger with a larger diameter. The borehole can be supported by mud, or be cased down to the sampling level. Before lowering a large sampler into the borehole, any loose debris or disturbed material shall be removed from the bottom of the borehole using a flat bottom auger with a larger diameter.

b) Sampling procedure and sample recovery:

A large sampler can be operated by any drilling rod system that enables the relevant modes of operations for the sampler. The large sampler should be advanced at a slow rate into the soil, using a combination of static thrust, rotation and/or flushing. The sample shall be carefully separated from the surrounding soil before recovery and brought to the surface with minimum disturbance. Precautions should be taken to reduce the effect of suction when the sample is separated from the adjacent soil, and to avoid shocks and vibrations transferred to the rod system during upheaval of the sample.

6.5.2.2 Sampling using a large sampler is usually used as a category A sampling method.

Table 4 — Examples on sampling methods with respect to the sampling category in different soils

Soil type	Suitability depends on e.g.	Sampling method		
		Category A	Category B	Category C
Clay	Stiffness or strength sensitivity plasticity	PS-PU OS-T/W-PU ^b OS-T/W-PE ^a OS-TK/W-PE ^{a, b} CS-DT, CS-TT LS, S-TP, S-BB	OS-T/W-PE OS-TK/W-PE CS-ST HSAS AS ^a	AS
Silt	Stiffness or strength sensitivity groundwater surface	PS OS-T/W-PU ^b OS-TK/W-PE ^{a, b} LS, S-TP	CS-DT, CS-TT OS-TK/W-PE HSAS	AS CS-ST
Sand	sizes of the particles density groundwater surface	S-TP OS-T/W-PU ^b	OS-TK/W-PE ^b CS-DT, CS-TT HSAS	AS CS-ST
Gravel	size of the particles density groundwater surface	S-TP	OS-TK/W-PE ^{a, b} HSAS	AS CS-ST
Organic soil	state of decay	PS OS-T/W-PU ^b S-TP	CS-ST HSAS AS ^a	AS

^a Can be used only in favourable conditions.

^b See also 6.4.2.3 for the detailed geometry.

Key

OS-T/W-PU	Open-tube samplers, thin-walled/pushed	CS-ST	Rotary core drilling, single tube
OS-T/W-PE	Open-tube samplers, thin-walled/percussion	CS-DT, CS-TT	Rotary core drilling, double or triple tube
OS-TK/W-PE	Open-tube samplers, thick-walled/percussion	AS	Augering
PS	Piston samplers	HSAS	Hollow stem augering
PS-PU	Piston samplers, pushed	S-TP	Sampling from trial pit
LS	Large samplers	S-BB	Sampling from borehole bottom

7 Rock sampling methods

7.1 General

7.1.1 Techniques for obtaining rock samples can be divided in the following groups:

- a) sampling by drilling (see Table 5)
- b) block sampling;
- c) integral sampling.

Combinations of these sampling methods are possible and sometimes required due to the geological conditions.

7.1.2 Rock samples are of the following types:

- a) cores (complete and incomplete);
- b) cuttings and retained returns;
- c) block samples.

7.1.3 The quality of the rock recovery is achieved by applying the following three parameters (see also Figure 2):

- total core recovery, TCR (see 3.3.14.1);
- rock quality designation, RQD (see 3.3.14.2);
- solid core recovery, SCR (see 3.3.14.3);

7.1.4 After recovery of the corebarrels to the surface, the core recovery shall be assessed. In cases where core samples are extruded from the corebarrel and placed in a core box, the sample shall be logged. If liners are used, it shall be decided in advance where and when they shall be opened for examination of the core. Core losses shall be filled with a dummy. The drilling direction has to be marked on the core boxes or samples by arrows. The depths of the cores also have to be marked.

7.2 Categories for rock sampling methods

7.2.1 There are three categories of rock sampling methods, depending on the best obtainable quality of rock samples under given ground conditions:

- category A sampling methods;
- category B sampling methods;
- category C sampling methods.

7.2.2 By using category A sampling methods, it is intended to obtain samples in which no or only slight disturbance of the rock structure has occurred during the sampling procedure of the samples. The strength and deformation properties, water content, density, porosity and the permeability of the rock sample correspond to the *in situ* values. No change in constituents or in the chemical composition of the rock mass has occurred. Certain unforeseen circumstances, such as varying of geological conditions, can lead to lower sample quality being obtained.

7.2.3 By using category B sampling methods, it is intended to obtain samples that contain all the constituents of the *in situ* rock mass in their original proportions and the rock pieces have retained their

strength and deformation properties, water content, density and porosity. By using category B sampling, the general arrangement of discontinuities in the rock mass can be identified. The structure of the rock mass has been disturbed and thereby the strength and deformation properties, water content, density, porosity and permeability for the rock mass itself. Certain unforeseen circumstances, such as varying of geological conditions, can lead to lower sample quality being obtained.

7.2.4 By using category C sampling methods, the structure of the rock mass and its discontinuities have been totally changed. The rock material may have been crushed. Some changes in constituents or in the chemical composition of the rock material can occur. The rock type and its matrix, texture and fabric can be identified.

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Table 5 — Soil sampling using samplers

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Equipment		Drilling method less suitable for ^a	Samples		Achievable sampling category ^b	Remarks
	Flushing medium	Extraction of sample by	Designation	Sampling tool	Guideline for borehole diameter range ^a mm		Cores ^a	Cuttings		
1	No	Drilling tool attached to drill rods	Rotary dry core drilling	Single-tube corebarrel	70 ^c to 200	Rock of medium to high hardness	Soft, erodable, water-sensitive rock; short core runs	None	B (A)	To prevent overheating of the bit, core runs should not exceed 0,5 m.
2	Yes	Drilling tool attached to drill rods	Rotary core drilling	Single-tube corebarrel	70 ^c to 200	Rock of medium to high hardness	Jointed, soft rock	Sieve residue and suspended matter	B (A)	Flushing medium can cause disturbance of core material
3	Yes	Drilling tool attached to drill rods	Rotary core drilling	Double-tube corebarrel	70 ^c to 200	Erodable, water-sensitive rock	All types of rock	Sieve residue and suspended matter	A (B)	—
4	Yes	Drilling tool attached to drill rods	Rotary core drilling	Triple-tube corebarrel	70 to 200	—	All types of rock	Sieve residue and suspended matter	A	—
5	Yes	Drilling tool attached to drill rods, with wireline extractable inner barrel	Wireline core drilling	Wireline corebarrel, or triple-tube corebarrel	70 to 180	—	All types of rock	Sieve residue and suspended matter	A	—
6	Yes	Drilling tool attached to drill rods	Open hole drilling	Solid bit, roller bit, DTTH	50 to 350	—	None	Sieve residue and suspended matter	C	—

^a Guideline values considering the possible use of a casing.

^b The sampling categories given in parentheses can only be achieved in particularly favourable or unfavourable ground conditions, which shall be explained in such cases.

^c In some crystalline rocks, a minimum borehole diameter of 30 mm may be sufficient for the identification and description of rock.

DTTH Down-the-hole-hammer.

NOTE The sample diameter is smaller for the same borehole diameter when a triple-tube corebarrel is used, instead of a single-tube corebarrel.

7.3 Sampling by drilling

7.3.1 General

7.3.1.1 Drilling methods and equipment shall be selected as a function of the required sampling category (see Table 5) geological and hydrogeological conditions.

7.3.1.2 The flushing medium should be selected to meet the requirements of the investigation and if necessary appropriate additives can be added to the flushing medium. Hydrogeological requirements shall be considered when selecting flushing medium.

7.3.1.3 In soft rocks, only double-tube or triple-tube corebarrels shall be used.

7.3.1.4 The bit type shall be selected to efficiently cut the rock type (see Table C.16).

7.3.1.5 Cementing can be necessary to stabilise the borehole or to sample when a crushed rock zone shall be passed.

7.3.1.6 The orientation and inclination of boreholes shall be specified, including the maximum acceptable deviation, taking the expected investigation targets and ground conditions into account.

7.3.2 Sampling by rotary dry core drilling

7.3.2.1 In sampling by rotary dry core drilling, a tube system is fitted with a bit at its lower end and is rotated and fed into the rock mass by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool is a single tube with a borehole diameter of 70 mm to 200 mm. This sampling technique can be used to recover core samples in soft, erodable, water-sensitive rocks. It is less suitable for rocks of medium to high hardness.

7.3.2.2 To prevent overheating of the bit, core runs should not exceed 0,5 m.

7.3.2.4 Sampling by rotary dry core drilling is a category B sampling method (see Table 5).

7.3.3 Sampling by rotary core drilling

7.3.3.1 In sampling by rotary core drilling, a tube system fitted with a bit at its lower end is rotated and fed into the rock mass by the drill rig via the drill string. This action produces a core sample within the tube system. The sampling tool, i.e. the corebarrel, can be a single tube, double tube or triple tube with a borehole diameter of 70 mm to 200 mm. A flushing medium is normally used.

7.3.3.2 A **single-tube corebarrel** consists of a core tube fitted with a bit at its lower end and a corebarrel head that attaches to the drill rods at its upper end. A core lifter can be fitted between the bit and the core tube or directly within the bit. The flushing medium passes between the inside diameter of the core tube and the recovered rock core and continuously washes the length of the recovered sample.

7.3.3.3 A **double-tube corebarrel** consists of two concentric tubes and a bearing arrangement in the corebarrel head which allows the inner tube to remain stationary, whilst the outer and bit is rotated by the drill string. A core lifter is fitted between the bit and the inner tube. The flushing medium passes through the annulus between the inner and outer tubes, thus protecting the recovered sample from erosion.

7.3.3.4 A **triple-tube corebarrel** is similar in construction to the double-tube design but is fitted with an additional third tube within the inner tube.

7.3.3.5 Both double-tube and triple-tube corebarrels can be fitted with extensions to their inner tubes that pass through the bit, for use in very soft formations.

7.3.3.6 Samples can be obtained by this method as cores/cuttings. The single-tube corebarrel only allows core recovery in consolidated formations, whereas double-tube and triple-tube corebarrels can be used in all rock formations. All these types of corebarrels can be fitted with plastic liners within the inner tube to assist core recovery and protect the recovered core sample.

7.3.3.7 Sampling by rotary core drilling with either single- or double-tube corebarrel is generally a category B sampling method. The sampling method using a triple-tube corebarrel is generally category A (see Table 5).

7.3.4 Sampling by wireline core drilling

7.3.4.1 In sampling by wireline core drilling, a double-tube or triple-tube corebarrel with a bit fitted to the lower end is rotated and fed into the rock type to be drilled by the drill rig via the wireline drill rods. This action produces a core sample within the inner tube of the corebarrel. The borehole diameter range is from 70 mm to 180 mm. When the coring run is completed, the inner tube containing the core sample is withdrawn through the drill rods by means of a wireline cable and winch. The bit, outer tube and drill rods remain in the borehole during this process.

7.3.4.2 Sampling by wireline core drilling is a category A sampling method.

7.3.5 Sampling of cuttings by rotary open hole drilling

In sampling by rotary open hole drilling a rock roller, drag or button bit is rotated and fed into the rock type so generating cuttings. These cuttings are raised to the surface by the velocity of the flushing medium and collected or sampled at the borehole mouth. The borehole diameter usually ranges from 70 mm to 311 mm. No core samples are produced by this method, only disturbed cuttings, and therefore the sampling category is C.

7.4 Block sampling

7.4.1 In block sampling, samples are obtained from a trial pit, heading, shaft or from the bottom of the borehole by using special samplers with cutting procedure.

7.4.2 This sampling technique is usually a category A sampling method.

7.5 Integral sampling

7.5.1 In integral sampling, complete, orientated and undisturbed core samples can be taken in order to preserve the rock mass characteristics – untainted by the drilling effects – in the core samples, and to determine the primary conditions of the natural discontinuities and their orientation.

7.5.2 In this technique, a perforated central tube shall be placed in a predrilled hole with a minimum diameter of 25 mm. This predrilled hole shall be connected with the surrounding rock material by an appropriate binding material, e.g. cement, over its entire length. The binding material shall be inserted through the central tube without pressure. The sample shall be recovered by over-drilling with an appropriate larger minimum core diameter of 100 mm, after the required setting time of the binding material. Consequently, a sampling method of sampling category B shall be chosen.

NOTE For further information on integral sampling, see also Reference [23] in the Bibliography.

8 Groundwater sampling methods for geotechnical purposes

8.1 General

8.1.1 Groundwater sampling methods shall be selected according to need. The quality of a groundwater sample is characterized by the extent to which it contains original constituents, such as suspended matter,

dissolved gases and salts, or to which it has been contaminated during drilling. Groundwater can be sampled for the following purposes:

- a) to determine its aggressiveness to concrete;
- b) to determine its corrosive nature;
- c) to establish any risk to subsurface drainage systems and filters due to clogging and similar effects;
- d) to identify changes in groundwater quality resulting from construction work;
- e) to determine its suitability to be used as mixing water for construction material.

8.1.2 The number, location and the depth of sampling points shall be specified in advance on the basis of the engineering problems involved and the local geological and hydrological conditions (see EN 1997-2). If a group of aquifers is encountered, it can be necessary to collect separate samples from each aquifer.

8.1.3 If it is intended to take water samples for chemical analysis, only air and clean water can be used as flushing medium.

8.2 Equipment

8.2.1 For groundwater sampling, the following minimal equipment is required:

- a) clean sample bottles with airtight stopper;
- b) pump;
- c) groundwater sampler;
- d) thermometer;
- e) thermally-insulated or refrigerated box for the transport of sample bottles.

8.2.2 Specific equipment and measures shall be defined by the purpose of the water sampling and laboratory requirements.

8.2.3 Water sample containers should be made from an inert material against the parameters to be determined (e.g. polyethylene, polypropylene or glass), should be clean and should be completely filled.

8.3 Techniques of groundwater sampling

8.3.1 General

The samples shall be taken from groundwater which has freshly entered into the horizon to be investigated, care being taken to ensure that any stagnant or contaminated water is pumped out prior to sampling. To ensure correct sampling from boreholes, measures shall be taken to preclude the following:

- a) inflow of water from the surface or from other aquifers (due to inadequately sealed pipe runs through aquicludes);
- b) ingress of air by the action of drilling tools;
- c) residue from the flushing medium or sediments.

8.3.2 Extraction by pumping

Where pumps extract water, the tube shall have a sufficient internal diameter to allow sampling. For extraction, one end of the hose shall be attached to the outlet cock or pump discharge pipe, the other end being introduced into the sample bottle so as to reach its bottom. If samples are to be taken from water flowing at a high rate (e.g. during pumping tests or groundwater lowering work), the extraction point shall be located immediately adjacent to the well. The *in situ* parameters (conductivity, pH-value, temperature) should be constant before sampling.

8.3.3 Extraction by water sampler

The sampler shall be lowered slowly to the prescribed depth so that the water enters through the bottom or side inlet without turbulence. Any contact of the water sample with air should be avoided during filling and extraction.

8.3.4 Extraction by vacuum bottles

In cohesive soils and other low permeable soils, water can be sampled by vacuum bottles. For this purpose, a special filter tip shall be installed at the actual sampling level beneath the groundwater surface into which the vacuum bottle is lowered and the sample sucked out (see Annex D).

9 Groundwater measuring stations and piezometers

9.1 General

9.1.1 Groundwater measuring stations

9.1.1.1 In order to obtain data on the magnitude, variation and distribution of the groundwater heads or pore pressures in the ground, appropriate groundwater measuring stations shall be installed.

9.1.1.2 The type and arrangement of groundwater measurements shall be specified in accordance with EN 1997-2.

9.1.1.3 When drilling for piezometers, flushing additives should be avoided. When flushing additives are used, the effects on the filter and the ground shall be considered and, if necessary, special measures shall be taken.

9.1.2 Piezometers

9.1.2.1 Open or closed systems can be used to conduct groundwater measurements. The choice between open or closed systems should be made depending on the permeability of the ground, the rate of change in pore water pressure and the required precision and duration of the measurements.

NOTE 1 In open systems, a piezometer pipe is used to measure the groundwater head at the installation point of the filter in the ground. For hydrostatic pressure distribution, the groundwater head in unconfined aquifers corresponds to free groundwater surface and in confined aquifers to groundwater pressure. In closed systems, the pore water pressure in the ground is measured directly by a pressure transducer. The transducer is therefore an integral part of the measuring system.

NOTE 2 In confined aquifers, the measurements of the water level in the piezometer pipe can be considerably attenuated or subject to a time lag compared with the variations in groundwater pressure, depending on the permeability of the aquifer. When using open systems in confined aquifers, the measurements of the water level in the piezometer pipe may be subject to attenuation and time lags compared with variations in pore pressure. The groundwater flow required for filling and emptying the piezometer pipe depends on the ground permeability and the pipe's cross section surface.

9.1.2.2 The water level measured in the piezometer pipe of an open system corresponds to the mean head of the groundwater potential in the filter zone. In homogeneous aquifers with an approximately horizontal

groundwater flow, the filter zone can extend over the entire depth of the aquifer as, in this case, the head of the groundwater potential is virtually the same along the filter zone. Very different groundwater potentials can occur over the depth of stratified aquifers and in the proximity of groundwater flows with pronounced vertical flow sections. In this case, filtering should only be carried out over a relatively short vertical section of the aquifer for which the head of the groundwater potential is to be determined.

9.1.2.3 In both systems, a filter should be installed in the ground at the location at which the groundwater head or the pore pressure shall be measured. The filter shall prevent ingress of soil particles into the measuring system.

9.1.2.4 All components and equipment intended for installation in the ground shall be sufficiently resistant to mechanical loading and chemical attack by constituents in the groundwater. Any reactions between the materials used and the ground, in particular the formation of galvanic effects, shall be prevented.

NOTE Galvanic effects may cause modified pore pressure. This effect emanates from gases generated by electric currents from galvanic cell created by using different metals or alloys in the piezometer tip.

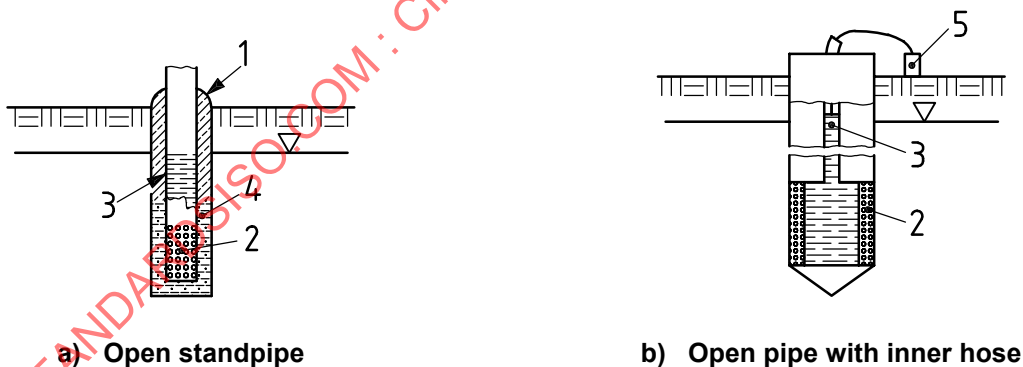
9.1.2.5 Groundwater measuring stations shall be positioned and secured in such a way that third parties are not at risk. Appropriate measures shall be taken to avoid any risk to the groundwater measuring station due to contamination, flooding, traffic or frost. Measures to protect the installation during the observation period shall be carried out as requested in, e.g. national regulations, see Annex E.

9.2 Piezometers

9.2.1 Open systems

9.2.1.1 Open systems can be divided in two groups as follows (see Figure 6):

- a) open standpipe;
- b) open pipe with inner hose.



Key

- 1 seal
- 2 filter
- 3 tube
- 4 filter pack
- 5 indicating instrument

Figure 6 — Examples of open systems

9.2.1.2 The piezometer in open systems shall consist of a filter and a piezometer pipe which extends up to or above the ground surface and permits equilibration with atmospheric pressure.

NOTE 1 In stable soils and rocks, groundwater observations may be made in open holes.

NOTE 2 The groundwater is able to oscillate freely in the piezometer pipe. Groundwater measurements in piezometer pipes can be conducted either by determining the water level, or by measuring the water pressure in the piezometer pipe, at a specified depth below the water surface. In open systems, the pressure is determined in relation to the actual atmospheric pressure at the ground surface.

9.2.1.3 Measurements shall be recorded either manually (e.g. by an electric contact gauge) or automatically (e.g. by a pressure transducer).

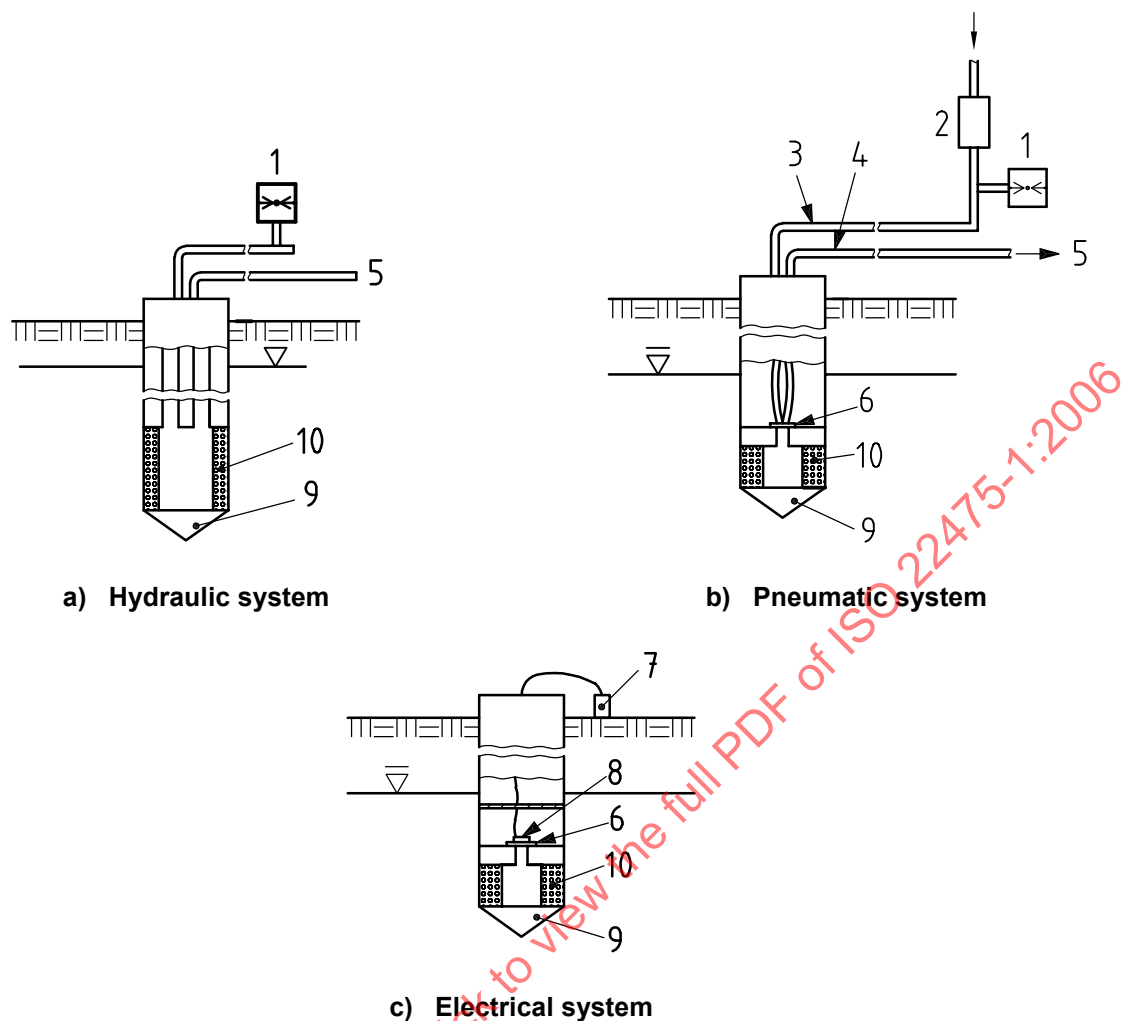
9.2.1.4 Depending on the design, open systems should be used for measuring the groundwater heads in medium to high permeable soils or rock. In general, they should not be used for determining groundwater heads in soils and rock with very low permeability or for measuring rapid changes in pore pressure in low permeable soils and rock.

9.2.2 Closed systems

9.2.2.1 General

9.2.2.1.1 The piezometer in closed systems shall consist of a robust casing which is installed in the ground with a filter at the lower end (filter tip) and a water-filled chamber, behind which the water pressure is transmitted to the measuring device. Filters with sufficiently high air entry values shall be used. The pressure measurements can be performed using measuring systems as illustrated by Figure 7:

- hydraulic measuring systems;
- pneumatic measuring systems;
- electrical measuring systems.



Key

- 1 pressure transducer
- 2 flow regulator
- 3 pressure supply tube
- 4 return tube to atmosphere
- 5 valve for flushing
- 6 membrane
- 7 measuring instrument
- 8 electrical transducer
- 9 filter tip
- 10 filter

Figure 7 — Examples of closed systems

9.2.2.1.2 The pore size and air entry value of the filter shall be selected on the basis of the *in situ* soil and the expected pore pressure so as to prevent ingress of air bubbles.

9.2.2.1.3 Pore pressures shall be expressed as the pressure in relation to the atmospheric pressure at the ground surface. When using an absolute pressure transducer, both the absolute pore pressure at the location of installation in the ground and the actual atmospheric pressure at the ground surface should be determined simultaneously.

9.2.2.1.4 Closed systems can be used to measure pore pressures and thus to determine the distribution of the groundwater potential in all types of soil. In particular, closed piezometers are required when determining pore pressures in soils and rock with very low permeability, measuring rapid changes in pore pressures and in artesian conditions. Electrical measuring systems should be used when performing measurements of rapid changes in pore pressure and for continuous data recording. Closed systems may only be used for long-term applications (i.e. over several years) when an adequate level of redundancy is available or if the system can be checked and repeatedly calibrated.

9.2.2.1.5 The required precision of the measurements for a certain project shall be decided in advance so that a proper equipment for the project can be chosen.

Taking into account all possible sources of error and the compensation for the atmospheric pressure, the precision of the measurements should normally not be less than 1 kPa in the range of 1 kPa to 100 kPa, and 2 kPa for values greater than 100 kPa.

9.2.2.2 Hydraulic systems

The pore pressure shall be transmitted by a fluid-filled pressure tube to a pressure transducer on the ground surface. The system shall allow the removal of entrapped gas bubbles. It shall be protected against frost.

Hydraulic systems shall not be used if the geodesic difference in levels between the pressure transducer at the ground surface and the groundwater surface or groundwater pressure surface exceeds about 7 m for water-filled systems and about 9 m for oil-filled systems, in order to avoid cavitation in the pressure tube.

9.2.2.3 Pneumatic systems

Pneumatic systems shall have a membrane placed behind the filter and two tubes (one supply tube and one return tube) connecting the back of the membrane with the measuring and control instruments on the ground surface. A flow meter and a flow controller shall ensure a constant flow of compressed air in the supply tube for all measurements. Dry gas shall be used to prevent condensation in the tubes. The readings may not be taken until the measured values remain constant with respect to the required purpose.

NOTE The membrane closes the connection between the supply tube and the return tube before the supply tube is pressurised. In order to perform the measurement, the air pressure in the supply tube is increased until the air pressure at the back of the membrane is equal to the pore pressure acting on front of the membrane and the membrane lifts, resulting in a connection to the return tube. The slight excess pressure required to open the membrane therefore also remains constant. The pressure is measured by a pressure transducer in the supply tube after the specified constant air flow has been set. Because of the open return tube, pneumatic systems always measure the pressure in relation to the actual atmospheric pressure at the ground surface. In order to prevent the membrane being overloaded, the air flow is increased gradually so that the membrane is lifted only slightly. As the membrane is closed before the supply tube is pressurised, loading is virtually independent of the pore pressure. Pneumatic systems are therefore largely unsusceptible to drift. It is not possible to check either the membrane or the filter directly during the operating period.

9.2.2.4 Electrical systems

Electrical systems measure absolute or relative pore pressures using an electrical transducer behind the filter. When measuring absolute pore pressure, the atmospheric pressure at the ground surface shall be measured simultaneously.

NOTE If the pressure transducer on the side not exposed to the pore pressure is fitted with a means of equalizing the pressure with the atmospheric pressure (e.g. a venting tube), the pressure in relation to the atmospheric pressure at the ground surface is measured. Electrical data recording systems are comparatively robust as the filter, membrane and electrical sensor are placed in a common sturdy housing and the data is transmitted to the ground surface through electric cables that are relatively unsusceptible to disturbance. Data can be transmitted and recorded either by a readout device or continuously by a logger. However, electrical systems are very sensitive to hydraulic overloading as the pore pressure acts directly on the membrane. The constant movement and tension also subject the membrane to a high level of loading, which affects its long-term performance. It is not possible to check the filter, the membrane or the electrical pressure transducer directly during the operating period unless a pick-up pressure transducer system is used.

9.3 Installation of piezometers

9.3.1 Execution

9.3.1.1 General

9.3.1.1.1 An installation plan shall be drawn up and documented prior to configuring a piezometer.

9.3.1.1.2 If the ground conditions are unknown, an investigation of the soil or rock properties shall be carried out in advance. In stratified grounds, the variation of groundwater potential with depth shall be considered when choosing the installation level and filter length.

9.3.1.1.3 The installation of piezometers shall not permanently affect the groundwater flow and quality and shall be made in such a way that the groundwater conditions can be measured correctly in accordance with the design. Any hydraulic connections opened up between different layers during installation shall be closed again by means of suitable seals immediately and prior to the measurements. A seal at the ground surface shall be made to prevent precipitation, condensation or seepage water entering the system directly. The installation of the piezometer shall be documented in a record (see 12.1.7).

9.3.1.1.4 Upon completion, the position and elevation shall be established (e.g. height of upper edge of the open measuring pipe above reference level for the groundwater measurement) and documented on a site plan.

9.3.1.1.5 Protective measures shall be carried out as requested.

9.3.1.2 Open systems

9.3.1.2.1 Open systems can be installed in boreholes or by ramming, pushing or water-jetting the piezometer pipe into the ground.

9.3.1.2.2 When installing piezometer pipes in boreholes, a separate borehole shall in general be drilled for each groundwater layer and for each piezometer pipe. If more than one piezometer should be installed in one borehole, it shall be proven that the equipment and the procedure allow for correct measurements in all layers. Attention shall be paid to the difficulties involved in sealing groundwater layers so as to prevent connections between them. The threaded joints of piezometer pipes passing through several groundwater layers shall be watertight. Installation of several piezometer pipes in the same borehole should be restricted to special cases. The diameters selected for the drilled holes shall depend on the intended configuration of the borehole and depth of drilling.

9.3.1.2.3 Open piezometers comprise a filter fitted with filter pipes to hold back soil material and solid-walled pipes placed on top of the filter pipes which extend up to the ground surface.

9.3.1.2.4 The piezometer pipe shall be constructed and dimensioned in such a manner as to fulfil its purpose safely during installation and measurement.

9.3.1.2.5 The types of filter and filter pipe shall be selected according to the ground structure and method of installation.

9.3.1.2.6 If a filter pack is used, the filter material shall enclose the filter pipe completely and extend at least two times the diameter of the borehole over the top of it to allow for possible settlement. The top of filter pack shall not be higher than the top of the layer of interest. The filter gravel or sand shall be placed continuously in small quantities to avoid bridging ($D_{\max}$ less than 15 % of free annular spacing). The filter pipes and solid-walled pipes shall be installed with centring devices to ensure that the annulus is completely filled. A seal shall be installed above the filter pack to avoid any pressure equalisation via the area outside the pipe.

9.3.1.2.7 In order to ensure the filter stability, the thickness and gradation of the filter pack shall be assessed as a function of the gradation of the surrounding ground and the purpose of the measurements. The construction of the screen shall be chosen as a function of the filter pack. Filter packs are generally required in

open systems to prevent soil particles from entering the filter and clogging it. They shall be filter-stable against the surrounding ground and the sealing.

9.3.1.2.8 The length and depth of the filter pipe depend on their intended purpose and the ground conditions.

9.3.1.2.9 When configuring piezometers in boreholes, all layers which separate groundwater head shall be sealed using swelling clay or by injecting a suspension. The swelling clay used (e.g. pellets, beads, granules) shall have good settling properties to ensure that the entire annulus is filled uniformly over the required height.

9.3.1.2.10 The sealing suspension should be placed by means of injection pipes, inserted in the annular space or an injection device inserted in the casing. The injection process shall proceed without interruption from the bottom of the borehole to its top.

9.3.1.2.11 The height of the seal and the seal material depend on the thickness and permeability of the layer to be sealed. It shall be not less than 1 m.

9.3.1.2.12 Penetration of surface water shall be prevented by a seal of swelling clay which should generally be at least 1 m high and installed at least 0,5 m below frost depth. Where shallow piezometers should not allow for this, the seal shall be installed between ground level and the top of the filter pack. Piezometers shall be protected against frost heave by installing frost-proof material between the seal and the ground surface.

9.3.1.2.13 A graphical presentation of the installation with the corresponding soil and rock strata should be prepared for all groundwater measuring stations (see 12.1.7).

9.3.1.2.14 The piezometer pipes shall have cover and be locked, if required.

9.3.1.3 Closed systems

9.3.1.3.1 Prior to and during the installation, the filters shall be saturated and the system shall be calibrated (see 10.1.3).

NOTE The preferred method for saturation is boiling or vacuum boiling.

9.3.1.3.2 Any contamination (e.g. by oily or greasy substances such as by touching) and insufficient saturation during storage and transportation, which effects the permeability of the filter shall be avoided.

Depending on the ground conditions and installation depths, there are the following methods to install closed systems:

- by pushing or driving down to the installation depth;
- by pushing in after pre-drilling;
- by placing in a borehole.

When selecting one of the above methods, consideration shall be given to ensure that there will be a good contact between the pore pressure and the transducer.

9.3.1.3.3 Piezometers with press-in tips fitted below the filter shall be used when installing a piezometer by pushing. Extension pipes are used to push the piezometer into the ground. The diameter of the pipes over the lowest metre shall be equal to or larger than that of the press-in tip to prevent leakage to the filter.

9.3.1.3.4 If it is intended to reuse the pushed piezometer (e.g. after short-term measuring operations), the pipes are left in the ground until the entire piezometer is subsequently retracted. The extension pipes should otherwise be retracted after the piezometer has been installed to avoid the ground above it being affected, particularly in the case of ground susceptible to settlement (e.g. embankments). A section of pipe with a length of at least around 1 m should be left in the ground above the press-in tip and filter, to act as a seal. When

retracting the extension pipes, the resultant cavity shall be sealed by filling it up to the ground surface with a suitable slurry with a permeability lower than that of the original soil.

9.3.1.3.5 In low-permeable soils, pushing can generate considerable local excess pore pressure. There is thus a risk that the transducers used in electrical systems, in which the pore pressure acts directly on the membrane, can be damaged (e.g. zero shift due to irreversible stretching of the membrane). Overloading should be checked by measurements or other means. Excess pore pressure during pushing can be reduced by lowering the rate of pushing. Overloading of the membrane can also be avoided by using a pick-up transducer during insertion in order to control pressure.

9.3.1.3.6 Piezometers installed in holes drilled down to below the measuring level shall be installed in a saturated filter pack. A seal shall be placed above the filter pack. In artesian groundwater conditions, drilling with sufficiently high water pressure in the casing is necessary. The piezometer and seal can then be installed in the casing after displacement of the groundwater. Where the groundwater inflow is low owing to a low permeability of the layer with confined groundwater conditions, the piezometers should preferably be installed by pushing. (Figure 8).

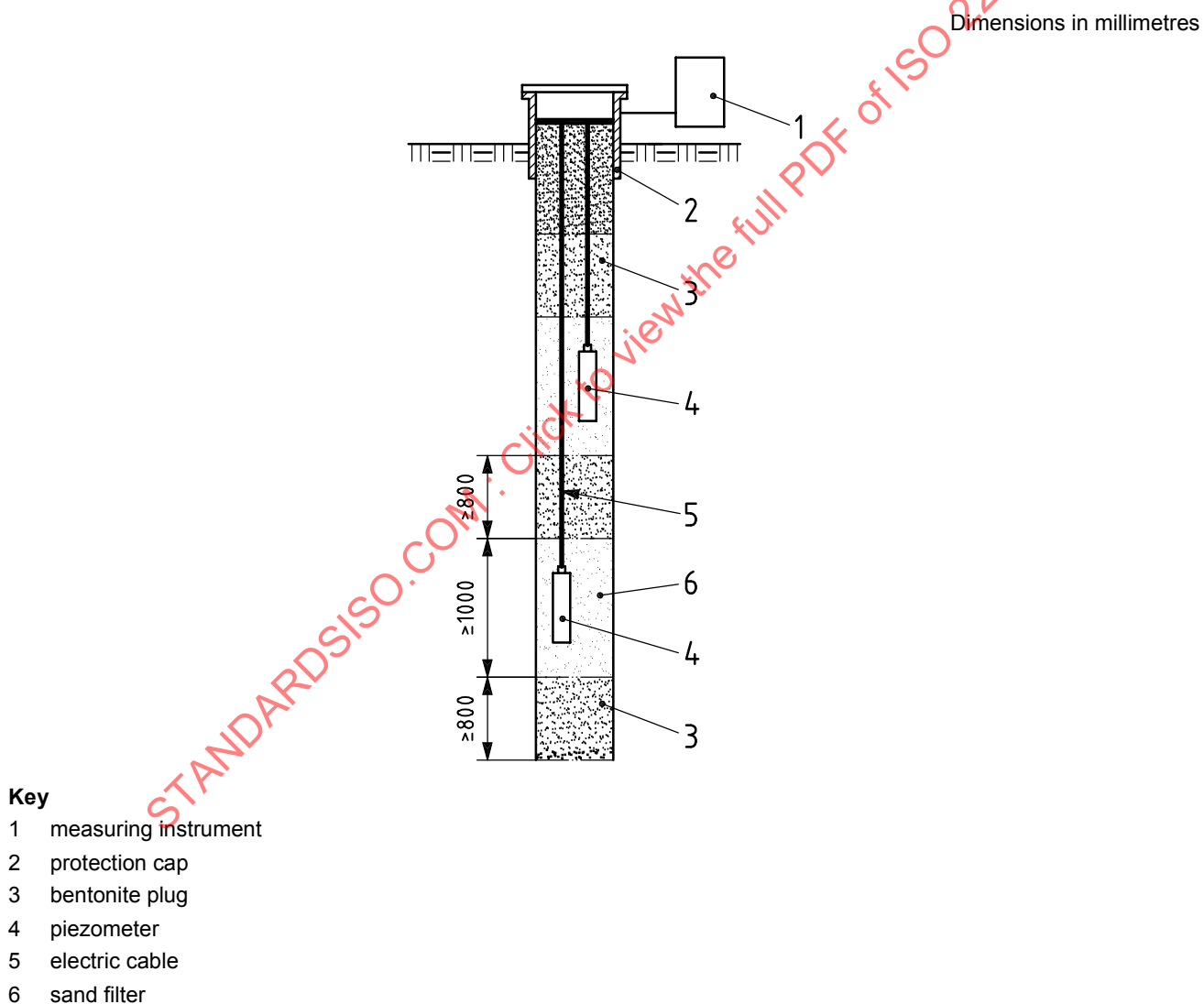


Figure 8 — Closed system with filter pack and sealing in a borehole

9.3.1.3.7 Incorrect measurements obtained by closed groundwater measuring systems with pneumatic transducers can be caused by droplets of condensation in the tubing system. The droplets can be removed by flushing the tubing with dry gas. Furthermore, there is a risk of overloading the measuring membrane, on which the air exerts a back-pressure, if the pressure in the supply tube is increased too rapidly. In low-permeable soils in particular, excess pore pressure corresponding to the air pressure is initially generated at the front of the membrane. The membrane can be over-stretched when the excess pore pressure decreases, resulting in distortion of the values measured.

9.3.2 Checking installation

9.3.2.1 General

Function controls shall be performed during installation if possible and immediately after installation to ensure the proper function of the groundwater measuring system. All groundwater measuring stations shall be marked indelibly. A record of installation shall be prepared for each piezometer (see 12.1.7).

9.3.2.2 Open systems

The filling shall be checked by control soundings. The function of open piezometers shall be tested prior to commissioning. After reading the stable water level, the water level in open piezometer pipe shall be raised or lowered and the fall/rise rate shall be measured and recorded. Flushing until water runs clear at the measuring station should also be performed.

9.3.2.3 Closed systems

9.3.2.3.1 In case of closed groundwater measuring equipment, no direct function control by means of the read-out device shall be made after reading.

9.3.2.3.2 In pneumatic systems, the air pressure shall be applied to the supply tube after installation and the stabilisation process monitored until a constant pressure is obtained at the specified flow. The process should be repeated after releasing the air pressure in the supply tube for control purposes. The pressure should be plotted against time to check if the piezometer is functioning.

9.3.2.3.3 The hydraulic system and belonging read-out device shall be insulated against frost and thermal variations.

9.3.2.3.4 The hydraulic systems shall be flushed for gas bubbles before being connected.

9.3.2.3.5 All pipes, tubes and cables in closed systems shall be protected from mechanical damages between the measuring point and the read-out device, e.g. in excavated and refilled trenches.

9.3.2.3.6 After connecting the read-out device, the response shall be observed and recorded.

9.4 Maintenance

9.4.1 To ensure the correct function of piezometers, maintenance controls shall be performed regularly during lifetime depending on the purpose and when clogging of the filter is suspected.

9.4.2 Functioning checks for open systems shall be performed according to 9.3.2.2 and for closed systems according to 9.3.2.3. The results shall be compared to the earlier checks.

9.4.3 If the results of the functioning checks of the open piezometer differ considerably from the earlier ones, the following measures shall be taken:

- a) total inside length of the piezometer shall be measured in order to determine the amount of sludge which shall be removed, if possible;

- b) the revitalisation of the piezometer can usually be done by flushing the piezometer pipe with clean water or air, using for instance a rigid hose pushed to the bottom of the pipe; flushing shall be continued until the up-coming water is clear;
- c) after revitalisation of the piezometer, an additional functioning check shall be carried out and the results shall be compared with earlier checks.

9.4.4 If revitalisation fails, a new installation shall be considered.

9.5 Decommissioning

The piezometers shall be de-installed when required and the borehole shall be back-filled according to 5.5.

10 Groundwater measurements

10.1 Calibration

10.1.1 General

10.1.1.1 All measuring systems used shall be calibrated prior to commissioning the piezometer. This applies to both new and reused equipment. All parts of the measuring system that affect the accuracy of the measurements shall be calibrated.

10.1.1.2 The calibration results shall be documented in a report which, in addition to a description of the calibration procedure, shall include all information required to evaluate the measurements (see 12.1.8.2).

10.1.2 Open systems

Open groundwater measuring systems only need be calibrated if a pressure transducer is used in the piezometer pipe. The water level in the piezometer pipe shall be determined by measuring the difference between the level of the measuring point (i.e. upper edge of the piezometer pipe) and that of the pressure transducer relevant to the measurements (e.g. membrane).

10.1.3 Closed systems

Transducers in closed systems groundwater measuring systems shall be calibrated prior to installation of the completed measuring system in the ground as, unlike open systems, subsequent checking of the calibration is usually not possible. Transducers shall be calibrated together with the readout device to be used in the field, step by step, until the specified maximum pressure is reached. The difference between the level of the membrane in the transducers of pneumatic or electrical measuring systems and the mid-point of the filter, which is usually located below them, shall be established to enable the values measured in the field to be corrected. Pneumatic measuring systems shall be calibrated complete with all equipment and tubing to be used in the field and with the gas flow required to make the membrane lift when the measurements are performed. Electrical systems shall also be calibrated complete with all equipment and tubing to be used in the field. When calibrating transducers that measure absolute pressure, the atmospheric pressure shall be measured simultaneously.

10.2 Performance of the measurements

10.2.1 General

10.2.1.1 Measurements shall be checked if an influence from installation of the measuring system is detected or if unexplainable time lags or groundwater fluctuations occur, compared to other measurements.

NOTE Effects of installation are, e.g. effects of flushing medium (change of water density), excess pore pressure, clogging, short cuts between aquifers.

10.2.1.2 The results of the measurements shall be documented in a report which shall enable the values measured to be related to a particular stratum and interpreted unambiguously (see 12.1.8).

10.2.2 Open systems

10.2.2.1 Groundwater measurements in open piezometers can be performed at separate specified times (e.g. manually by electric contact meter) or continuously (e.g. by pressure transducers, pipes and loggers). The atmospheric pressure shall also be measured when using pressure transducers measuring absolute pressure. For manual measurements, the head of the groundwater potential is determined by measuring the distance between the identified level of the measuring point at the head of the piezometer and the water level in the piezometer pipe. When measuring the pressure in the piezometer pipe, the head of the groundwater potential is determined taking into account the distance between the level of the measuring point and the measuring level of the pressure transducer, and the atmospheric pressure if necessary. Continuous automated measurements shall be checked at least every six months by measuring the water level in the piezometer pipe manually.

10.2.2.2 The time lag of the open groundwater measuring system shall be determined.

10.2.3 Closed systems

10.2.3.1 Measurements in closed piezometers with pneumatic transducers are carried out by increasing the gas pressure in the supply tube until the specified flow rate required to lift the membrane is reached. The pressure shall be controlled gradually to allow equalisation of the back-pressure and the pore pressure acting on the other side of the membrane and thus to avoid overloading the membrane. The values measured shall be corrected by the hydrostatic pressure difference calculated from the height difference between the level of the membrane and the mid-point of the filter on the basis of the calibration.

10.2.3.2 Closed piezometers with electrical transducers should be used in particular for continuous data recording at regular, short intervals, the values being recorded by a logger. For transducers without equalisation of atmospheric pressure, the atmospheric pressure at the ground surface shall also be recorded at the same measuring times. Where necessary, the values measured shall be corrected by the atmospheric pressure on the basis of the calibration and by the difference in hydrostatic pressure from the difference in level between the membrane and the mid-point of the filter in the same way as for pneumatic systems.

11 Handling, transport and storage of samples

11.1 General

11.1.1 Handling according to this part of ISO 22475 starts when the sample comes out of the sampling tool.

11.1.2 The relevant conditions of soil and rock samples that were present after the sample had come out of the sampling tool, shall be preserved.

11.1.3 National laws or safety regulations shall be considered when transporting samples known or suspected to contain hazardous material.

11.1.4 A separate traceability record shall accompany each shipment so that the possession of the sample is traceable from collection to shipment to laboratory disposition.

11.1.5 When transferring the possession of samples the persons(s) relinquishing and receiving the samples shall sign, date, record the time and check completely the traceability record.

11.1.6 Every soil and rock sample shall be protected at all times from direct sun light, heat, frost and rain.

11.2 Preservation materials and sample containers

The type of preservation materials and sample containers depend on the sampling categories (A, B, and C), and on the climate, transporting mode and distance. Preservation materials and sample containers include

- a) sealing wax, e.g. microcrystalline wax;
- b) metal discs, ca 2 mm thick and having a diameter slightly less than the inside diameter of the tube liner or ring and to be used together with wax or caps and tape ;
- c) waterproof duct tape;
- d) caps, either plastic, rubber or metal, to be placed over the end of thin-walled tubes together with tape or wax;
- e) O-ring (sealing and caps) used to seal the ends of samples within thin-walled tubes by mechanically expanding the O-ring against the tube wall;
- f) jars with a lid, e.g. 250 ml, 500 ml and 1 000 ml;
- g) plastic pails;
- h) glass jars;
- i) aluminium foil;
- j) plastic bags;
- k) packing material, to protect against vibration and shock;
- l) insulation against temperature changes, e.g. granule (lead), foam;
- m) shipping containers, either box or cylindrical type and of proper construction to protect against vibrations, shock and the elements to the degree required.

11.3 Handling of samples

11.3.1 Handling of soil and rock samples according to sampling categories A and B

11.3.1.1 Plastic bags shall be placed around the sample as tight as possible.

11.3.1.2 Lids of plastic pails and jars or glass jars shall be placed around the sample as tight as possible. Lids of plastic pails and jars or glass jars have to be airtight. Glass jars additionally need sealing rings for air tightness.

11.3.1.3 Sample ends within tubes shall be sealed with plastic expandable packers or by a soil filling and end caps in order to maintain the conditions for a specified period (see Figure 9).

NOTE For long-term sealing, microcrystalline wax up to 15 % beeswax, paraffin or resin can be used to avoid shrinkage cracks.

11.3.1.4 Cylindrical, cubic or other rock samples wrapped in plastic or aluminium foil can be further protected with three coats of wax.

11.3.2 Handling of water samples

The water sample containers shall generally be kept in the dark, filled and thermally-insulated or refrigerated, without any contact with materials that could affect the water quality. They should be transported to the laboratory daily.

11.4 Labelling of samples

11.4.1 All samples shall be immediately numbered, documented and labelled after sampling and sealed.

11.4.2 The label shall show the following information:

- a) identification of the project;
- b) identification of trial pit, borehole, etc.;
- c) date of sampling;
- d) identification of sample;
- e) sampling category;
- f) depth of the sample from reference level.

11.4.3 The samples shall be marked, so that there is no doubt about the upper and lower end of the sample. The label should indicate the soil and rock type, the weathering and possible discontinuities from visual identification, if possible.

11.5 Transport of samples

11.5.1 Transport of soil samples

11.5.1.1 Sampling category A

11.5.1.1.1 Soils sample obtained according to sampling category A shall be preserved in their liners or in containers. Samples in core boxes shall be transported horizontally.

11.5.1.1.2 Block and special samples without a tube shall be wrapped in suitable plastic film or/and aluminium foil, and coated with several layers of wax or sealed in several layers of cheese cloth and wax.

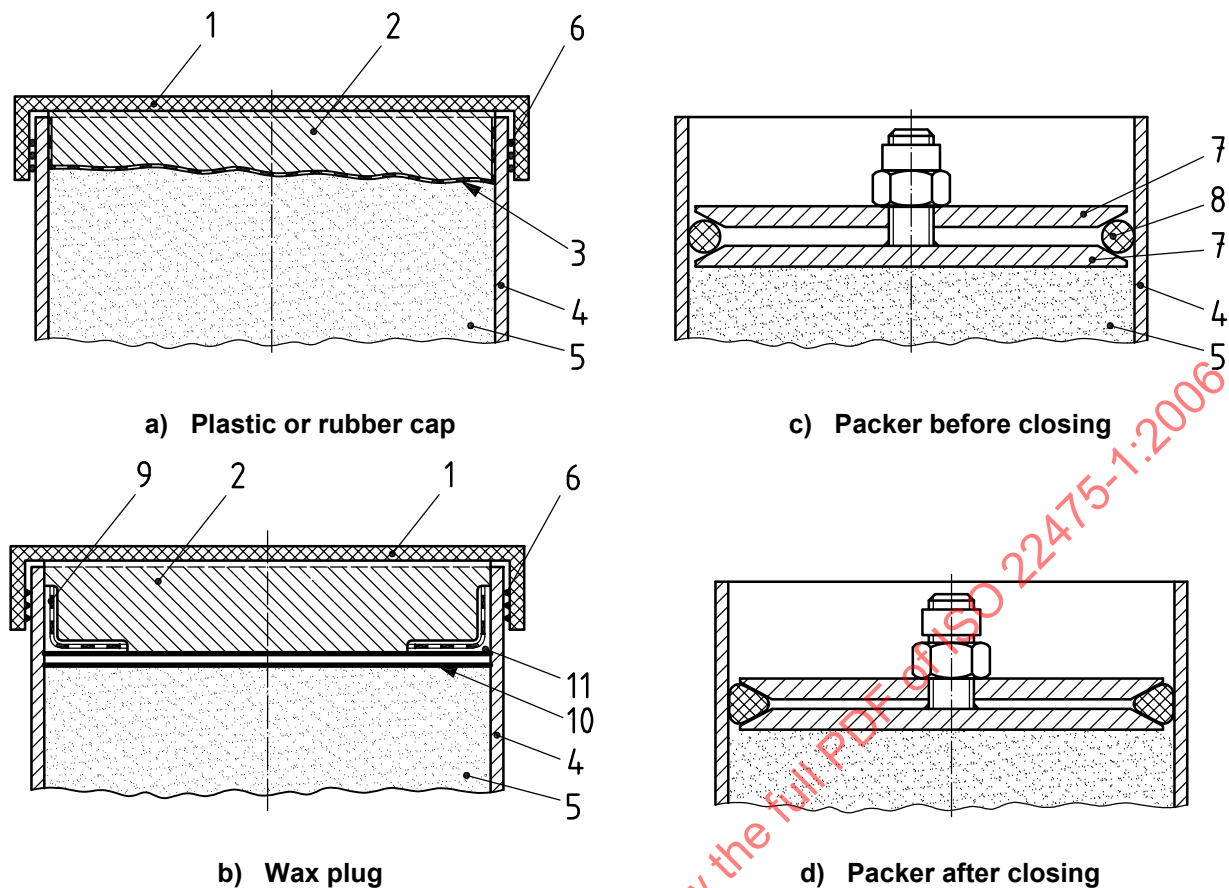
11.5.1.1.3 The samples shall be protected against vibration, shocks and extreme temperatures. Samples shall only be placed in solid boxes into which the samples fit snugly preventing bumping, rolling, dropping, etc.

11.5.1.1.4 For all other methods of transporting samples, the sealed samples shall be placed in suitable shipping containers that provide cushioning or/and insulation for the sample or container.

11.5.1.1.5 The cushioning material (sawdust, rubber, polystyrene, urethane foam, or material with similar resiliency) shall completely encase the samples in such a way that they are not disturbed during transport.

NOTE A satisfactory cushioning between samples and walls of the shipping container can have a minimum thickness of 25 mm. A minimum thickness of 50 mm can be provided on the container floor.

11.5.1.1.6 The shipping container can be made from wood, metal, plastic or styrene and shall meet the requirements for the correct transportation of the sample.



Key

- 1 plastic or rubber cap
- 2 soil to fill the space between end of tube and sample
- 3 plastic sheeting
- 4 sampler tube
- 5 sample
- 6 sealing lips
- 7 metal plate
- 8 rubber seal
- 9 adhesive tape
- 10 two layers of molten wax
- 11 wax plug

Figure 9 — Examples of sealing and securing samples

11.5.1.2 Sampling category B

11.5.1.2.1 Soil samples obtained according sampling category B shall be preserved and transported in sealed moisture-protected containers. All containers shall be of sufficient thickness and strength to ensure no breakage and moisture loss.

11.5.1.2.2 The following container types can be used:

- waterproof glass or plastic jars;
- thin-walled tubes, liners or rings;
- caps or lids.

11.5.1.2.3 Cylindrical and cube samples shall be wrapped in suitable plastic film and/or aluminium foil and coated with several layers of wax, or sealed in several layers of cheese cloth and wax.

11.5.1.2.4 These samples shall be transported in larger shipping containers, e.g. bags, card bowls or wooden boxes by available transportation.

11.5.1.3 Sampling category C

Samples obtained according to sampling category C can be transported in any type of container by way of available transportation. If the natural water content of the samples is to be determined, water-tight containers shall be used.

11.5.2 Transport of rock samples

11.5.2.1 General

A detailed log has to be completed on the drill site in cases where the rock sample is likely to deteriorate or otherwise change before being examined again.

11.5.2.2 Sampling category A

11.5.2.2.1 Rock samples obtained according to sampling category A have to be placed in solid containers individually. If samples were not obtained in tubes, they immediately have to be tight wrapped with film or foil completely. They have to be protected against vibration, shock, heat and coldness and temperature changes. Samples shall be horizontally transported and stored in suitable shipping containers made of wood, metal or other material, that provide cushioning and/or thermal insulation for each sample and each container. Rocks sensitive to changes in moisture content shall be sealed with wax or a similar material.

11.5.2.2.2 The cushioning material (sawdust, rubber, polystyrene, urethane foam, or material with similar resiliency) shall completely encase the samples in such a way that they are not disturbed during transport.

NOTE A satisfactory cushioning between samples and walls of the shipping container can have a minimum thickness of 25 mm. A minimum thickness of 50 mm can be provided on the container floor.

11.5.2.3 Sampling category B

Rock samples obtained according to sampling category B have to be placed in solid containers individually. If samples were not obtained in tubes, they shall immediately be completely wrapped with film or foil. They have to be protected against vibration, shock, heat and coldness and temperature changes. Samples shall be transported horizontally.

11.5.2.4 Sampling category C

Rock samples obtained according to sampling category C shall be placed and transported in structurally sound core boxes. They have to be placed regarding the *in situ* strata and have to be coated with film or foil. They shall be transported and stored horizontally.

11.5.3 Transport of water samples

Water samples shall be transported within 24 h to the laboratory after sampling. They shall be protected against heat, frost, light and damage.

11.6 Preparation of storage and shipping containers

Core boxes shall be constructed rigidly enough to prevent flexing of the core when the box is picked up by its ends. The lid should have sturdy hinges and a strong hasp or screw closure. Nails shall not be driven in the lid. A core stop block shall be placed at the ends of each core run. Unnecessary breaking of the core to fit the

core box is not allowed. Any necessary breaks shall be recorded on the log. Depth of the top and bottom of the core length in the box shall be marked with a waterproof manner near the core ends and corresponding box corners. Intermediate depth that are accurately known shall also be similarly marked. The effective length of the core boxes should be 5 % longer than the core length (e.g. a core box with a length of 105 cm for a core with a length of 100 cm).

11.7 Storage of samples

Single samples in sample containers and core samples in core boxes shall be stored in such a way that the mechanically-relevant soil and rock characteristics of these samples do not change. Samples shall be tightly sealed with a foil and unnecessary handling should be avoided. Usually samples may not be exposed to frost. The samples shall be stored in a cool environment. For special purposes, the storage room temperature should be the same as the ground temperature (+ 6 °C to + 12 °C) and moisture content (85 % to 100 %). If there is a doubt that a sample has been disturbed during storage, a remark shall be marked on the laboratory forms.

12 Report

12.1 Field report

12.1.1 General

At the project site, for each borehole, etc., a field report of sampling and groundwater measurements shall be completed. This field report shall consist of the following, if applicable:

- a) summary log (see 12.1.2);
- b) drilling record (see 12.1.3);
- c) sampling record (see 12.1.4);
- d) record of identification and description of soil and rock (see 12.1.5);
- e) backfilling record (see 12.1.6);
- f) record of the installation of piezometers (see 12.1.7);
- g) record of groundwater measurements (see 12.1.8).

All field investigations shall be recorded and reported such that third persons are able to check and understand the results.

12.1.2 Summary log

The summary log shall include the following essential information, if applicable (see also B.1).

- a) General information:
 - 1) name of the enterprise performing the sampling and/or groundwater measurements;
 - 2) name of the client or representative;
 - 3) date of sampling and/or groundwater measurements;
 - 4) identification of the project;
 - 5) number of the borehole, trial pit, heading or shaft.

b) Information on the project site:

- 1) position and elevation of the borehole, trial pit, heading or shaft location;
- 2) borehole direction: inclination and orientation;
- 3) whenever possible, the depth of the free groundwater surface.

c) Other information:

- 1) the specifications and the type of sampler used;
- 2) any interruptions, obstructions and difficulties encountered during the sampling operation, drilling, excavation or groundwater measurements;
- 3) information on any attached records;
- 4) name and signature of the qualified operator.

12.1.3 Drilling record

The drilling record shall be attached to the summary log and include the following essential information, if applicable (see also B.2).

a) General information:

- 1) name of the enterprise performing the drilling;
- 2) name of the client or representative;
- 3) date of drilling;
- 4) identification of the project;
- 5) identification of the borehole.

b) Information on the used equipment:

- 1) cutting tool (type of drill bit);
- 2) depth where a bit was changed;
- 3) the method of the pre-drilling, if used;
- 4) ramming used;
- 5) the use of the casing.

c) Information on the execution:

- 1) borehole diameters;
- 2) depth of the casing tip;
- 3) the use of flushing medium and the level of the flushing medium in the borehole;
- 4) colour and colour shifts of flushing medium;

- 5) loss, if any, of flushing medium;
 - 6) flushing medium pressure and circulated volume;
 - 7) drilling parameters.
- d) Other information:
- 1) name and signature of the qualified operator.

12.1.4 Sampling record

The sampling report shall be clear and accurate, and it may contain not only the data required for determination of the soil and rock strata and the location (x, y, z) of the samples obtained but also any observations which will contribute to an estimate of the condition of the samples and the physical properties of the soil and rock mass *in situ*.

The sampling record shall be attached to the summary log and include the following essential information, if applicable (see also B.3).

- a) General information:
- 1) name of the enterprise performing the sampling;
 - 2) name of the client or representative;
 - 3) number of the sample;
 - 4) date of sampling;
 - 5) identification of the project;
 - 6) identification of the borehole, trial pit, heading or shaft;
- b) Information on the used equipment:
- 1) the specifications and the type of sampler used;
 - 2) cutting edge damaged;
 - 3) core lifter used.
- c) Information on the sampling procedure:
- 1) the diameter or the size of the sample;
 - 2) the position (top and bottom of the sample) and the length of the sample;
 - 3) the core run interval;
 - 4) determination of the rock quality and core recovery according to Clause 7 (TCR, RQD, SCR);
 - 5) disturbance of the sample;
 - 6) sample container filled up;
 - 7) number of the liner or other identification of sample;
 - 8) ramming used during cutting of the sample;
 - 9) sampling methods.

d) Other information:

- 1) preliminary identification of the soil or rock type;
- 2) for water samples: the temperature, pH-value fixing agents, sampling operations;
- 3) name and signature of the qualified operator.

All unsuccessful sampling operations shall be recorded.

12.1.5 Record of identification and description of soil and rock

The record of identification and description of soil and rock shall be attached to the summary log and include the following essential information, if applicable (see also B.4):

- a) name of the enterprise performing the sampling;
- b) name of the client or representative;
- c) date of the sampling;
- d) identification of the project;
- e) identification of the borehole, trial pit, heading or shaft;
- f) orientation and diameter of the borehole;
- g) sampling methods;
- h) preliminary identification and description of the soil and rock based on the visual examination, according to ISO 14688-1 and ISO 14689-1;
- i) photographic documentation of the obtained cores/samples;
- j) name and signature of the qualified operator.

12.1.6 Backfilling record

The record of the applied backfilling shall be attached to the summary log and include the following essential information, if applicable (see also B.5):

- a) name of the enterprise performing the backfilling;
- b) name of the client or representative;
- c) date of backfilling;
- d) identification of the project;
- e) identification of the borehole, trial pit, heading or shaft;
- f) backfilling material and process;
- g) sections of backfilling;
- h) name and signature of the qualified operator.

12.1.7 Record of the piezometer installation

The record of the piezometer installation shall be attached to the summary log and include the following essential information, if applicable (see also B.6).

a) General information:

- 1) name of the enterprise installing the piezometer;
- 2) name of the client or representative;
- 3) date of the piezometer installation;
- 4) identification of the project;
- 5) identification of the borehole or groundwater measuring station;
- 6) position and elevation of borehole or groundwater measuring station;
- 7) whenever possible the depth of the free groundwater surface;
- 8) installation level (filter or perforated part of pipe).

b) Information on the used equipment:

- 1) type and manufacturer of the equipment;
- 2) method of installation (e.g. in a borehole, pushed, rammed);
- 3) type of filter and tube (inside diameter filter, percentage, length and width of the slots, wall thickness, filter material, pushed or drilled, etc.);
- 4) type and depths of the filter pack;
- 5) type and depths of sealing;
- 6) number of the equipment for closed systems.

c) Information on the installation:

- 1) level of the ground surface and the upper end of the extension pipe;
- 2) depth from the upper end of the pipe to the midpoint of the filter or perforated part of pipe;
- 3) level of sensor in read-out device (i.e. level of manometer or transducer in hydraulic systems and level of measuring membrane in pneumatic and electrical systems).

d) Other information:

- 1) observations and readings during installation;
- 2) observations and readings before, during and after function control;
- 3) date and result of first relevant reading;
- 4) name and signature of the qualified operator.

For all measuring stations, a graphical presentation of the installation (with the corresponding soil and rock strata, if possible) should be prepared for documentation of the entire measuring system. In particular, the height level of the built-in filters should be recorded; for hydraulic systems, the height level of the transducer on the ground should also be recorded.

Dimensions in metres

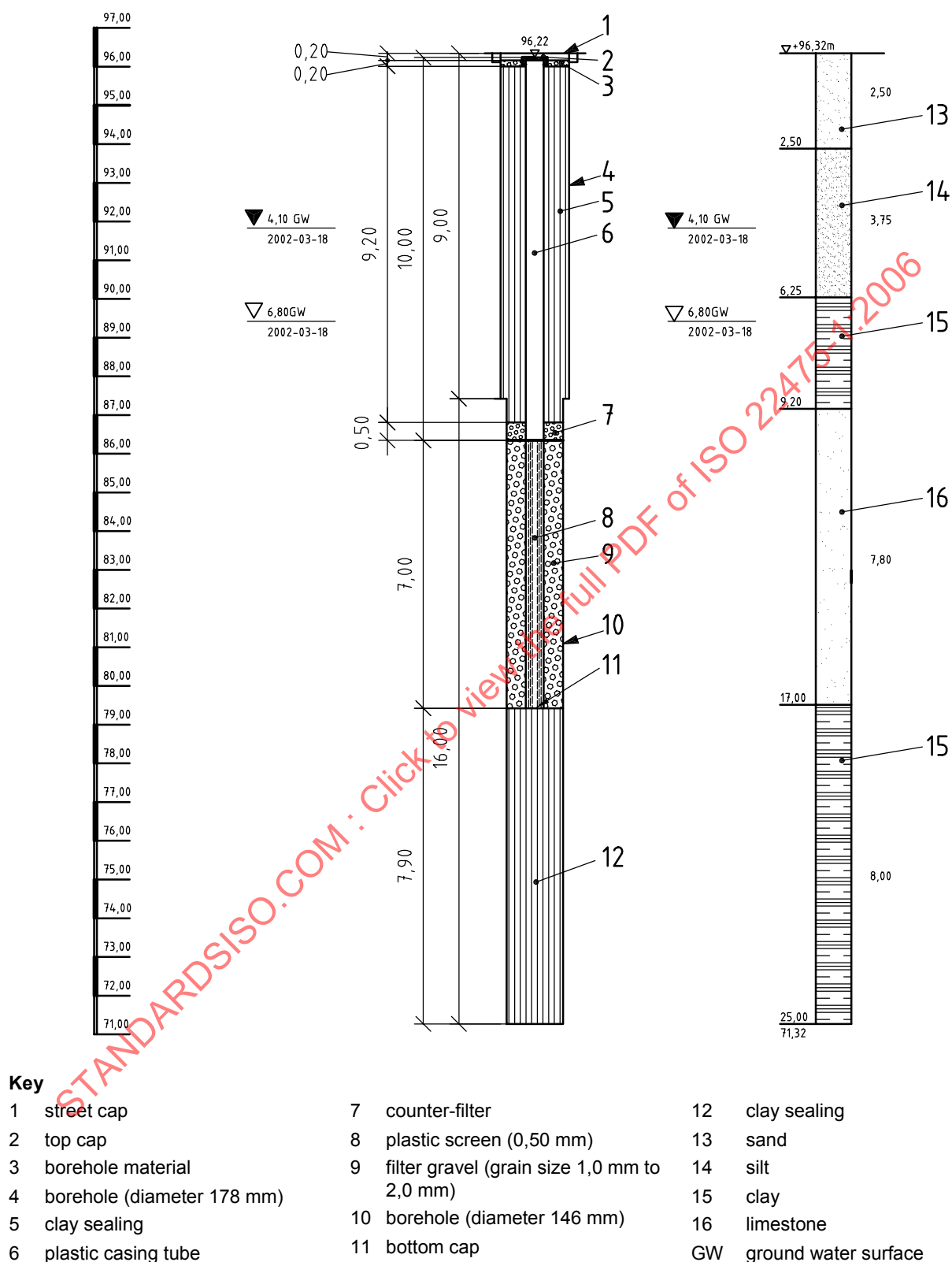


Figure 10 — Example of the configuration of an open groundwater measuring system

12.1.8 Record of groundwater measurements

12.1.8.1 The record of groundwater measurements shall be attached to the summary log and include the following essential information, if applicable (see B.7).

a) General information:

- 1) name of enterprise performing the groundwater measurements;
- 2) name of client or representative;
- 3) date of groundwater measurements;
- 4) identification of the project;
- 5) identification of the borehole or piezometer.

b) Information on the measurement:

- 1) time for each separate groundwater measurement;
- 2) measured values;
- 3) measured atmospheric pressure;
- 4) calculated pressures;
- 5) comments on observations or performed checks of importance for the interpretation.

c) Other information:

- 1) name and signature of the qualified operator.

12.1.8.2 Further, a record of the calibration of groundwater measuring systems shall be supplied to the record of the groundwater measurements. The record of the calibration of groundwater measuring systems shall include the following essential information, if applicable (see B.8):

- a) date and place of calibration;
- b) the manufacturer and number of the calibrated device;
- c) the type, number and precision of the reference instrument;
- d) latest calibration;
- e) any information relevant for the application of the calibration;
- f) name and signature of the person who is responsible for the calibration.

12.2 Report of the results

The report of the results shall include the following essential information, if applicable:

- a) The field report (in original and/or computerised form);
- b) a final record of the identification and description of soil and rock, according to ISO 14688-1 and ISO 14689-1;

- c) a graphical presentation of the record of the drilling parameters;
- d) a graphical presentation of the final record of the identification and description of soil and rock;
- e) a graphical presentation of the backfilling;
- f) a graphical presentation of the piezometer;
- g) a graphical or numerical presentation of the results of the groundwater measurements;
- h) name and signature of the responsible expert.

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Annex A

(informative)

Example of a form for the preliminary information on the intended sampling and groundwater measurements

Preliminary information on the intended sampling and groundwater measurements	
Project	
Location	
Number of boreholes, excavations and/or groundwater measurements	
Orientation, inclination and acceptable deviations in boreholes	
Surveying requirements and expected geological and hydrogeological conditions	
Required accuracy and uncertainty of measurements	
Frequency of measurements	
Environmental and safety risks (associated with, e.g. flushing media, suspensions)	☐ yes ☐ no If yes, please specify
Hazardous assessment for contaminated sites	☐ done ☐ not done ☐ not known ☐ not necessary
Possible risks	☐ yes ☐ no If yes, please specify ☐ underground services, such as ☐ overhead services, such as ☐ traffic, such as ☐ unexploded ordnance ☐ contamination, such as ☐ other, such as

Page 2	Preliminary information on the intended sampling and groundwater measurements	
Planned depth of the borehole or excavation		
Sampling category	☐ A	☐ B ☐ C
Sampling method(s)		
Sample handling		
Sample storage		
Sample transport		
Intended <i>in situ</i> testing	☐ yes	☐ no
	If yes, please specify ☐ standard penetration test ☐ borehole expansion tests, such as..... ☐ geophysical borehole tests, such as..... ☐ geohydraulic tests, such as..... ☐ piezometer installation ☐ other, such as.....	
Borehole completion method and site reinstatement (needs, material, methods, etc.)		
Environmental care		
Emergency arrangements		
Name of the contact person (client or representative)		
Flow of information		
Name of qualified operator		
Name of responsible expert		
Remarks		

Annex B (informative)

Field reports

B.1 Summary log

Summary log	Name of the enterprise		
Investigation type: borehole/trial pit/shaft/head *	Name of the client		
Name of the project		Number of the project	
Date:		Elevation	
Position		Borehole inclination	
		Borehole orientation	
Depth of the free groundwater surface	m	Borehole depth	m
Specifications and type of sampler used			
Attached records **	☐ drilling record ☐ sampling record ☐ backfilling record ☐ record of identification and description of soil and rock ☐ record of the installation of piezometers ☐ record of groundwater measurements ☐ others, such as		
Remarks (interruptions, obstructions, difficulties, etc.)			
Name of the responsible operator			
Signature of the responsible driller			
* delete if not applicable ** tick as applicable			

B.2 Drilling record

Drilling record		Name of the enterprise												
		Name of the client												
Name of the project						Number of the project								
Date of drilling						Identification of the borehole								
Drill rig (type, manufacturing year)						End depth of borehole								
Method of pre-drilling *						Ramming *								
Borehole diameters		mm				mm				mm				
Depth		Drilling		Drilling tool				Casing				Flushing medium		Remarks
from	to	Method	Soil cutting technique	Type, bit	Diameter mm	Drive	Flushing medium	Inner diameter mm	Outer diameter mm	Depth mm	Pressure	Circulated volume		
Remarks (interruptions, obstructions, difficulties, etc.)														
Name of the responsible operator														
Signature of the responsible operator														
* if used														

B.3 Sampling record

[illegible]

B.4 Record of identification and description of soil and rock

Name of the enterprise: Name of the client: Drilling method: Diameter: Project name:		Record of identification and description of soil and rock according to ISO 14688-1 and ISO 14689-1					Page: Trial pit: Project number:
Name and signature of the qualified operator:							
1	2	3	4	5	6	7	
Depth to m	Identification of soil or rock type Additional remarks Geological designation/stratigraphy	Colour Carbonate content	Description of the sample - Consistency, plasticity, hardness, uniaxial strength - Particle shape, matrix - Weathering, discontinuities, etc.	Description of drilling progress - Drillability/core shape - Use of chisel - Observations, etc.	Samples tests - Type - Number - Depth	Remarks - Seepage/flushing medium - Drilling tools/casing - Core loss - Core length	

[illegible]

B.5 Backfilling record

Backfilling record		Name of the enterprise			
		Name of the client			
Name of the project				Number of the project	
Date of backfilling:				Identification of the borehole, etc.	
Depth m		Fill material		Depth m	Fill material
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
from	to			from	to
Remarks					
Name of the qualified operator					
Signature of the qualified operator					

B.6 Record of the installation of a piezometer

Record of piezometer installation					Name of the enterprise							
					Name of the client							
Name of the project									Number of the project			
Date of installation									Identification of the borehole/piezometer			
Position of piezometer									Elevation of piezometer		m	
No. of equipment for closed systems									Elevation of filter			
Tube					Filter material				Sealing material			
No	Type	from m	to m	Diameter	Material	Type	from m	to m	grain size mm	Type	from m	to m
Water level prior to testing					m				Date:		Time:	
Water level after lowering, etc.					m				Date		Time	
First relevant reading					m				Date		Time	
Further readings of the water levels												
No	Date		Time		Depth of water level m		Depth of the casing m		Depth of the borehole m			
Remarks												
Name of the qualified operator												
Signature of the qualified operator												

B.7 Record of groundwater measurements

[illegible]

B.8 Record of the calibration of groundwater measuring systems

Record of the calibration of a groundwater measuring system	
Date and place of calibration	
Manufacturer of the calibrated device	
Number of the calibrated device	
Type of the reference instrument	
Number of the reference instrument	
Precision of the reference instrument	
Latest calibration	
Additional remarks	
Name of the person responsible for the calibration	
Signature of the person responsible for the calibration	

Annex C (informative)

Drilling and sampling equipment for soil and rock

C.1 General

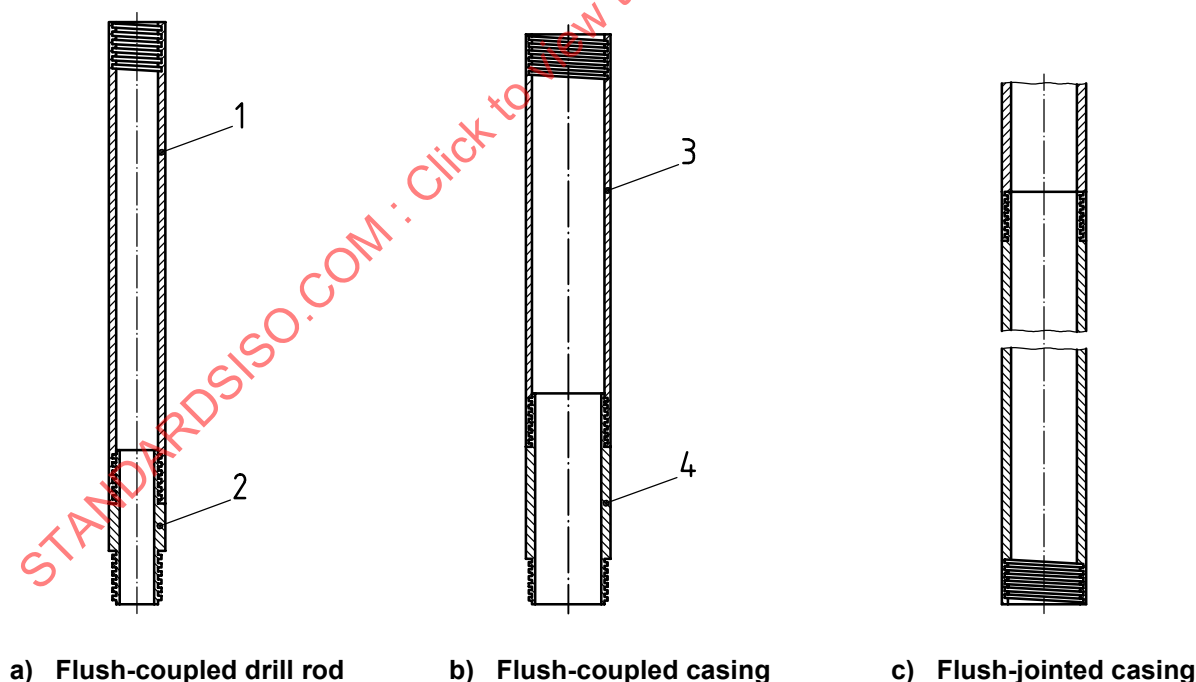
The object of this annex is to provide an illustrated reference guide of the most frequently and universally used equipment for drilling and sampling in soils and rock. The annex includes information regarding basic dimensions and nomenclature. For complete information and dimensions, reference should be made to the appropriate International, European or National Standard quoted herein.

This annex also includes data charts to assist with core bit type selection in relation to ground conditions and to core bit profile selection.

Examples of the execution of certain sampling methods are also included in this annex in order to clarify certain areas in the text of this part of ISO 22475.

C.2 Drill rods and casing

See Figure C.1.



Key

- 1 drill rod tube
- 2 drill rod coupling
- 3 casing tube
- 4 casing coupling

Figure C.1 — Drill rods and casing

C.2.1 Drill rods and casing “W”-series according to ISO 3551-1

See Table C.1.

Table C.1 — Drill rods and casing “W”-series according to ISO 3551-1

Dimensions in millimetres

Drill rod	Rod tube	Rod coupling	Casing flush coupling	Casing tube		Casing flush jointed	Casing		Casing reaming shell	Casing bit		Casing shoe	
				OD	ID		OD	ID		Set OD	Set ID	Set OD	Set ID
RW	27,89 27,76	10,57 10,19	RX	36,63 36,50	30,48 30,23	RW	36,63 36,50	30,48 30,23	—	37,85 37,59	25,53 25,27	37,85 37,59	30,18 30,05
EW	35,05 34,93	11,35 10,97	EX	46,28 46,02	38,35 38,10	EW	46,28 46,02	38,35 38,10	48,13 47,88	47375 47,50	35,81 35,56	47375 47,50	38,02 37,90
AW	43,89 43,64	16,13 15,75	AX	57,40 58,15	48,67 48,41	AW	57,40 58,15	48,67 48,41	60,07 59,82	59,69 59,44	45,34 45,09	59,69 59,44	48,31 48,18
BW	54,23 53,98	19,30 18,92	BX	73,28 73,03	60,58 60,33	BW	73,28 73,03	60,58 60,33	75,82 75,56	75,44 75,18	56,39 56,13	75,44 75,18	60,25 60,12
NW	66,93 66,68	35,18 34,80	NX	89,28 88,90	76,58 76,20	NW	89,28 88,90	76,58 76,20	92,33 92,08	91,95 91,69	72,26 72,01	91,95 91,69	76,12 75,87
HW	89,28 88,90	60,71 60,32	HX	114,68 114,30	100,38 100,00	HW	114,68 114,30	101,60 101,22	—	117,65 117,27	96,06 95,81	117,65 117,27	99,82 99,57
			PX	140,74 138,66	127,38 123,57	PW	140,74 138,66	127,38 123,57	—	143,76 143,26	117,86 117,48	143,76 143,26	123,44 123,06
			SX	169,55 167,00	152,45 147,70	SW	169,55 167,00	155,55 151,21	—	172,72 172,21	143,26 142,88	172,72 172,21	146,94 146,56
			UX	195,12 192,23	179,20 176,20	UW	195,12 192,23	180,54 175,79	—	198,50 197,74	171,83 171,32	198,50 197,74	175,64 175,13
			ZX	220,73 217,42	205,94 201,60	ZW	220,73 217,42	208,46 203,00	—	224,16 223,39	197,23 196,72	224,16 223,39	201,04 200,53
OD Outer diameter ID Inner diameter — not required													

C.2.2 Drill rods and casing “metric” series according to ISO 3552-1

See Table C.2.

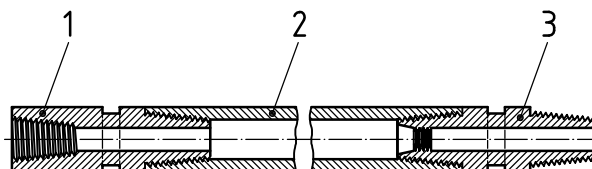
Table C.2 — Drill rods and casing “metric” series according to ISO 3552-1

Dimensions in millimetres

Drill rod size	Rod tube	Rod coupling	Casing flush jointed	Casing		Casing bit		Casing shoe	
	OD	ID		OD	ID	Set OD	Set ID	Set OD	Set ID
33	33,70 33,30	15,14 14,86	46	44,35 43,95	37,40 36,90	46,10 45,90	35,10 34,90	46,10 45,90	37,10 36,90
42	42,20 41,80	22,16 21,84	56	54,35 53,95	47,40 46,90	56,10 55,90	45,10 44,90	56,10 55,90	47,10 46,90
50	50,20 49,80	22,16 21,84	66	64,55 63,95	57,50 57,00	66,10 65,90	55,10 54,90	66,10 65,90	57,10 56,90
			76	74,55 73,95	67,50 67,00	76,10 75,90	65,10 64,90	76,10 75,90	67,10 66,90
			86	84,65 83,85	77,50 77,00	86,10 85,90	75,10 74,90	86,10 85,90	77,10 76,90
			101	98,40 97,60	88,70 87,90	101,10 100,90	86,60 86,40	101,10 100,90	88,10 87,90
			116	113,50 112,50	103,80 102,80	116,10 115,90	101,60 101,40	116,10 115,90	103,10 102,90
			131	128,50 127,50	118,80 117,80	131,10 130,90	116,60 116,40	131,10 130,90	118,10 117,90
			146	143,50 142,50	134,20 132,80	146,10 145,90	131,60 131,40	146,10 145,90	133,10 132,90
OD Outer diameter									
ID Inner diameter									

C.2.3 Drill rods taper threaded “Y” series

See Figure C.2 and Table C.3.



Key

- 1 tool joint-box
- 2 rod tube
- 3 tool joint-pin

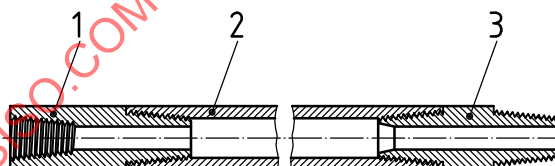
Figure C.2 — Drill rods taper threaded “Y” series

Table C.3 — Drill rods taper threaded “Y” series

		EWY		AWY		BWY		NWY		HWY	
		inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
Rod tube	OD	1,38	34,90	1,72	43,70	2,12	54,00	2,62	66,70	3,50	88,90
Tool joint	ID	0,44	11,10	0,62	15,90	0,75	19,00	1,25	31,30	1,62	41,10
Threads per inch		5		5		5		4		4	
OD Outer diameter											
ID Inner diameter											

C.2.4 Drill rods taper threaded “J” series

See Figure C.3 and Table C.4.



Key

- 1 rod end-box
- 2 rod tube
- 3 rod end-pin

Figure C.3 — Drill rods taper threaded “J” series

Table C.4 — Drill rods taper threaded “J” series

		AWJ		BWJ		NWJ		KWJ		HWJ	
		inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
Rod tube	OD	1,75	44,50	2,12	54,00	2,62	66,70	2,87	73,00	3,50	88,90
End	ID	0,62	16,00	0,75	19,00	1,12	29,00	1,37	34,90	1,75	44,50
Threads per inch		5		5		4		4		4	
OD Outer diameter											
ID Inner diameter											

C.3 Corebarrel data

NOTE For schematic illustrations of corebarrel types, see C.4.

C.3.1 Corebarrels “W” series, according to ISO 3551-1

See Table C.5.

Table C.5 — Corebarrels “W” series, according to ISO 3551-1

Corebarrel designs				Coring bits		Rea- ming shells	Kerf width	Kerf area	Core area	Hole area	Core to hole area	Nomi- nal core size	Nomi- nal hole size
WF	WG	WM	WT	Set ID	Set OD	Set OD	mm	cm ²	cm ²	cm ²	%		
			RWT	18,80 18,54	29,59 29,34	29,97 29,72	5,59	4,25	2,74	6,99	39,10	18,50	30
	EWG	EWM		21,59 21,34	37,46 37,21	37,85 37,59	8,13	7,55	3,62	11,17	32,40	21,50	38
			EWT	23,11 22,86	37,46 37,21	37,85 37,59	7,37	7,03	4,15	11,17	37,10	23,00	38
	AWG	AWM		30,23 29,97	47,75 47,50	48,13 47,88	8,94	10,99	7,12	18,10	39,30	30,00	48
			AWT	32,66 32,41	47,75 47,50	48,13 47,88	7,72	9,79	8,32	18,10	45,90	32,50	48
	BWG	BWM		42,16 41,91	59,69 59,44	60,07 59,82	8,94	14,34	13,88	28,22	49,10	42,00	60
			BWT	44,58 44,32	59,69 59,44	60,07 59,82	7,75	12,70	15,52	28,22	55,00	44,50	60
	NWG	NWM		54,86 54,61	75,44 75,18	75,82 75,56	10,46	21,46	23,53	44,99	52,20	54,50	76
			NWT	58,88 58,62	75,44 75,18	75,82 75,56	8,46	17,88	27,11	44,99	60,00	58,50	76
HWF	HWG			76,33 76,07	98,98 98,60	99,36 99,11	11,51	31,74	45,61	77,34	59,00	76,00	99
			HWT	81,08 80,82	98,98 98,60	99,36 99,11	9,14	25,88	51,46	77,34	66,50	81,00	99
PWF				92,33 91,95	120,27 119,76	120,78 120,40	14,22	47,53	66,68	114,21	58,40	92,00	121
SWF				112,95 112,57	145,57 145,16	146,18 145,80	16,61	67,52	99,86	167,39	59,70	112,50	146
UWF				140,08 139,57	174,12 173,36	174,75 174,24	17,32	85,59	153,56	239,15	64,20	140,00	175
ZWF				165,48 164,97	199,52 198,76	200,15 199,64	17,32	99,43	214,41	313,84	68,30	165,00	200
OD Outer diameter ID Inner diameter WT and WG are single-tube corebarrel types WF, WG and WM are double-tube corebarrel types													

C.3.2 Corebarrels “metric” series, according to ISO 3552-1

See Table C.6.

Table C.6 — Corebarrels “metric” series, according to ISO 3552-1

Corebarrel type			Coring bits		Reaming shells	Kerf width	Kerf area	Core area	Hole area	Core to hole area
B	T	Z	Set OD	Set ID	Set OD	mm	cm ²	cm ²	cm ²	%
36	36		21,80 21,60	36,10 35,90	36,40 36,20	7,15	6,55	3,80	10,35	36,50
46	46		31,80 31,60	46,10 45,90	46,40 46,20	7,15	8,80	8,04	16,84	47,80
		46	27,80 27,60	46,10 45,90	46,40 46,20	9,15	10,68	6,16	16,84	36,50
56	56		41,80 41,60	56,10 55,90	56,40 56,20	7,15	11,04	13,85	24,89	55,90
		56	33,80 33,60	56,10 55,90	56,40 56,20	11,15	15,81	9,08	24,89	36,50
66	66		51,80 51,60	66,10 65,90	66,40 66,20	7,15	13,28	21,24	34,52	61,60
		66	43,80 43,60	66,10 65,90	66,40 66,20	11,15	19,31	15,21	34,52	44,10
76	76		61,80 61,60	76,10 75,90	76,40 76,20	7,15	15,53	30,19	45,72	66,70
		76	53,80 53,60	76,10 75,90	76,40 76,20	11,15	22,83	22,90	45,72	50,00
86	86		71,80 71,60	86,10 85,90	86,40 86,20	7,15	17,78	40,71	58,49	69,80
		86	61,80 61,60	86,10 85,90	86,40 86,20	11,15	28,30	30,19	58,49	53,00
101			86,80 86,60	101,10 100,90	101,40 101,20	7,15	21,25	59,45	80,60	72,70
		101	74,80 74,60	101,10 100,90	101,40 101,20	13,15	36,42	44,18	80,60	54,90
116			101,80 101,60	116,10 115,90	116,40 116,20	7,15	24,52	81,71	106,23	76,80
		116	89,80 89,60	116,10 115,90	116,40 116,20	13,15	42,61	63,62	106,23	59,70
131			116,80 116,60	131,10 130,90	131,40 131,20	7,15	27,89	107,51	135,40	79,40
		131	104,80 104,60	131,10 130,90	131,40 131,20	13,15	48,81	86,59	135,40	64,00
146			131,80 131,60	146,10 145,90	146,40 146,20	7,15	31,26	136,85	168,11	81,40
		146	119,80 119,60	146,10 145,90	146,40 146,20	13,15	55,01	113,10	168,11	67,30

OD Outer diameter

ID Inner diameter

B and Z are single-tube corebarrel types

T is a double-tube corebarrel type

C.3.3 Air flush corebarrels

See Table C.7.

Table C.7 — Air flush corebarrels

Bit set	HWA F		412 F	
	inch	mm	inch	mm
OD	3,906	99,20	4,220	107,20
ID	2,812	71,40	2,942	74,70

The PWF, SWF, UWF and ZWF double-tube swivel type corebarrels are also suitable for use with air flush by the incorporation of an air flush type core bit.

C.3.4 Drill rods and casing

See Table C.8.

Table C.8 — Drill rods and casing

Casing				Core or drilling diameter			Rotary core drilling									
"W" series standard	Metric standard						Double-tube barrel		Single-tube barrel		Wireline barrel		Drill rods			
OD ID mm	OD mm	ID mm	Mass kg/m				Type	Core Ø mm	Type	Core Ø mm	Type	Core Ø mm	OD Ø mm	OD Ø "	Cplg. inside mm	Mass kg/m
				mm												
	508	480	101,5	508							PR					
	419	394	126	419												
	343	318	102	343												
	324	299	85,3	324												
	311	286	91,3	311												
	298	273	88,8	298												
	273	248	80,9	273												
	254	232	74,7	254												
244	223	69,6	246/244													
ZW	219	199	51,6	222												
219,1	203	183	47,6	219												
203,1				202/199			SF 219	190,0								
UW																
193,7	194	174	45,3	198			SF 199	170,0								
177,7																
	178	163	30	182												
SW																
168,3	168	154	28,3	176/179			SF-179	150,0								
152,3							K3	140,0	Z	146,0	SK	176,0	132,0			
PW																
139,7	143	134	16,3	146/150 SQ			T 6	123,0								
127							T 6 S	116,0	B	132,0						
							K 3	116,0	Z	120,0	SK	146,0	102,0			
							D	122,0								

C.4 Schematic illustrations of single- and double-tube corebarrels

C.4.1 Corebarrels “metric” series, according to ISO 3552-1

See Figure C.4 and Table C.9.

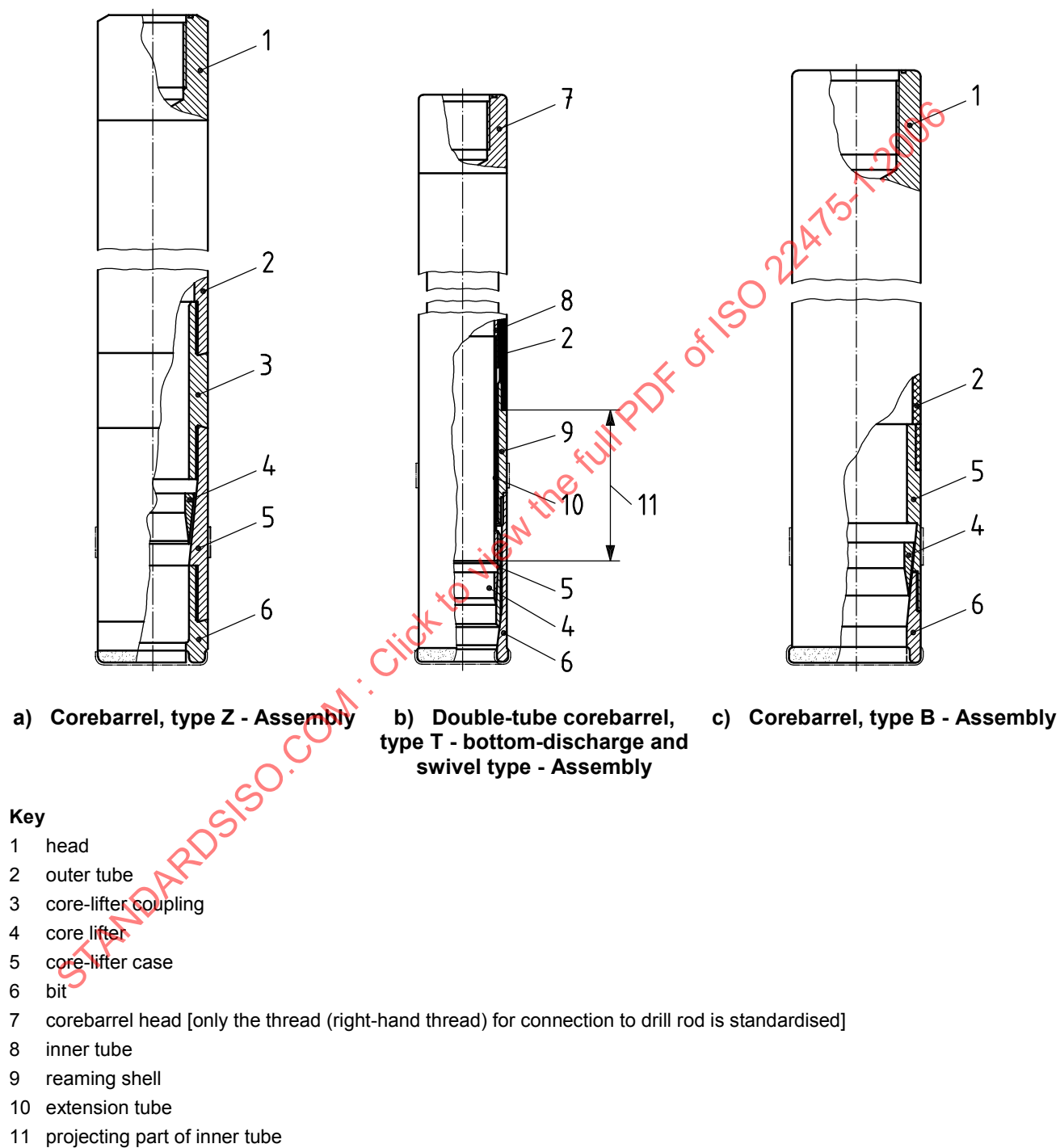


Figure C.4 — Corebarrels “metric” series, according to ISO 3552-1

Table C.9 — Corebarrels “metric” series, according to ISO 3552-1

Size	Projection mm $\pm 0,5$
36	117
46	118
56	116,50
66	117,50
76	
86	

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C.4.2 Corebarrels “W” series, according to ISO 3551-1

See Figure C.5 and Figure C.6.

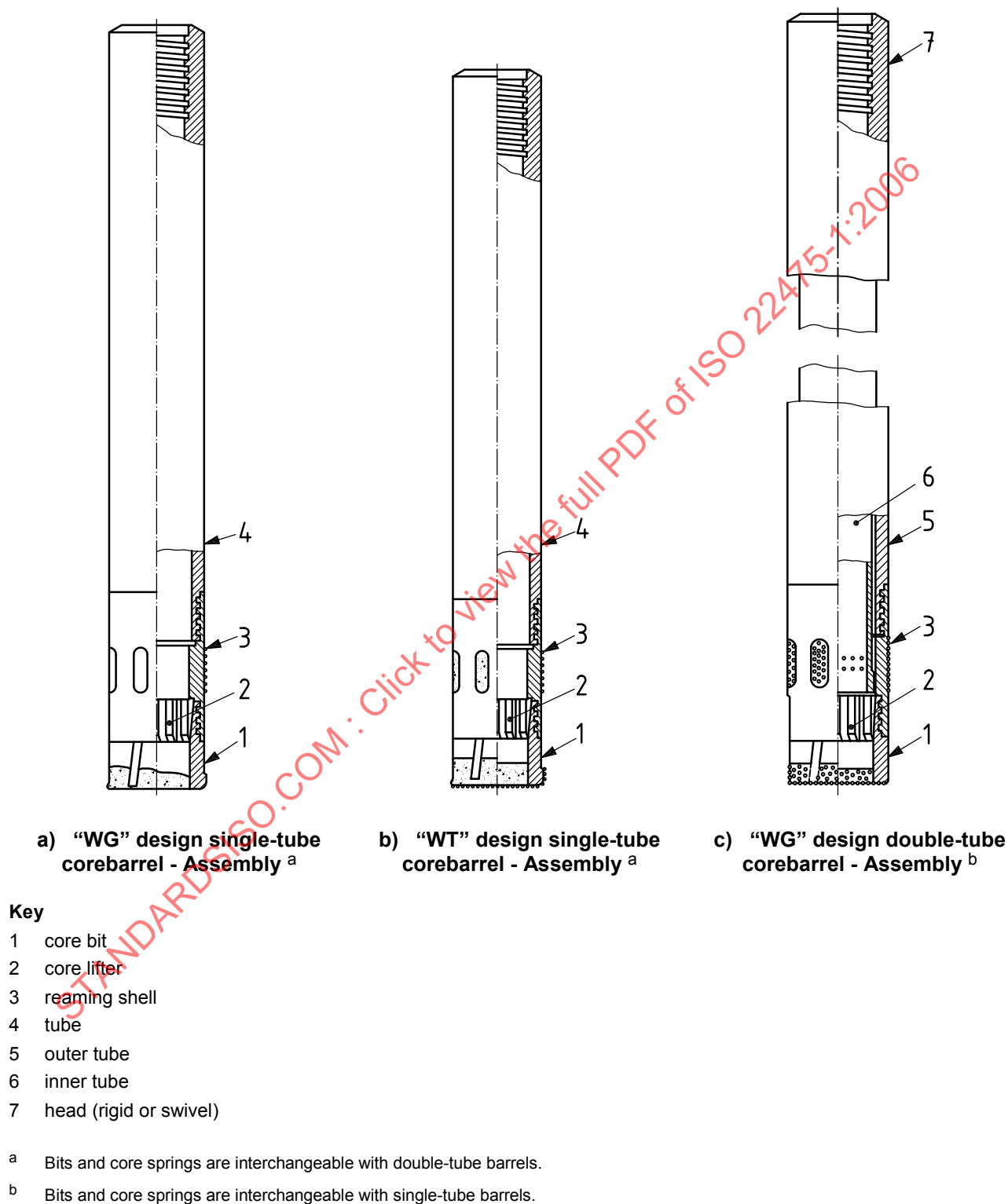
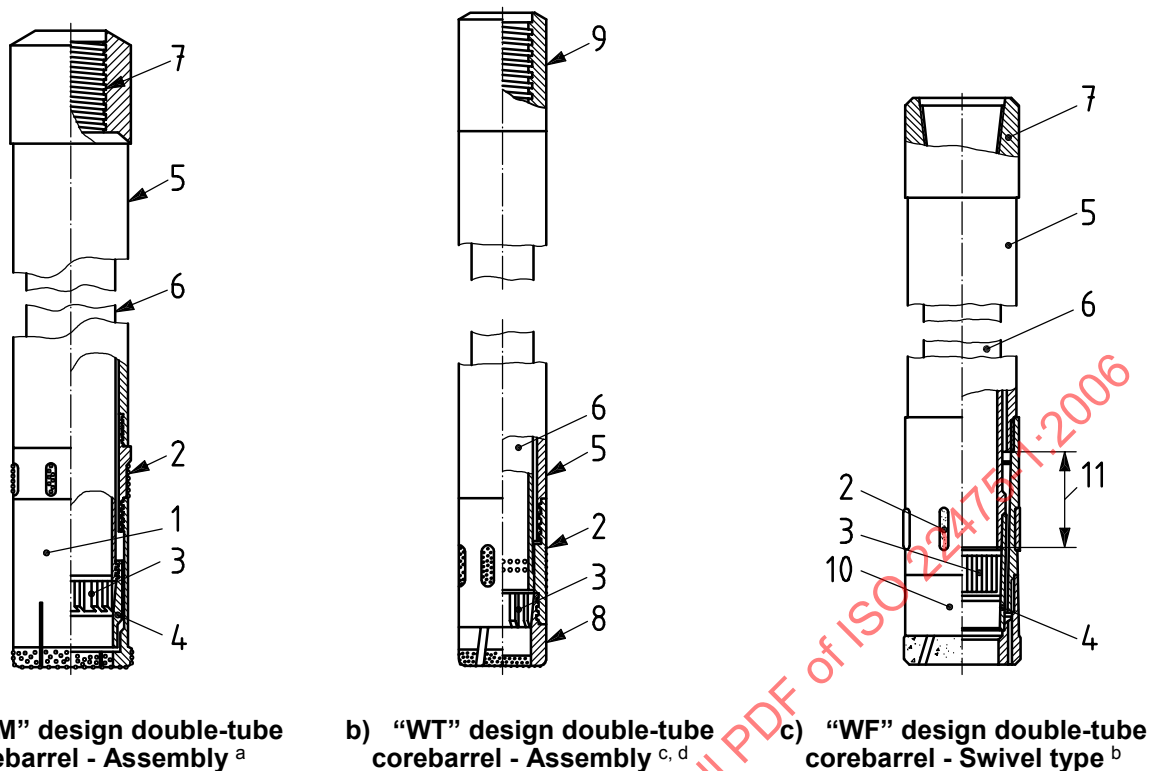


Figure C.5 — Corebarrels “W” series, according to ISO 3551-1



Key

- | | |
|--------------------|--|
| 1 core bit | 7 head thread only |
| 2 reaming shell | 8 core bit bevel wall or core bit straight wall |
| 3 core lifter | 9 head (rigid type) |
| 4 core-lifter case | 10 core bit for use with shell or core bit without shell |
| 5 outer tube | 11 inner tube protection (dimension for checking, see Table C.9) |
| 6 inner tube | |

^a Standard "WM" design corebarrel lengths are 1,5 m and 3 m (lengths refer to core capacity).

^b Standard "WF" design corebarrel lengths are 1,5 m and 3 m (lengths refer to core capacity).

^c No core spring is used with straight-walled bits.

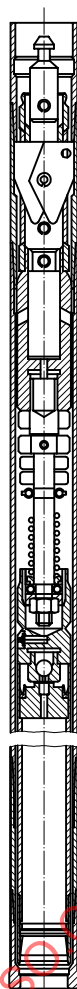
^d Standard "WT" design corebarrel lengths are 1,5 m and 3 m (lengths refer to core capacity).

Figure C.6 — Corebarrels "W" series, according to ISO 3551-1

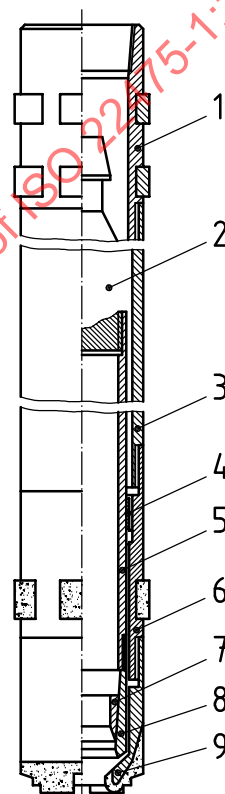
C.5 Schematic illustrations of wireline and geotechnical wireline corebarrels

C.5.1 Wireline corebarrel assembly

See Figure C.7 and Tables C.10 and C.11.



a) Typical wireline corebarrel



b) Parts standardised in ISO 10097-1 ^a

Key

- 1 head (not standardised)
- 2 bearing unit (not standardised)
- 3 outer corebarrel
- 4 stabiliser (not standardised)
- 5 retractable inner tube assembly
- 6 reaming shell
- 7 core lifter
- 8 core-lifter case
- 9 bit

^a For full information regarding standardised dimensions refer to ISO 10097-1.

Figure C.7 —Wireline corebarrel assembly

Table C.10 — Wireline drill rod dimensions

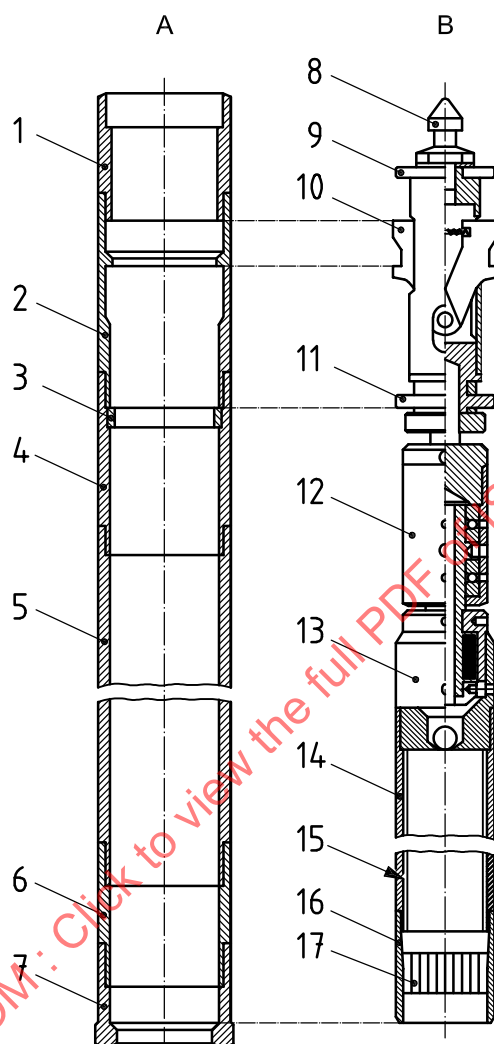
Equipment	A size mm	B size mm	N size mm	H size mm	P size mm
Rod OD	44,5	55,6	69,9	88,9	114,3
Rod ID	34,9	46,0	60,3	77,8	103,2
Cplg OD	—	—	—	—	117,5
Cplg. ID	—	—	—	—	103,2
Thds / in.	3	3	3	3	3

Table C.11 — Wireline corebarrel dimensions

Equipment	A size mm	B size mm	N size mm	H size mm	P size mm
Core size	27,0	36,5	47,6	63,5	85,0
Hole size	48,0	60,0	75,6	96,1	122,7
Outer tube OD	46,0	57,2	73,2	92,1	117,5
Outer tube ID	36,5	46,0	60,5	77,8	103,2
Inner tube OD	32,5	42,9	55,6	73,0	95,3
Inner tube ID	28,6	38,1	50,0	66,7	88,9

C.5.2 Geotechnical wireline corebarrel

See Figure C.8 and Tables C.12 and C.13.



a) Outer tube assembly

b) Inner tube assembly

Key

- 1 drill and coupling
- 2 locking coupling
- 3 landing ring
- 4 adapter coupling
- 5 outer tube
- 6 blank reaming shell
- 7 core bit (not included)
- 8 lifting spear
- 9 upper stabiliser

- 10 latches
- 11 lower stabiliser
- 12 bearing assembly
- 13 inner tube bung
- 14 outer tube
- 15 plastic coreliner
- 16 core-lifter case
- 17 core lifter

Figure C.8 — Geotechnical wireline corebarrel (inner and outer tube assembly)

Table C.12 — Geotechnical wireline corebarrel drill pipe dimensions

Equipment	P size	P size	S size	S size
	flush jointed	flush coupled	flush jointed	flush coupled
	mm	mm	mm	mm
Rod OD	114,3	114,8	140,0	140,0
Tube ID	101,6	102,8	125,0	128,0
Coupling OD	—	118,0	—	140,0
Coupling ID	—	102,8	—	125,0

Table C.13 — Geotechnical wireline corebarrel dimensions

Equipment	P size mm	S size mm
Core size	83,0	102,0
Borehole size	127,7	146,0
Outer tube OD	117,6	140,0
Outer tube ID	103,2	128,0
Inner tube OD	95,2	117,0
Inner tube ID	88,9	111,0
Third tube OD	88,3	110,0
Third tube ID	84,7	105,6
NOTE The third tube can be metal or plastic.		

C.6 Water-well casing

See Figures C.9 and C.10 and Tables C.14 and C.15.

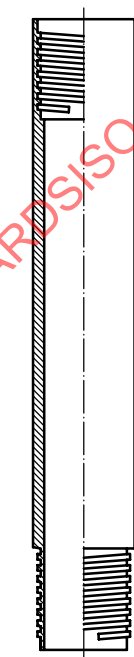


Figure C.9 — Water-well casing with flush butt joints according to BS 879

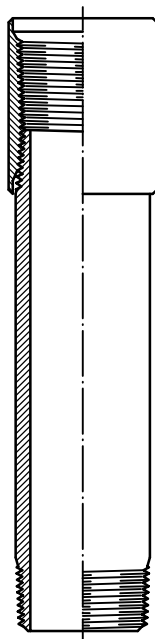


Figure C.10 — Water-well casing with screwed and socketed joints, according to BS 879

Table C.14 — Dimensions of water-well casings with flush butt joints

Equipment	4 in.		5 in.		6 in.		8 in.		10 in.		12 in.		13 in.		15 in.		18 in.		21 in.		24 in.	
	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
Casing OD	4,50	114,30	5,50	139,70	6,62	168,30	8,62	219,10	10,75	273,00	12,75	323,90	14,00	355,60	16,00	406,60	19,00	482,80	22,00	558,80	25,00	635,00
Nominal bore	3,86	98,40	4,87	123,80	5,87	149,20	7,87	200,00	9,87	250,80	11,87	301,60	13,12	333,40	15,00	381,00	18,00	457,20	21,00	533,40	24,00	609,60
Threads (inch)	4		4		4		4		4		4		4		4		4		4		4	

Table C.15 — Dimensions of water-well casings with screwed and socketed joints

Equipment	4 in.		6 in.		8 in.		10 in.		12 in.		13 in.		15 in.		18 in.		21 in.		24 in.	
	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
Casing OD	4,50	114,30	6,62	168,30	8,62	219,10	10,75	273,00	12,75	323,90	14,00	355,60	16,00	406,40	19,00	482,60	22,00	558,80	25,00	635,00
Casing ID	4,00	101,60	6,00	152,40	8,00	203,20	10,00	254,00	12,00	304,80	13,25	336,60	15,25	357,40	18,25	463,60	21,12	536,60	24,12	612,80
Socket OD	5,12	130,00	7,25	184,00	9,31	237,00	11,43	291,00	13,62	346,00	14,87	378,00	16,87	429,00	20,00	508,00	23,12	587,00	26,12	644,00
Threads (inch)	10		10		8		8		8		8		8		8		8		8	

C.7 Bit selection chart

See Table C.16.

Table C.16 — Bit selection chart

Group	Rock description	Hardness abrasivity	TC	GTS	PDC	TSP	Surface set stones per carat					Impregnated type number					
							10/15	20/25	30/40	40/60	60/80	2	4	6	8	9	10
1	Clay	Soft															
	Soft Shale																
	Chalk																
	Soft Limestone																
	Gypsum																
Volcanic Tuff																	
2	Sand	Soft to medium															
	Loose sandstone																
	Shale																
	Marble																
	Medium limestone																
Salt																	
3	Soft sandstone	Med-hard low abrasivity															
	Sandy shale																
	Claystone																
	Sandy limestone																
	Soft schist																
4	Medium sandstone	Med-hard high abrasivity															
	Siltstone																
	Calcitic limestone																
	Medium limestone																
	Hard shales																
5	Hard limestone	Hard, low abrasivity															
	Dolomitic limestone																
	Schist																
	Serpentine																
	Dolomite																
	Marble																
	Syenite																
	Andesite																
	Pegmatite																
	Hematite																
	Magnetite																
	6																
Granite																	
Basalt																	
Gabbro																	
Rhyolite																	
***	Abrasive sandstone							Carbonado									
	Pyritic formations																
	Banded hematite																
	Conglomerate																
	Taconite																
TC	Tungsten carbide set					Impregnated type number:											
GTS	Geotechnical saw-tooth carbide set					2 for abrasive or fractured softer formations											
PCD	Polycrystalline diamond set					4 for medium hard and abrasive formations											
TSP	Thermally stable polycrystalline set					6 for hard moderately abrasive formations											
						8 for hard uniform non-abrasive formations											
						9 for hard to very hard and medium abrasive formations											
10 for ultra hard non-abrasive formations																	

C.8 Core bit profiles

See Table C.17.

Table C.17 — Core bit profiles — Diamond set, impregnated, TC and PCD

1		Semi-round profile Profile for high penetration rate. Lower carat weight than other profiles. Standard profile for surface set thin kerf wireline drill bits.
2		Full-round profile A full-round crown for thick kerf bits.
3		Semi-flat profile This profile is used when coring in soft, friable or broken formation, for thin kerf bits.
4		Tapert pilot profile Stronger than profile 7, but slower penetration for wireline range. Can replace profile 7 when formations are very broken.
5		Pilot profile The pilot profile provides stability and directional contact for increased penetration. For thick kerf bits it helps to solve deviation problems.
6		Tapered concave profile Standard profile for non-coring bits
7		Multi-step profile Allows higher penetration rates than round profiles. Fragile in fractured formation, i.e. standard for surface set wireline bits.
8		Concave profile Standard profile for non-coring bits.
9		Pilot concave profile Used to solve deviation problems when using non-coring bits.
10a		Two wide steps To be used in soft formations.
10b		Two wide steps with face discharge profile To be used in soft formations with face discharge.
11		W profile Standard profile for impregnated wireline bits.
12		Flat profile Profile for impregnated bits.
13		Sawtooth profile (side view) Sawtooth profile used mainly for Geotech bits.
14		Tower profile (side view)
Flush alternatives CF (channel flush) standard core bit flush design ECF (expanded channel flush) Optional flush (on request) FD (face discharge flush) standard with oval holes SCAL (scallop) a combination of FD and CF NOTE Core bits with face discharge are used in loose formations where the flushing medium may destroy the core.		

C.9 Rock bit types and sizes

See Figures C.11 and C.12 and Tables C.18 and C.19.

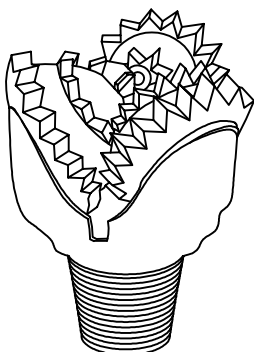


Figure C.11 — Three-cone milled tooth rock bit

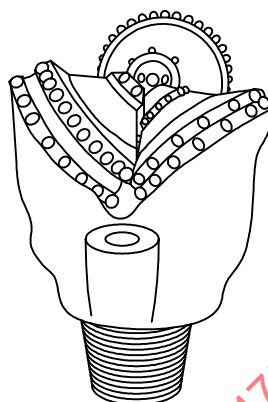


Figure C.12 — Tungsten carbide button bit

Table C.18 — Three-cone milled tooth rock bit

Bit size		Thread	Approx. weight	
inch	mm		lb	kg
2 7/8	73	4 tpi-N	3	1,4
2 15/16	75	4 tpi-N	3	1,4
3	76	4 tpi-N	3	1,4
3 1/8	79	4 tpi-N	4	1,8
3 1/4	83	4 tpi-N	4	1,8
3 1/2	89	4 tpi-N	4	1,8
3 5/8	92	2 3/8 API	5	2,3
3 3/4	95	2 3/8 API	5	2,3
3 7/8	98	2 3/8 API	6	2,7
4	102	2 3/8 API	7	3,2
4 1/8	105	2 3/8 API	8	3,6
4 1/4	108	2 3/8 API	9	4,1
4 1/2	114	2 3/8 API	10	4,5
4 5/8	118	2 7/8 API	11	5,0
4 3/4	121	2 7/8 API	13	5,9
4 7/8	124	2 7/8 API	14	6,4
5	127	2 7/8 API	15	6,8
5 1/8	130	2 7/8 API	16	7,3
5 1/4	133	2 7/8 API	17	7,7
5 1/2	140	2 7/8 API	20	9,0
5 5/8	143	3 1/2 API	22	10,0
5 7/8	149	3 1/2 API	23	10,5
6	152	3 1/2 API	23	10,5
6 1/8	156	3 1/2 API	24	10,9
6 1/4	159	3 1/2 API	26	11,8
6 3/4	172	3 1/2 API	32	14,5
7 3/8	187	3 1/2 API	66	29,9
7 7/8	200	4 1/2 API	75	34,0
9	229	4 1/2 API	95	43,0
9 7/8	251	6 5/8 API	143	65,0
10 5/8	270	6 5/8 API	162	74,0
12 1/4	311	6 5/8 API	215	98,0

Table C.19 — Tungsten carbide button bit

Bit size		Thread	Approx. weight	
inch	mm		lb	kg
2 15/16	75	4 tpi-N	3	1,4
3	76	4 tpi-N	3	1,4
3 1/8	79	4 tpi-N	4	1,8
3 1/4	83	4 tpi-N	4	1,8
3 1/2	89	4 tpi-N	4	1,8
3 7/8	98	2 3/8 API	6	2,7
4	102	2 3/8 API	7	3,2
4 1/8	105	2 3/8 API	8	3,6
4 1/4	108	2 3/8 API	9	4,1
4 1/2	114	2 3/8 API	10	4,5
4 3/4	121	2 7/8 API	13	5,9
4 7/8	124	2 7/8 API	14	6,4
5	127	2 7/8 API	15	6,8
5 1/8	130	2 7/8 API	16	7,3
5 1/4	133	2 7/8 API	17	7,7
5 1/2	140	2 7/8 API	20	9,0
5 5/8	143	3 1/2 API	22	10,0
5 7/8	149	3 1/2 API	23	10,5
6	152	3 1/2 API	23	10,5
6 1/8	156	3 1/2 API	24	10,9
6 1/4	159	3 1/2 API	26	11,8
6 3/4	172	3 1/2 API	32	14,5
7 3/8	187	3 1/2 API	62	28,1
7 7/8	200	4 1/2 API	78	35,5
9	229	4 1/2 API	98	44,5
9 7/8	251	6 5/8 API	143	65,0
10 5/8	270	6 1/2 API	162	74,0
11	279	6 1/2 API	167	76,0
12 1/4	311	6 1/2 API	215	98,0

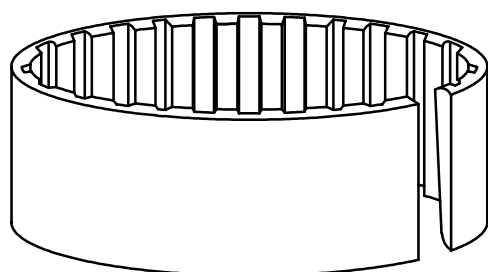
C.10 Examples of core lifter and sample retainer design

Core lifters are used to break off the core sample at the end of a coring run and then to retain the sample within the corebarrel for return to the surface. Figure C.13 shows a few of the more common types used.

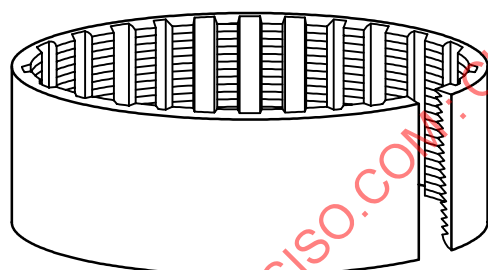
C.10.1 Typical corebarrel lifters



a) Plain



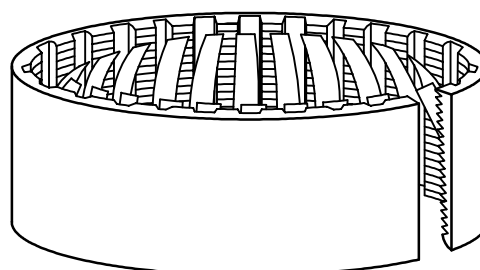
b) Internal slotted



c) Internal slotted and serrated



d) Internal slotted with basket fingers



e) Internal slotted and serrated with basket fingers

Figure C.13 — Typical corebarrel lifters

C.10.2 Typical sampler retainers

Sample retainers are used to retain the soil sample within the sampling tube as the sample tube is withdrawn to the surface. Figure C.14 shows a few examples of the most popular.

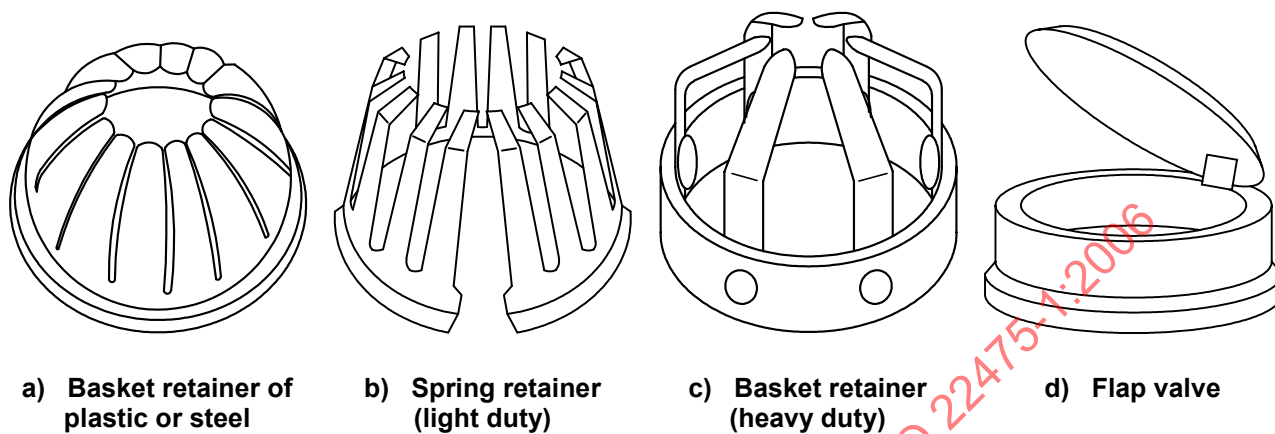
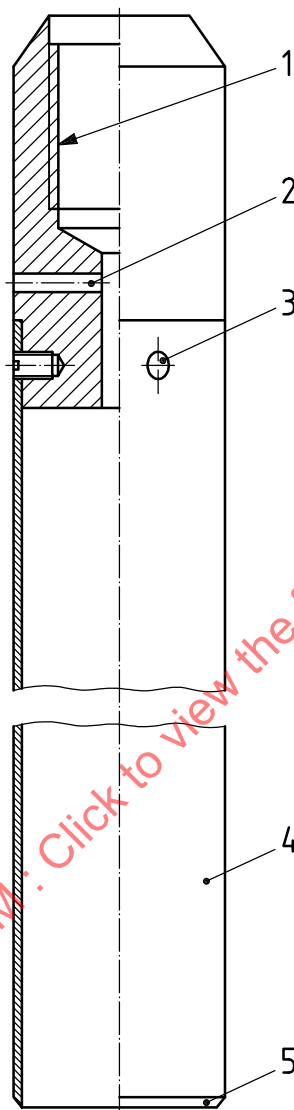


Figure C.14 — Typical sampler retainers

C.11 Sampling equipment

C.11.1 Thin wall sampler (Shelby tube)

See Figure C.15.



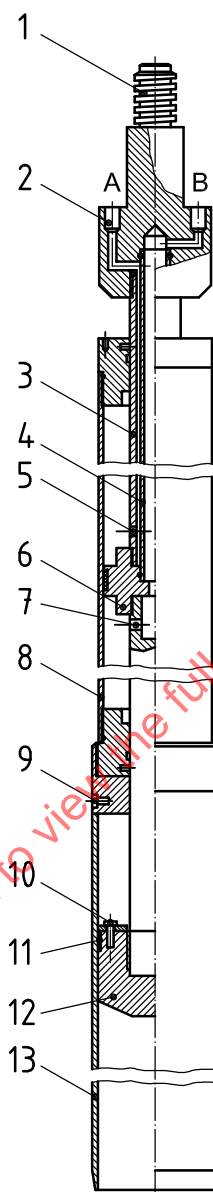
Key

- 1 sampler head with drill rod box connection
- 2 air relief port
- 3 grub screws (3) secure sample tube to head
- 4 thin wall Shelby tube
- 5 chamfered cutting edge

Figure C.15 — Thin wall sampler (Shelby tube)

C.11.2 Hydraulic piston sampler

See Figure C.16.



Key

- 1 drill rod pin
- 2 1/4" BSP hose connection
- 3 outer conductor tube
- 4 inner conductor tube
- 5 oil port A
- 6 inner piston
- 7 oil port B
- 8 hydraulic cylinder (5 litre)
- 9 grub screw for securing sample tube
- 10 black plate with allen-cap screw
- 11 piston seal
- 12 piston head
- 13 aluminium sample tube

Figure C.16 — Hydraulic piston sampler

C.11.3 Stationary piston sampler

Figure C.17 shows a stationary piston sampler with a 50-mm diameter liner for taking samples in soft to stiff cohesive soils and silts (sampling category A).

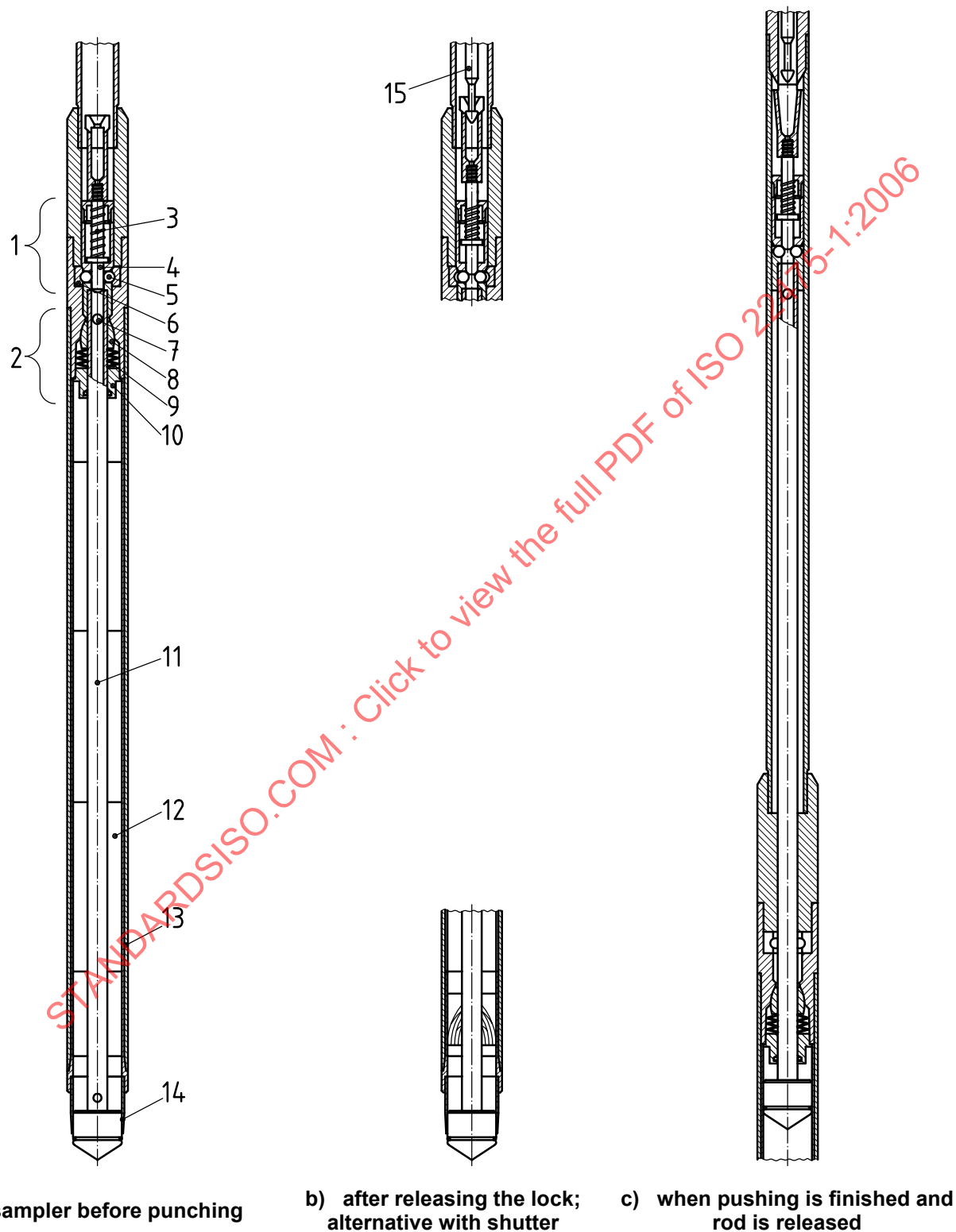


Figure C.17 — Stationary piston sampler with a 50-mm diameter liner — Sampling category A

Key

- 1 lock
- 2 brake
- 3 spring
- 4 plunger
- 5 ball
- 6 hardened ring
- 7 vent
- 8 wedges
- 9 springs
- 10 set screw
- 11 piston rod
- 12 sample tube
- 13 outer cylinder
- 14 cutting edge
- 15 release rod

a To be adjusted based on the material.

Figure C.17 (*continued*)

Figure C.18 shows the different parts of a stationary piston sampler with a 50-mm liner.

