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Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for the sampling of soil, rock and groundwater

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

Partie 1: Principes techniques pour le prélèvement des sols, des roches et des eaux souterraines

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

Page

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Foreword

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

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

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

This second edition cancels and replaces the first edition (ISO 22475-1:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

— clauses on groundwater measurement will be part of ISO 18674-4;

— new sampling categories for soils have been added;

— editorial updates have been made.

A list of all parts in the ISO 22475 series can be found on the ISO website.

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

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Geotechnical investigation and testing — Sampling methods and groundwater measurements —

Part 1: Technical principles for the sampling of soil, rock and groundwater

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1 Scope

This document deals with principles of sampling of soil, rock and groundwater as part of the programme of geotechnical investigation and testing.

NOTE 1 This document fulfils the requirements for sampling of soil, rock and groundwater, and groundwater measurements as part of the programme of geotechnical investigation and testing according to EN 1997-1 and EN 1997-2.

The aims of such ground investigations are:

a) to recover soil, rock and water samples of a quality appropriate to assess the general suitability of a site for geotechnical engineering purposes and to determine the required ground characteristics in the laboratory;

b) to obtain information on the sequence, thickness and orientation of strata and discontinuities;

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.

Soil sampling for the purposes of agricultural and environmental soil investigation is not covered.

NOTE 2 Guidance on soil sampling for these purposes including of contaminated or potentially contaminated sites is provided in the ISO 18400 series. ISO 18400-204 provides in addition guidance on sampling and measurement of soil (ground) gas.

NOTE 3 The sampling methods, presented in this document may not be suitable for all types of soil e.g. peat with strong fibrous structure.

NOTE 4 Some of the sampling methods presented in this document are suitable for both soil and rock.

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 5 Water sampling for these purposes can be found in the ISO 5667 series.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 14689, *Geotechnical investigation and testing — Identification, description and classification of rock*

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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*

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

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 98-3:2008/Suppl 1:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) — Supplement 1: Propagation of distributions using a Monte Carlo method*

ISO/IEC Guide 98-1, *Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement*

3 Terms, definitions and abbreviated terms

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

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

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

3.1 Ground investigation methods

3.1.1
trial pit
open excavation constructed to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.2
shaft
open or steeply inclined excavation, typically more than 5 m deep, constructed to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.3
heading
adit

small tunnel driven horizontally or with a slight inclination from a *shaft* (3.1.2) or into sloping ground to examine the ground conditions in-situ, recover *samples* (3.3.4) or carry out field testing

3.1.4
borehole
hole of any predetermined diameter and length formed in any geological formation or manmade material by *drilling* (3.1.5)

Note 1 to entry: Investigations carried out in such a hole can be to recover rock, soil or water *samples* (3.3.4) from a specified depth or to carry out field tests and measurements.

3.1.5
drilling
process by which a *borehole* (3.1.4) is produced in any geological formation by rotary, rotary percussive, percussive, resonance/sonic or thrust methods and in any predetermined direction in relation to the *drill rig* (3.2.3)

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3.1.6
small diameter drilling
drilling (3.1.5) 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* (3.1.4)

3.2 Drilling rigs and equipment

3.2.1
drilling tool
device, which is attached to, or an integral part of, the drill string that is used for penetrating the geological formation as a cutting tool

3.2.2
drill bit
device, which is attached to, or an integral part of, the drill string that is used as a cutting tool to penetrate the formation being drilled by the *drilling method* (3.1.7) employed

3.2.3
drill rig
device which carries out the *drilling* (3.1.5) function

3.2.4
casing
tubing temporarily or permanently inserted into a *borehole* (3.1.4)

Note 1 to entry: It is used e.g. to stabilise it, to prevent the loss of *flushing medium* (3.2.5) to the surrounding formation or to prevent cross flow between different groundwater horizons.

3.2.5
flushing medium
liquid or gaseous medium to remove *cuttings* (3.3.10) from the *borehole* (3.1.4), to aid sampling and to lubricate and cool the *drilling tool* (3.2.1)

3.2.6
additive
substance added to the *flushing medium* (3.2.5) in order to affect or change its properties to improve its functioning and can include *borehole* (3.1.4) stabilization

3.2.7
core lifter
split, internally slotted or serrated conical spring steel ring fitted to the core barrel to hold and retain the *core sample* (3.3.8) whilst the core barrel is being hoisted from the *borehole* (3.1.4)

3.2.8
sample retainer
cylindrical device containing flexible spring fingers, hinged wedged-shaped fingers or a hinged flap mounted in a carrier ring and mounted at the lower end of the sampler tube and used to retain the *sample* (3.3.4) in the tube as the sampler is being lifted from the ground

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3.3 Sampling

3.3.1
sampling by drilling
continuous sampling
process by which *samples* (3.3.4) are obtained by the *drilling tools* (3.2.1) as the *borehole* (3.1.4) proceeds

Note 1 to entry: The *drilling* (3.1.5) 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 using sampler
process by which *samples* (3.3.4) are obtained by samplers from *trial pits* (3.1.1), *headings* (3.1.3), *shafts* (3.1.2) or *boreholes* (3.1.4) at selected positions

3.3.3
soil sampling by small diameter drilling
sampling by drilling (3.3.1) in soils using *drilling tools* (3.2.1) with a diameter greater than 30 mm but less than 80 mm

3.3.4
sample
representative specimen of rock, soil or groundwater recovered from a recorded location

3.3.5
sampling method
set of equipment and procedures employed in a sampling operation

3.3.6
sampling category
sampling methods (3.3.5) to enable a certain quality of soil or rock *samples* (3.3.4) to be obtained

3.3.7
sampling disturbance
changes to the sample due to the sampling operation

Note 1 to entry: These changes can be of physical, chemical and/or state properties of the sampled material.

3.3.8
core
core sample
cylindrical *sample* (3.3.4) of soil or rock obtained from a *borehole* (3.1.4)

3.3.9
block sample
sample (3.3.4) of soil or rock cut out by special techniques to minimise disturbance

3.3.10
cuttings
particles of geological formations formed in the *borehole* (3.1.4) by the cutting action of the *drilling tool* (3.2.1) and carried to the surface by the *flushing medium* (3.2.5) or by an appropriate device

3.3.11
suspended matter
abraded ground material in the *flushing medium* (3.2.5) generated by *drilling* (3.1.5), in which the individual particle size cannot be recognised with the naked eye

3.3.12
core run
length of core sampling in an exploratory hole defined by the start and end depths (or other linear measurement) of the sampling tool

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3.3.13
core loss
difference between a *core run* (3.3.12) and the length of the *core* (3.3.8) recovered

3.3.14
area ratio
C_a
ratio of the area of soil displaced by the sampler tube in proportion to the area of the *sample* (3.3.4):

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

Note 1 to entry: See Figure 1.

Note 2 to entry: Area ratio is expressed in %.

Note 3 to entry: Area ratio is one of the factors that determine the mechanical disturbance of the soil.

3.3.15
inside clearance ratio
C_i

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

Note 1 to entry: See Figure 1.

Note 2 to entry: Inside clearance ratio is expressed in %.

Note 3 to entry: Inside clearance ratio is one of the factors that determine the mechanical disturbance of the *sample* (3.3.4) caused by the friction on the inside wall of sample tube or of the liner.

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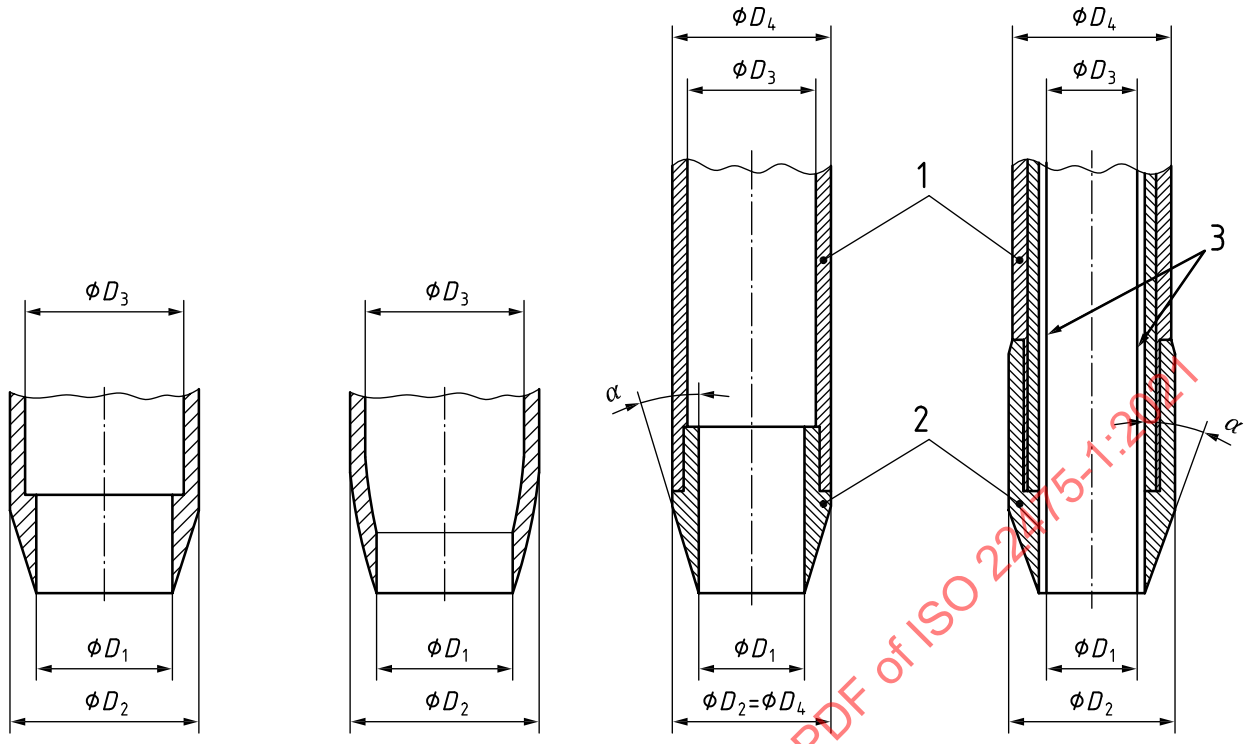

Key

D_1	inside diameter of the cutting shoe	α	taper angle
D_2	greatest outside diameter of the cutting shoe	1	sample tube
D_3	inside diameter of the sample tube or liner	2	cutting shoe
D_4	outside diameter of the sample tube	3	liner (optional)

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

3.3.16
total core recovery in rock
TCR
total length of *core sample* (3.3.8) recovered (solid and non-intact), expressed as a percentage of the length of the *core run* (3.3.12)

Note 1 to entry: See Figure 2.

3.3.17
rock quality designation
RQD
summed length of solid core pieces recovered in the *core run* (3.3.12) where each piece is at least 100 mm long between natural fracture, expressed as a percentage

Note 1 to entry: See Figure 2.

3.3.18
solid core recovery
SCR
length of solid *core* (3.3.8) recovered in the *core run* (3.3.12), where solid core has at least one full diameter, expressed as a percentage of the length of the core run

Note 1 to entry: See Figure 2.

Note 2 to entry: 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.

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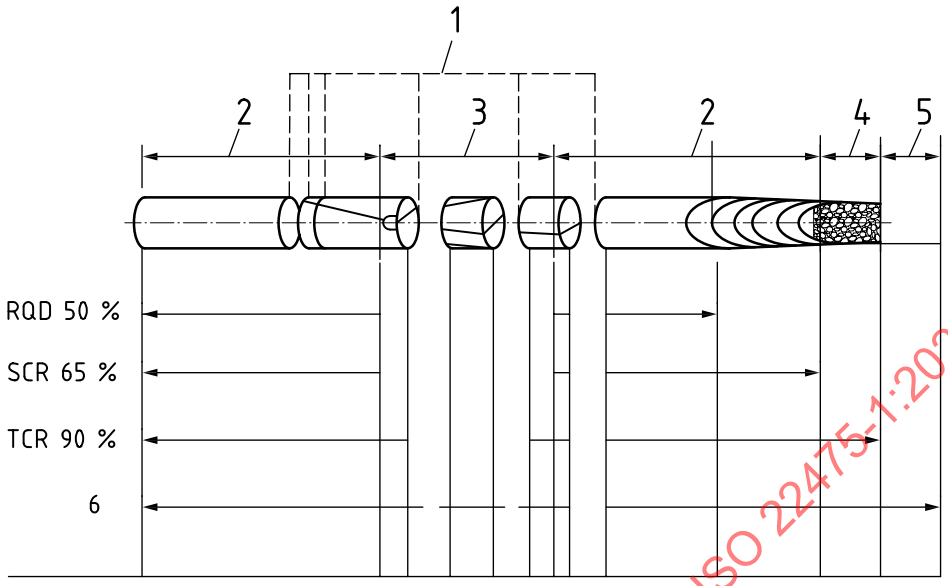
Note 3 to entry: Core without at least one full diameter is termed non-intact.



Key

1	*drilling* (3.1.5) induced fractures	RQD	*rock quality designation* (3.3.17)
2	at least one full diameter	SCR	solid core recovery
3	no single full diameter	TCR	*total core recovery in rock* (3.3.16)
4	non-intact		
5	no recovery		
6	core run		

NOTE All features shown are natural discontinuities unless stated otherwise.

Figure 2 — Application of fracture state terms for rock cores

3.3.19
sample recovery ratio in soil
TC
ratio of the length of the *sample* (3.3.4) l_g to the length of the sample run H

Note 1 to entry: See Figure 3.

3.3.20
net sample recovery ratio
IC
ratio of the net length of the *sample* (3.3.4) l_n to the length of the sample run H

Note 1 to entry: See Figure 3.

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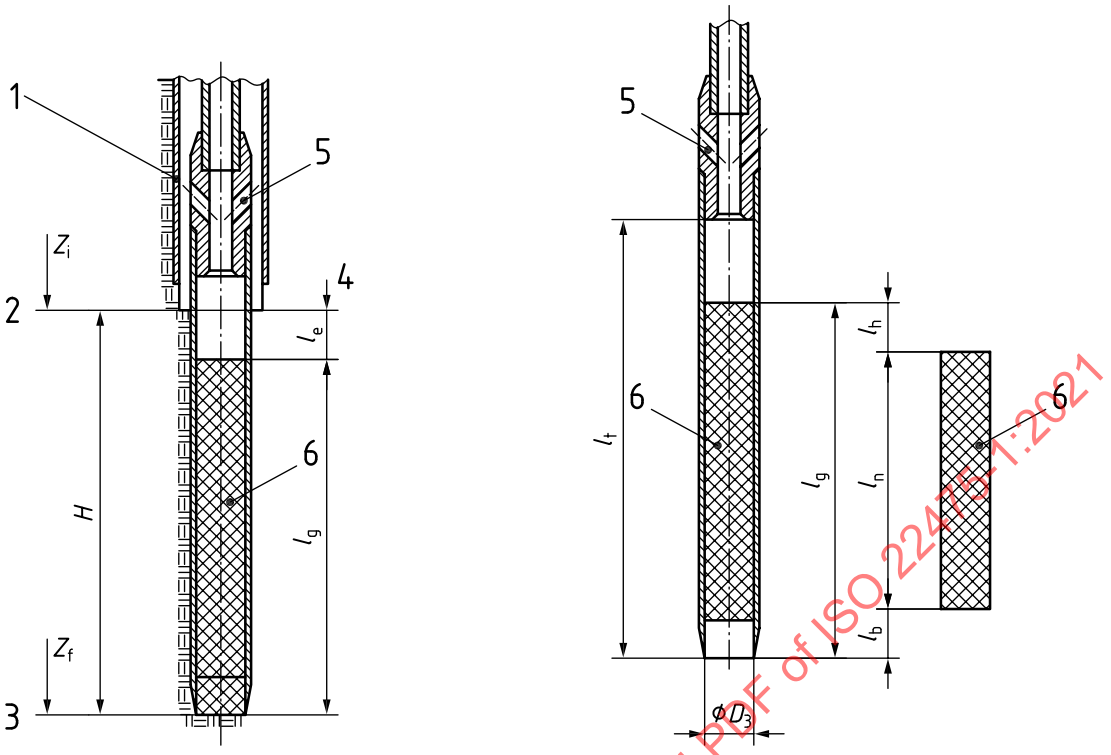

a) Before withdrawal of sampler **b) After withdrawal of sampler**

Key

1	*casing* (3.2.4)
2	beginning of coring
3	end of coring
4	bottom of predrilled *borehole* (3.1.4)
5	vent-hole
6	sample
D_3	the 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 with drawing the sampler
Z_i	depth under the natural ground level of the borehole bottom before sampling, and of the beginning of the following *core run* (3.3.12)
l_b	length of the lower part of the sample, which was remoulded or lost
l_e	difference between the sample run and the actual length of the sample
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
l_h	length of the remoulded or polluted upper part of the sample
l_n	net length of the sample, before its conditioning
l_t	effective (useful) length of the sampling tube

Figure 3 — Lengths of core run and sample

3.3.21
thin-walled
<soil sampler> having a low *area ratio* (3.3.14), a low taper angle and a thin edge

3.3.22
thick-walled
<soil sampler> having an *area ratio* (3.3.14), taper angle and/or edge larger than that of a *thin-walled* (3.3.21) sampler

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3.4 Rock and soil properties

3.4.1
structure
pattern of discontinuities in soil and rock mass which subdivides the mass into individual units

3.4.2
texture
size, shape and arrangement of the grains for soil and rock

3.5 Abbreviated terms

AS	disturbed sample from augering
B	bulk disturbed samples
BS	hand trimmed block sample
CP	cable percussion drilling
CPT	cone penetration testing
CS	rotary core sample
D	small disturbed sample
DLDS	Deltares large diameter sampler
DT	double tube drilling
GS	grab sample
HSAS	liner sample from hollow stem augering
LS	large samplers
OS	open-tube samplers
PE	percussion
PS	piston samplers
PU	pushed
RC	rotary coring
RO	rotary open holing
S-SPT	standard penetration test sampler
S-TP	disturbed sampling from trial pit
S-BB	sampling from borehole bottom
SN	resonance/sonic drilling
ST	single tube drilling
T/W	thin-walled
TK/W	thick-walled

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TP trial pitting

TT triple tube drilling

WS window sampler

4 Equipment

4.1 Requirements for the drilling rigs and equipment

Drilling rigs with appropriate stability, power and equipment such as drill rods, casing, core barrels 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.

If applicable, the drilling and sampling equipment shall be in accordance with ISO 3551-1, ISO 3552-1 and ISO 10097-1.

4.2 Drilling parameters

The drilling rig and equipment shall allow control of relevant drilling functions listed below. Following drilling parameters should be measured and recorded against depth, if required and applicable:

— drill head rotational torque (Nm);

— drill head rotational speed (rpm);

— 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).

NOTE Measuring while drilling is covered by ISO 22476-15.

4.3 Safety and special requirements

Precautions regarding the safety on the site and the safety of the working practices for the execution of boreholes, trial pits, heading and shafts shall be taken.

NOTE EN 16228-1 and EN 16228-2 deal with safety matters concerning drill rigs.

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 taken into consideration.

Trial pits, other excavations, headings and shafts shall be planned and executed under supervision. Slopes and walls can undergo sudden failure and shall be respected as such.

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Excavations present gas and groundwater accumulation hazards, which shall also be considered in their planning and execution.

NOTE ISO 18400-103 provides general guidance on safety during sampling including on contaminated and potentially contaminated sites.

5 Procedures

5.1 General requirements for sampling

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

The type and extent of sampling shall be specified in advance according to the purpose of the project, the geological and hydrogeological conditions and the anticipated field and laboratory testing.

NOTE For further details see EN 1997-2.

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.

5.2 Selection of techniques and methods

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

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

A specific sampling category shall be selected in order to enable a required sample quality to be obtained in soil and rock (see Table 1 and Table 2).

Different degrees of disturbance of the sample can be expected when using different sampling methods. The quality 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 types of 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.

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

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

5.3 Sampling categories for soil

5.3.1 General

Five sampling categories are defined for soil sampling. These represent the best practices that should be followed in order to match the quality of soil samples for suitable laboratory testing.

The best practices that should be followed by drilling for each sampling category can never guarantee that a certain quality is obtained as many factors can cause soil disturbance that are beyond the influence of the drilling.

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5.3.2 Sample disturbance

Sample disturbance can cause a decrease in effective stress, a reduction in the inter-particle bonds, and a rearrangement of the soil particles, that determine the eventual quality of a soil sample.

NOTE An example for quality are given in Annex H.

Soil sample disturbances can be caused by:

— hard pieces such as gravel, shell fragments or wood in the soil, which can cause voids to develop along the sides of the sampling tube during the sampling process;

— soil adjustment caused by stress relief when making a borehole;

— disruption of the soil structure due to rotation, hammering or pushing the sampling tube into the soil stratum;

— tensile and torsional stresses which are produced in separating the sample from the subsoil;

— creation of a partial or full vacuum below the sample as it is extracted from the subsoil;

— expansion of gas during retrieval of the sampling tube as the confining pressure is reduced to zero;

— roughly removing the soil from the sampling tube;

— time causing disturbance in sampling and laboratory analysis;

— handling, transportation and storage (see Clause 9);

— crudely cutting the soil specimen to a specific size for a laboratory test;

— oxidation due to exposure to aerobic conditions;

— loss of soil moisture due to evaporation;

— geo-chemical processes due to temperature changes;

— physical disturbance due to freezing or damage of sampling containers;

— compaction and dewatering due to compression during sampling or extrusion of samples from sampling tubes;

— compaction and dewatering due to vibration during drilling, handling and transport;

— expansion due to pressure release at surface level.

It is recommended that laboratory testing be commenced as soon as practicable after sampling has taken place, as sample quality may suffer from long-term storage.

5.3.3 Category A sampling

The aim of category A sampling is to obtain samples in which structure, texture, consistency and in-situ stresses are intact. This would allow laboratory testing for strength, compressibility and stiffness.

As a practical matter, it should be recognized that no soil sample can be taken from the ground and be in a perfectly undisturbed state. For special conditions high class reference samples may be useful, e.g. liquefaction potential of loose coarse soils or strength of very soft clays or peat with high water contents near the soil surface. For soft clays block sampling techniques such as the Laval sampler, Sherbrooke sampler or Deltares large diameter sampler (DLDS) may be used to take representative samples. For very soft peat the DLDS sampler may be considered. For loose coarse soils ground freezing or gel push sampling may be considered. Details of these special samplers and techniques are presented in C.15.

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5.3.4 Category B sampling

The aim of category B sampling is to obtain samples in which the structure, texture and consistency are intact. This would allow laboratory testing such as permeability, porosity and density of fine soils and detailed layer boundary analyses.

5.3.5 Category C sampling

The aim of category C sampling is to obtain samples in which the structure and texture are intact. This would allow laboratory testing such as the determination of the water content.

NOTE 1 For loose coarse soils and silts this is difficult to achieve without additional preparation such as ground freezing or special sampling techniques. Usually, the sampling process disturbs the fabric of loose coarse soils, often increasing its packing and reducing its moisture content.

For very soft clays and peats near the soil surface with high water contents, care should also be taken to prevent compression, deformation and dewatering of the samples.

NOTE 2 Deviations of in-situ water content are expected in loose coarse soils, silt and peat. The presence and depth of loose coarse soils in a soil profile can often be determined by carrying out appropriate field testing in the vicinity before sampling.

NOTE 3 To avoid changes in soil moisture during handling, transport and storage, it could be considered to determine the water content of a soil layer or unconsolidated material on site. For this purpose, a sub sample with a known volume of material could be taken on site with minimal disturbance of the water content immediately after sampling. The weight of the material can be determined on site.

5.3.6 Category D sampling

The aim of category D sampling is to obtain samples in which the structure is intact. This would allow laboratory testing for particle size distribution and Atterberg limits as well as organic content.

NOTE For non-cohesive unconsolidated sands this means that all the fines are still contained in the sample. It is possible that secondary minerals such as glauconite or shells and calcareous skeletons have been crushed as a result of which the in-situ grain size distribution can deviate.

5.3.7 Category E sampling

The category E sampling only obtains samples where all the initial soil properties have changed is wholly or partially separated due to the drilling process. Typically, the fine grain content is missing. Furthermore, all initial soil properties have changed. Based on these samples only a rough indication of soil type, strata type and thickness (approximately 0,5 m) can be determined.

EXAMPLE Cuttings from rotary drilling or samples taken from a bailer during cable tool percussion drilling.

5.4 Sampling categories for rock

5.4.1 General

Five sampling categories are defined for rock sampling. These represent the best practices that should be followed in order to match the quality of rock samples for suitable laboratory testing.

The best practices that should be followed by drilling for each sampling category can never guarantee that a certain quality is obtained as many factors can cause rock disturbance.

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5.4.2 Sampling disturbance

Sample disturbance can be ground-related whilst others relate directly to the drilling. Disturbances can be caused by:

— rock adjustment caused by stress relief when making a borehole;

— reduction in the inter-particle bonds;

— rearrangement of the rock grains;

— disruption of the rock structure due to rotation, hammering or pushing the sampling tube (core barrel) into the rock stratum;

— tensile and torsional stresses in separating the sample from the rock mass;

— inappropriate core size, core run length, core bit, flushing medium;

— inappropriate thrust and torque during drilling;

— removal of the rock from the sampling tube;

— time causing disturbance in sampling and laboratory analysis;

— handling, transportation and storage (see Clause 9);

— crudely cutting the rock specimen to a specific size for a laboratory test;

— oxidation due to exposure to aerobic conditions;

— loss of moisture due to evaporation (more critical for mudstones);

— geo-chemical processes due to temperature changes and oxidation;

— physical disturbance due to freezing, heating or damage of sampling containers;

— compaction and dewatering due to vibration during drilling, handling and transport;

It is recommended that laboratory testing be commenced as soon as practicable after sampling has taken place, as sample quality may suffer from long-term storage.

Any combination of the factors listed above could cause a reduction in the achievable quality and so whilst category A sampling can be specified, in practice if inappropriate combinations of drilling equipment are employed, the sampling category achieved could be one or more classes lower.

5.4.3 Category A sampling

The aim of category A sampling is to obtain samples in which structure, texture, strength and in-situ stresses are intact. This would allow laboratory testing for strength, and deformation properties. In addition, category A sampling would allow discontinuities and RQD to be accurately assessed.

As a practical matter, it should be recognized that no rock sample can be taken from the ground and be in a perfectly undisturbed state. For special conditions high class reference samples may be useful. For example, in weak rocks block sampling techniques may be used to take representative samples.

5.4.4 Category B sampling

The aim of category B sampling is to obtain samples in which the structure and texture are intact. This would allow laboratory testing such as permeability, porosity and density of rock samples and detailed layer boundary analyses. It should be noted that category B sampling can also allow non-definitive strength determinations to be made via tests such as the point load test. In addition, category B sampling would also normally allow discontinuities and RQD to be accurately assessed.

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5.4.5 Category C sampling

The aim of category C sampling is to obtain samples in which the overall rock structure and texture are intact. This would allow laboratory testing such as the determination of the water content. Fine strata boundaries and weathering should be discernible and in favourable circumstances (see 5.4.1) it may be possible to identify discontinuities.

5.4.6 Category D sampling

The aim of category D sampling is to obtain samples in which the overall material structure is intact, and in which mineralogical composition is unchanged. This would allow laboratory testing for thin sections and Atterberg limits. Layer succession and broad strata boundaries should be discernible.

5.4.7 Category E sampling

The category E sampling only obtains samples where all initial rock properties have changed due to the drilling process. Based on these samples only a rough indication of strata type and layer thickness (approximately 0,5 m) can be determined.

EXAMPLE Cuttings obtained from flush returns during rotary drilling.

5.5 Sampling in trial pits, other excavations, headings and shafts

Trial pits, other excavations, headings and shafts should be used to investigate the ground at a larger scale e.g. to get information on the composition, sequence, structure, geotechnical units, excavation circumstances and orientation of strata and possible rock surface.

Without groundwater lowering the depth is often limited to shallow depth above the groundwater table surface in permeable ground. Generally, test pits down to 5 m in depth can be carried out with ordinary available excavators. To reach larger depth special equipment is needed at sequenced excavation levels.

The following shall be determined and reported at least:

— geometry of the pit/excavation/heading/shaft;

— occurrence of very coarse material (cobbles and boulders);

— stratigraphy and recognised geological units;

— stability of excavated walls;

— inflow of groundwater and observed groundwater level.

5.6 Requirements for ground investigation sites and points

Ground investigation points on land shall be set out on the site before the investigation process commences. The "as-built" location and elevation shall be surveyed and indicated on a site plan on completion of the investigation.

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

Guidelines are given in ISO 18400-103. Unless deliberately located to investigate proposed foundation lines or existing foundations trial pits should be situated outside the planned foundation area as the excavation can loosen the ground. These 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.

Trial pits (with or without access), headings and shafts shall be constructed in accordance with appropriate national or international standards; national safety regulations shall be taken into

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consideration. 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.

Visual logging, photographic evidence of the soil strata, sampling and field tests should be carried out during and immediately after excavation.

The environmental impact of drilling and sampling shall be considered. Special requirements may apply on some ground investigation sites, e.g. water supply areas, near water courses and when drilling into aquifers.

5.7 Preliminary information needed before starting sampling

At least the following preliminary information shall be available at the site before the sampling can start (see e.g. Annex A, Table A.1):

a) objective of the sampling and groundwater measurements;

b) location of the planned borehole or excavation or groundwater measurements;

c) orientation, inclination and acceptable deviations in boreholes;

d) surveying requirements;

e) expected geological and hydrogeological conditions;

f) required accuracy and uncertainty of measurements in accordance with ISO/IEC Guide 98-3, ISO/IEC Guide 98-3:2008/Suppl 1:2008 and ISO/IEC Guide 98-1;

g) frequency of measurements;

h) environmental and safety risks associated with e.g. flushing media or suspensions intended to be used as well as regulations for their use and possible presence of flammable, explosive or toxic gas underground mine workings or deposited wastes;

i) possible risks, e.g. underground and overhead services, traffic, unexpected and unexploded ordnance, contamination;

j) identification and planned depth of borehole and/or excavation;

k) sampling method and category intended;

l) requirements on numbering of boreholes, excavations or samples;

m) sample handling, storage and transport intended;

n) field tests intended;

o) borehole or excavation completion method and site reinstatement (backfilling or grouting);

p) environmental care;

q) emergency arrangements;

r) name of contact person;

5.8 Backfilling and site reinstatement

When sampling is completed the site shall be restored and no hazards shall be left which would be of potential harm to the public, the environment or animals. The backfilling shall be carried out taking into consideration national regulations, technical or authority requirements, the strata, contamination of the ground and its bearing capacity.

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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.

Unless an exploratory hole is required to be kept open for a specific purpose, it should be backfilled and reinstated so as to minimise subsequent depression at ground level due to subsequent settlement to the backfill material.

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. Techniques which prevents voiding shall be used during the placement of the filling material in the borehole.

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.

6.1.3 There are five categories A to E of sampling methods for soil (see Table 1).

6.2 Sampling by drilling (continuous sampling)

6.2.1 General

6.2.1.1 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 1) gives normally the most valuable information of the ground conditions of all ground investigation methods by drilling. Sampling by drilling is therefore the preferred sampling method for heterogeneously layered soils.

6.2.1.2 Drilling methods and equipment shall be selected as a function of the required sampling category (see Table 1), tests and/or groundwater measurements to be carried out in the borehole.

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

6.2.1.4 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, it shall be selected with

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sufficient annular clearance and withdrawn slowly. An adequate water pressure shall be maintained in the borehole.

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Table 1 — Sampling by drilling in soils

Column		1	2	3	4	5	6	7	8	9	10
Line		Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
		Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
1	a	Rotary drilling	No	Drilling tool	Rotary dry core drilling[c]	Single-tube core barrel	100 to 200	coarse gravel, cobbles, boulders	clay, silt, fine sand, silt	D	Good interior, outside dried out see 6.2.2.1
	b					Hollow stem auger with core barrel	100 to 300		clay, silt, sand, organic soils	B (A)	see 6.2.2.2
2	a		Yes	Drilling tool	Rotary core drilling	Single tube core barrel	100 to 200	coarse soils	clay, clayey and cemented composite soils, boulders	D	—
	b					Double-tube core barrel[a]				C (A-B)	
	c					Triple-tube core barrel[a]				A	

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
3		Yes	Drilling tool	Rotary core drilling	Double/triple-tube core barrel with extended inner tube	100 to 200	gravel, cobbles, boulders	clay, silt	B (A)	—
4		No	Drilling tool	Auger drilling	Drill rods with shell or flight auger; hollow stem auger	100 to 2 000	boulders larger than $D_e/3$	all soils above water surface, all fine soils below water surface	D (C)	—
5		Yes	Reverse flow of flushing medium	Reverse circulation drilling	Drill rods with hollow chisel	150 to 300	—	all soils	E (D)	—

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
6		No	Drilling tool	Auger drilling with light equipment	Shell auger or spiral flight auger	40 to 80	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; fine soils below water surface	E[f]	Only to be used for shallow depths

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
7		No	Drilling tool	Percussive core drilling	Percussion clay cutter with cutting edge inside; also, with sleeve[b]	80 to 200	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 $D_e/3$	fine soil: B (A) coarse soil: C (B)[g]	Plotting of driving chart on the basis of number of impacts
8	Hammer driving	No	Drilling tool	Percussive drilling	Percussive clay cutter with cutting edge outside[b]	150 to 300	soils with a particle size larger than $D_e/3$	gravel and soils with a particle size up to $D_e/3$	D	
9		No	Drilling tool	Small diameter hammer driving	Hammer driving linkage with tube sampler (window)	30 to 80	soils with a particle size larger than $D_e/2$	soils with a particle size up to $D_e/5$	E[f]	Only to be used for shallow depths

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
10	Rotary hammer driving	Yes	Drilling tool	Rotary percussive drilling	Single- or double-tube core barrel	100 to 200	composite and pure sands with a particle size larger than 2,0 mm, gravel, firm and stiff clays	clay, silt, fine sand	fine soil: B (A) coarse soil: D (C)	—
11	Vibration drilling with an optional slow rotation	No (only for lowering casing)	Drilling tool	Resonance/ sonic drilling	Thick wall sampler or single tube core barrel with optional lining tube	80 to 200	—	all soils	fine soil: D (C) coarse soil: D	—

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
12	Percussion	No	Drilling tool	Cable percussion drilling	Cable with clay cutter	150 to 500	gravel above water surface, silt, sand and gravel below water surface	clay and silt above water surface, clay below water surface	D (C)	—
13		No	Drilling tool	Cable percussion drilling	Cable with shell bailer	100 to 1 000	recovery above water surface	gravel and sand in water	E (D)	Can also be used in fine soils if water is added
14	Pneumatic/ hydraulic continuous thrust	No	Drilling tool	Small diameter pneumatic/ hydraulic continuous thrust drilling	Pneumatic/hydraulic continuous thrust linkage, with tube sampler	30 to 80	dense and coarse-grained soils	clay, silt, fine sand	E[f]	Only to be used for shallow depths

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

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Table 1 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method				Equipment		Guideline for application and limitations [d]		Sampling categories[e]	Remarks
	Soil cutting technique[b]	Use of flushing medium	Extraction of sample by	Designation	Tool	Guideline values of borehole diameter range mm	Unsuitable for[d]	Preferred method for[d]		
15	Grabbing	No	Drilling tool	Grab drilling	Cable with grab	400 to 1 500	firm, fine soils, boulders of size larger than $D_e/2$	gravel, boulders of size less than $D_e/2$, cobbles	above water surface: D below water surface: E	—

[a] Conventional or wireline core barrel.

[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.

[d] D_e is the internal diameter of the sampling tool.

[e] The sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases.

[f] Sampling category D is sometimes possible in fine soils.

[g] A method according to sampling category for coarse soils is given in Annex G.

NOTE 1 Straight flush drilling is not covered because the sample quality that can be achieved are mostly worse than 5.

NOTE 2 This table can also be used for rock, if suitable, e.g. weak to extremely weak rock.

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6.2.2 Sampling by rotary drilling

6.2.2.1 Sampling by rotary dry core drilling

6.2.2.1.1 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 a 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.

6.2.2.1.2 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 core drilling is generally unsuitable for sampling coarse gravel, cobbles and boulders.

6.2.2.2 Sampling by rotary core drilling

6.2.2.2.1 The equipment for sampling by rotary core drilling shall consist of a tube system fitted with a bit at its lower end which 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 may be used.

6.2.2.2.2 The single tube core barrel shall consist of a core tube with a bit at its lower end and a core barrel 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 should pass between the inside of the core tube and the recovered soil core continuously washing the length of the recovered sample.

6.2.2.2.3 The double tube core barrel shall consist of two concentric tubes and a bearing arrangement in the core barrel head which allows the inner tube to remain stationary whilst the outer tube is rotated by the drill string. A core lifter should be fitted between the core bit and the inner tube. The flushing medium shall pass through the annulus between the inner and outer tubes thus protecting the recovered core sample from damage. The double tube core barrel 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 should assist in improving core recovery in certain soil types and contain and protect the sample during transport. The double tube core barrel 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.

6.2.2.2.4 The triple tube core barrel is similar in construction to the double tube design but shall be fitted with an additional third tube within the inner tube as standard. This third tube should be a thin-walled 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 core barrel 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.

6.2.2.2.5 Sampling by rotary core drilling is generally suitable for clay, clayey and cemented composite soils and boulders; but it is unsuitable for all coarse soils.

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

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6.2.2.3 Sampling by flight auger drilling

6.2.2.3.1 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.

6.2.2.3.2 With the continuous sampling method, the flights act as a screw conveyor and continuously can bring the cuttings to the surface. The rotation of the auger shall be permanent and the penetration can be easier with additive movements of going up and down. Additional sections of auger can be added until the required depth is reached. At the mouth of the borehole, the obtained samples are remoulded.

6.2.2.3.3 With the non-continuous sampling method, the flight auger can be 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 may 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.

6.2.2.3.4 Sampling by flight auger drilling shall be only used if the borehole is stable.

6.2.2.3.5 Sampling by flight auger drilling is suitable for fine soils and soils above the groundwater surface.

6.2.2.4 Sampling by shell auger drilling

6.2.2.4.1 In sampling by shell auger drilling, a shell auger shall be used as the sampling tool. The auger shall be screwed into the soil with the penetration rate suitable for the auger rotational speed. The sampling length into the soil may 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.

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

6.2.2.4.3 Sampling by shell auger drilling is suitable for fine soils and clay to medium gravel above groundwater surface.

6.2.2.5 Sampling by reverse circulation drilling

6.2.2.5.1 In sampling by reverse circulation drilling, the flushing fluid shall pass 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. In certain cases, duplex drill rods can be used to protect the borehole wall.

6.2.2.5.2 The borehole diameter should be between 150 mm and 300 mm.

6.2.2.5.3 This sampling technique is suitable for all soils.

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6.2.3 Sampling by use of hammer driving methods

6.2.3.1 Sampling by percussive drilling

In sampling by percussive drilling, a clay cutter tube device with an internal cutting edge at the lower end shall be 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 $D_e/3$, where D_e is the internal diameter of the sampling tool, and with a borehole diameter up to 300 mm. The sample shall be retained within the clay cutter by a suitable retainer.

6.2.3.2 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 shall be 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 shall be retained within the clay cutter tube.

6.2.4 Sampling by cable percussion drilling

6.2.4.1 In sampling by cable percussion drilling, a tool string comprising sampling, drilling or bailing tools shall be attached to the drilling line (wire rope), which passes over a crown sheave at the top of the tripod/mast structure and then to a winch drum on the base unit. The tool string shall be raised by the winch and dropped by freefall action causing crushing and fragmentation of the formation and loosening of unconsolidated soils in the borehole being drilled.

6.2.4.2 The tools used when drilling by cable percussion in fine soils shall comprise a clay cutter or stubber and in coarse soils shall comprise a shell (bailer). These are used in conjunction with one or two additional weights (sinker bars). Chiselling may be used to penetrate boulders and other hard obstructions such as concrete and to prove the presence of harder formations at the base of a borehole.

6.2.4.3 Samplers used when sampling by cable percussion are typically driven thick-walled or thin-walled open tube samplers.

6.2.4.4 When drilling in silts, sands and gravels the water level in the casing shall be higher than the water level in the surrounding soil outside the casing to minimise soil disturbance.

6.2.5 Sampling by hollow stem auger drilling

6.2.5.1 In sampling by hollow stem auger drilling. the hollow stem auger which shall consist 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 6.2.2.3). Additional sections of hollow stem auger may be added till the required depth is reached.

6.2.5.2 Once the required depth is reached, a sampling system or core barrel 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.

6.2.6 Sampling by grab drilling

6.2.6.1 In sampling by grab drilling, the sampling tool shall be a cable with grab.

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

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6.2.6.3 This sampling technique is the preferred method for gravel, cobbles and boulders of size less than $D_e/2$. It is unsuitable for firm, fine soils, boulders of size larger than $D_e/2$.

6.2.7 Soil sampling by small diameter drilling

6.2.7.1 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 1 can be used.

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

6.2.7.3 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.

6.2.7.4 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.

6.2.8 Sampling by resonance drilling

In sampling by resonance (sonic) drilling, a tube fitted with a bit at its lower end shall be fed into the soil or rock by vibration of a frequency variable from 30 Hz to 150 Hz. The frequency shall be adjusted appropriate to the depth of the borehole and the formation being drilled such that optimum resonance is maintained at all times. When the penetration rate is too low the core barrel can be rotated in order to distribute the resonant energy evenly. The core barrel can be equipped with a plastic lining tube.

Dedicated samplers may also be incorporated into the drilling technique and advanced solely by either static or dynamic means, without the use of resonance.

6.3 Sampling using samplers

6.3.1 General

6.3.1.1 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.

6.3.1.2 Depending on the soil conditions, different samplers can be used (see Table 2, see Annex D). Usually sampling with samplers can be 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.

6.3.1.3 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.

6.3.1.4 Drilling of the casing with percussion is not allowed to the full depth in case of category A sampling when the water level or fluid pressure in the borehole is lower than in the surrounding soil.

6.3.1.5 If a casing is used in sensitive clays, it may 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.

6.3.1.6 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.

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6.3.1.7 Before taking undisturbed samples from borehole bottom, any loose or disturbed material shall be removed. In 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.

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Table 2 — Tube and block samplers

Column	1	2	3	4	5	6	7
Line	Type of sampler	Preferred sample dimensions		Technique used	Applications and limitations		Sampling category for soils as in column 6[a]
		Diameter mm	Length mm		Unsuitable for	Recommended for use in	
1	thin-walled (OS-T/W)	70 to 120	250 to 1 000	static or dynamic	gravel, loose sand below water surface, firm fine soils, soils including coarse particles	fine or organic soils of soft to stiff consistency	A
						(medium) dense sand below water surface	C (B)
						fine or organic soils of very stiff consistency	B (A)
2	thick-walled[b] (OS-TK/W)	>75	250 to 1 000	dynamic	gravel, sand below water surface, very soft and very stiff fine or organic soils, soils including coarse particles	fine or organic soils of soft to stiff consistency, and including coarse particles	C (B)
3	thin-walled (PS-T/W)	50 to 100	600 to 1 000	static	gravel, very loose and dense sands, very stiff fine or organic soils, soils including coarse particles	fine or organic soils of very soft or stiff consistency, and sensitive soils	A
						sand above groundwater	C
4	thick-walled (PS-TK/W)	50 to 100	600 to 1 000	static	gravel, sand below water surface, soft and very stiff fine or organic soils, soils including coarse particles	fine or organic soils of soft to stiff consistency, and sensitive soils	B (A)

Key

OS-T/W open-tube samplers, thin-walled

OS-TK/W open-tube samplers, thick-walled

PS-T/W piston samplers thin-walled

PS-TK/W piston samplers thick-walled

LS large sampler

S-SPT SPT sampler

[a] If the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – the higher quality indicated in the brackets can be achieved.

[b] Includes windowless samplers.

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Table 2 *(continued)*

Column	1	2	3	4	5	6	7
Line	**Type of sampler**	**Preferred sample dimensions**		**Technique used**	**Applications and limitations**		**Sampling category for soils as in column 6[a]**
		Diameter mm	**Length mm**		**Unsuitable for**	**Recommended for use in**	
5	cylinder (LS)	250	350	static or rotating	sand	clay, silt	A
6	cylinder (S-SPT)	35	450	dynamic	coarse gravel, boulders	sand, silt, clays	D
7	windowless	44 to 120	500 or 2 000	static or dynamic	sand, gravel	silt, clay	D (C)

Key

OS-T/W open-tube samplers, thin-walled

OS-TK/W open-tube samplers, thick-walled

PS-T/W piston samplers thin-walled

PS-TK/W piston samplers thick-walled

LS large sampler

S-SPT SPT sampler

[a] If the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – the higher quality indicated in the brackets can be achieved.

[b] Includes windowless samplers.

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6.3.2 Sampling using the open-tube sampler and the piston sampler

6.3.2.1 General

For recovering samples from boreholes in fine, sandy and organic soils, open-tube or piston samplers can be used. These samplers should 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 open tube sampler can be pushed directly into soft to stiff soil.

6.3.2.2 General geometry

6.3.2.2.1 Tube inner diameters should be between 50 mm and 120 mm, 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.

6.3.2.2.2 The sampling tube length should preferably be not greater than 10 times the sample diameter. An effective sampling length of 0,45 m to 1,00 m should be sufficient for ordinary soil testing. Longer tubes may be used if friction reducing systems are applied.

6.3.2.3 Detailed geometry

6.3.2.3.1 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.

6.3.2.3.2 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, should be less than 15 %;

c) taper angles between 5° and 15° and area ratios up to 25 % may be considered, but a reduction in sample quality may result;

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 maximum inside clearance ratio C_i of 0,5 %. When assessing the inside clearance, the worst case of manufacturing tolerances shall be applied.

6.3.2.4 Preparation of tubes

6.3.2.4.1 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.

6.3.2.4.2 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, may not be used.

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6.3.2.5 Field procedure

6.3.2.5.1 The sampler shall be pushed or driven into the soil (see column 4 of Table 2). If dynamic driving is used, either by a drop weight, sliding hammer or percussive head, the number of blows should be kept to a minimum. Thin wall tube samplers should be pushed into the soil by continuous static thrust. All open tube samplers which are dynamically driven create disturbance within the sample leading to a reduction in the sample quality, particularly in fine and sensitive soils. This influence shall be considered when the field procedure is chosen.

6.3.2.5.2 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.

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

6.3.2.5.4 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.

6.3.2.5.5 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 to 20 min so that sufficient adhesion is developed between the sample and the sampling tube or liner.

6.3.2.5.6 After withdrawal the sampler should be disassembled and, if necessary, the samples should be carefully extracted without any bending or torsion. 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.

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

6.3.2.6 Sampling using the open-tube sampler

6.3.2.6.1 In addition to the components mentioned in 6.3.2.3, open-tube samplers (OS) consist of a sampler tube with overdrive space and a sampler head with non-return valve tube. An overdrive space into which the softened material in the borehole can pass shall be provided. 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 overdrive space.

6.3.2.6.2 Windowless samplers may also be used to sample fine soils. The windowless sampler is generally a category C or D sampler in fine soils.

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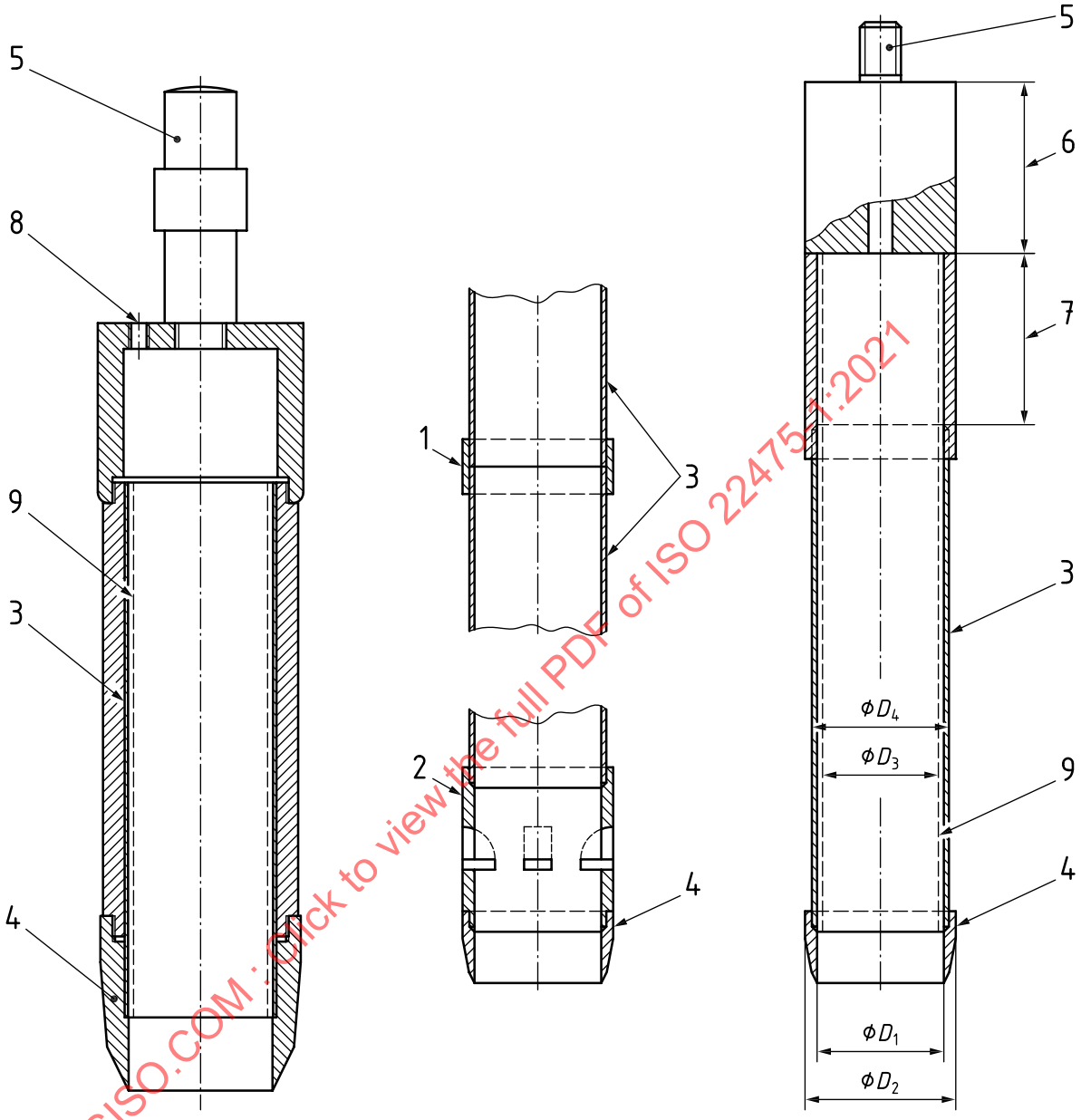

a) Schematic thick-walled open-tube sampler **b) Schematic thin-walled open-tube sampler**

Key

D_1	inside diameter of the cutting shoe	3	sample tube
D_2	greatest outside diameter of the cutting shoe	4	cutting shoe
D_3	inside diameter of the sample tube or liner	5	connection to drilling rods or sliding hammer
D_4	outside diameter of the sample tube	6	non-return valve
1	screw socket	7	overdrive space
2	sample retainer	8	valve
		9	liner (optional)

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

6.3.2.6.3 The sampling using the thin-walled open-tube sampler is usually regarded as category A to C sampling method depending on the soil conditions and whether the sampler is pushed or dynamically driven before (see Table 2).

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6.3.2.6.4 Thick-walled open-tube samplers should be used for stiff and dense soils and for soils containing coarse particles (see line 2 of Table 2). For soil types that are difficult to sample, sample retaining or closure devices should be used.

6.3.2.6.5 The thick-walled open-tube sampler can be usually regarded as a category C sampling method.

6.3.2.7 Sampling using the piston sampler

6.3.2.7.1 The piston sampler can be used in low strength fine soils like silt and clay, including sensitive clays. The method can be used either in boreholes or be pushed directly into the soil.

6.3.2.7.2 The piston sampler shall consist of a sample tube containing a close-fitting sliding piston, which is slightly coned at its lower face. The sample tube shall be fitted to the sampler head, whereas the piston is fixed to separate rods. This shall pass through a sliding joint in the sampler head and up inside the drill rods. Clamping devices, operated at ground level, shall 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.

6.3.2.7.3 Sampling using the piston sampler should be regarded as a category A or B sampling method (see Table 2). In certain circumstances, the piston sampler can be used in sands by use of an appropriate core lifter. The sampling category in this case should regarded as a category C 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.

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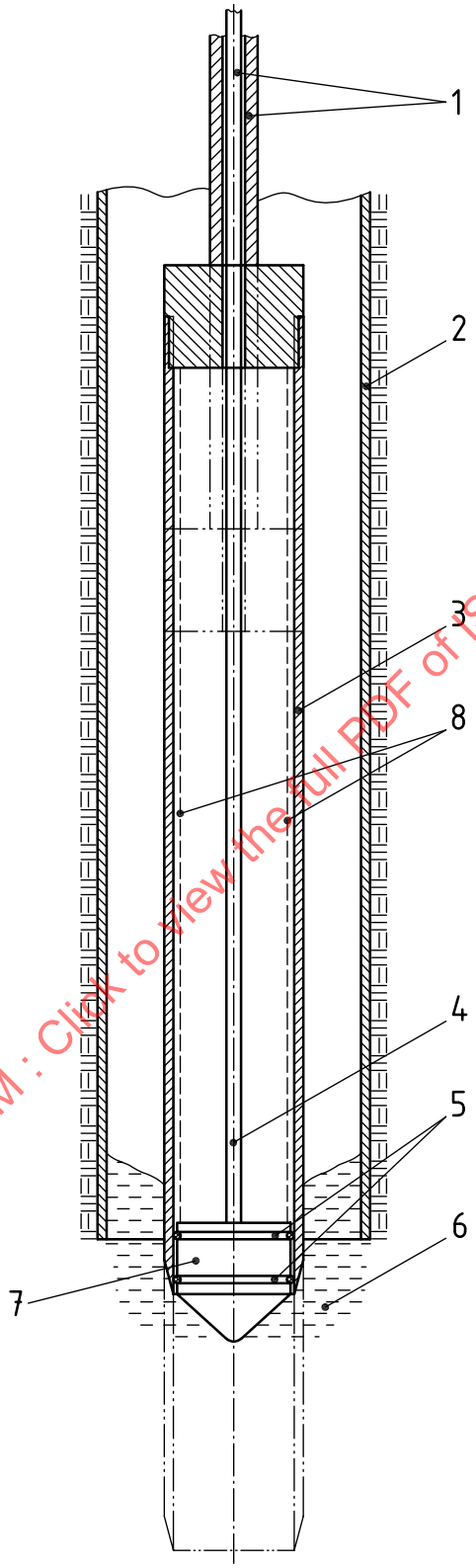

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Key

1 drill rod locking device above ground
2 casing
3 sample tube
4 vent
5 sealing ring

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6 disturbed soil
7 piston
8 liner (optional)

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

6.3.3 Sampling using the standard penetration test sampler

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

6.3.3.2 The sampling using the standard penetration test sampler can be usually used as category D sampling method (see Table 2). In certain homogenous fine-grained soils it can also be used as a category C sampling method.

6.3.4 Sampling by using the window sampler

6.3.4.1 Window samplers consist 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 and 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 shall be removed from the window (see Annex C).

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

6.3.4.3 The sampling using the window sampler can be usually used as category D sampling method, locally category C (see Table 2).

6.3.5 Sampling using the windowless sampler

6.3.5.1 Windowless samplers consist of a hollow tube containing a plastic liner, fitted with a shoe having a sharp cutting edge at its lower end and a pressure release valve or mechanism at its upper end. They are used to take samples by the application of static thrust or dynamic impact. After driving and removal from the soil, the cutting shoe is removed, the plastic liner extracted from the tube and the liner cut open to access the sample. In loose or soft soils, a sample retainer can be fitted between the hollow tube and the cutting shoe.

6.3.5.2 The sampling using the windowless sampler can be usually used as category D sampling method, locally category C (see Table 2).

6.4 Block sampling

6.4.1 Sampling from trial pits

6.4.1.1 In sampling from a trial pit, a sampler with cutting procedure should be used or block samples should be recovered.

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6.4.1.2 Block samples in fine soils can be cut using hand tools or sampling boxes, rings with a cutting edge or plastic pipe with a cutting shoe. The following precautions shall be taken:

a) remoulded soil shall be carefully removed from the sampling spot;

b) water shall not be permitted to 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.

6.4.1.3 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.30.

6.4.1.4 In sampling from trial pits, samples are removed from the bottom or walls using a sampling device such 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 loosing sample material during extraction of the sampler tube. Such material shall be added by hand in the sample to complete the sample.

6.4.2 Sampling using large samplers

6.4.2.1 The principles of sampling using a large sampler shall be as follows:

a) Preparation of the borehole:

The preparation of a borehole for a large sampler requires 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.

6.4.2.2 The sampling using a large sampler is usually used as category A sampling method.

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/coring (see Table 3);

b) block sampling.

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

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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 After recovery of the core barrels to the surface, the core recovery shall be assessed. In cases where core samples are extruded from the core barrel 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 spacer. The drilling direction shall be marked on the core boxes or samples by arrows. The depths of the cores shall also be marked.

7.1.4 There are five categories A to E of sampling methods for rock (see Table 3).

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Table 3 — Sampling by rotary drilling in rock

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Equipment		Drilling method less suitable for[a]	Samples		Sampling category[b]	Remark
	Flushing medium	Extraction of sample by	Designation	Sampling/drilling 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 core barrel	70[c] to 200	Rock of medium strength or greater	Weak, soluble and poorly cemented rock; short core runs	None	B (C,D))	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 core barrel	70[c] to 200	Rock of medium strength or greater	Jointed, weak rock	Sieve residue and suspended matter	B (A,C)	Flushing medium can cause disturbance of core material
3	Yes	Drilling tool attached to drill rods	Rotary core drilling	Double-tube core barrel	70[c] to 200	Soluble and poorly cemented rock	All types of rock	Sieve residue and suspended matter	A (B,C)	—
4	Yes	Drilling tool attached to drill rods	Rotary core drilling	Triple-tube core barrel	70 to 200	—	All types of rock	Sieve residue and suspended matter	A (B)	also suitable for stiff and very stiff fine-grained soils
5	Yes	Drilling tool attached to drill rods, with wireline extractable inner barrel	Wireline core drilling	Wireline core barrel, or triple-tube core barrel	70 to 180	—	All types of rock	Sieve residue and suspended matter	A(B,C)	also suitable for stiff and very stiff fine-grained soils

[a] Guideline values considering the possible use of a casing.

[b] If sampler of the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – higher quality samples can be achieved. Vice versa in unfavourable conditions, samplers of the next lower category should be chosen (e.g. line 3, column 9).

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

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

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Table 3 *(continued)*

Column	1	2	3	4	5	6	7	8	9	10
Line	Drilling method			Equipment		Drilling method less suitable for[a]	Samples		Sampling category[b]	Remark
	Flushing medium	Extraction of sample by	Designation	Sampling/drilling tool	Guideline for borehole diameter range[a] mm		Cores[a]	Cuttings		
6	No	Flight auger	Rotary auger	Auger	150 to 750	Rock of medium strength or greater	None	Variable size rock pieces and residue	E (D)	Samples typically recovered as by product of piling
7	Yes	Drilling tool attached to drill rods	Open hole drilling	Solid bit, roller bit, Down-the-hole-hammer	50 to 350	—	None	Sieve residue and suspended matter	E	—

[a] Guideline values considering the possible use of a casing.

[b] If sampler of the sampling categories given in brackets are used in particular favourable ground conditions – which shall be explained in such cases – higher quality samples can be achieved. Vice versa in unfavourable conditions, samplers of the next lower category should be chosen (e.g. line 3, column 9).

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

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

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7.2 Sampling by drilling

7.2.1 General

7.2.1.1 Drilling methods and equipment shall be selected as a function of the required sampling category (see Table 3) geological and hydrogeological conditions.

7.2.1.2 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.

7.2.1.3 In weak rock only double or triple core barrels shall be used.

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

7.2.1.5 Cementing can be necessary to stabilise the borehole or to sample when a crushed rock zone is encountered.

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

7.2.2 Sampling by rotary dry core drilling

7.2.2.1 In sampling by rotary dry core drilling, a tube system shall be 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 shall be 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 rock. It should not be used in rock of medium to high strength.

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

7.2.2.3 Sampling by rotary dry core drilling is a category B sampling method (see Table 3).

7.2.3 Sampling by rotary core drilling

7.2.3.1 In sampling by rotary core drilling, a tube system fitted with a bit at its lower end shall be 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 core barrel, can be single tube, double tube or triple tube with a borehole diameter of 70 mm to 200 mm. A flushing medium may be used.

7.2.3.2 A **single tube core barrel** shall consist of a core tube fitted with a bit at its lower end and a core barrel 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 shall pass between the inside diameter of the core tube and the recovered rock core and continuously washes the length of the recovered sample.

7.2.3.3 A **double tube core barrel** shall consist of two concentric tubes and a bearing arrangement in the core barrel head which allows the inner tube to remain stationary whilst the outer and bit is rotated by the drill string. A core lifter shall be fitted between the bit and the inner tube. The flushing medium shall pass through the annulus between the inner and outer tubes thus protecting the recovered sample from erosion.

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7.2.3.4 A **triple tube core barrel** shall be similar in construction to the double tube design but shall be fitted with an additional third tube within the inner tube.

7.2.3.5 Both double tube and triple tube core barrels can be fitted with extensions to their inner tubes that pass through the bit for use in very weak formations.

7.2.3.6 The samples obtained by this method include cores and cuttings. The single tube core barrel only allows core recovery in consolidated formations whereas double tube and triple tube can be used in all rock formations. All these types of core barrels can be fitted with liners within the inner tube to assist the recovered core run and protect the recovered core sample.

7.2.3.7 Sampling by rotary core drilling with either single or double core barrel is generally a category B sampling method. The sampling method using a triple tube core barrel is generally category A (see Table 3).

7.2.4 Sampling by wireline core drilling

7.2.4.1 In sampling by wireline core drilling a double tube or triple tube core barrel with a bit fitted to the lower end shall be 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 core barrel. The borehole diameter range shall be from 70 mm to 180 mm. When the core run is completed, the inner tube containing the core sample shall be withdrawn through the drill rods by means of a wireline cable and winch. The bit, outer tube and drill rods shall remain in the borehole during this process.

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

7.2.5 Sampling of cuttings by rotary open hole drilling

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

7.3 Block sampling

7.3.1 In block sampling, samples can be obtained from e.g. a trial pit, heading, shaft or from borehole bottom by using special samplers with cutting procedure.

NOTE Block sampling in rock is often used to collect samples of discontinuities for laboratory testing.

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

8 Groundwater sampling methods for geotechnical purposes

8.1 General

8.1.1 Groundwater sampling methods shall be selected as needed. The quality of a groundwater sample is characterised by the extent to which it contains original constituents, such as suspended matter, dissolved gases and salts, or to which they have been contaminated during drilling. Groundwater can be sampled for the following purposes:

a) to determine its aggressiveness to concrete;

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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 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 shall be used as flushing medium.

8.2 Equipment

8.2.1 For groundwater sampling, the following minimal equipment shall be 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 the horizon to be investigated, care being taken to ensure that any other sources of clean 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 are used to extract water, the pump or tubing intake shall be positioned adjacent to, or as close as possible to, the horizon to be sampled. Samples should be taken directly from the end of the discharge tubing from the pump. If high volume pumping is being used (e.g. during a pumping test or

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from a groundwater extraction well), a sampling valve and/or outlet shall be located at the top of the well.

During pumping, electrical conductivity, pH-value and temperature should be measured at specified intervals in accordance with the sampling objectives and the methodology being used. Pumping should continue until the readings have stabilised. The volume of water purged during pumping should be recorded and any contaminated purge water safely disposed.

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 fine 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 E).

9 Preservation, labelling, transport and storage of samples

9.1 General

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

9.1.2 A separate traceability record of each shipment shall be maintained in a manner to allow traceability of samples from collection at source to analysis within the laboratory.

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

9.1.4 The requirements for preservation and storage of samples will depend on the material type and likely range of laboratory tests to be carried out. This shall be determined before the samples are recovered as part of the assessment given in 5.2.

9.2 Preservation of samples

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

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

9.2.3 The type of preservation materials and sample containers shall be selected depending on the sampling categories and on the climate and transporting mode and distance:

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 or tube;

c) water proof duct tape;

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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 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.

NOTE See Annex F.

9.2.4 Following preservation, in order to minimise disturbance, sample moving should be kept to a minimum.

9.2.5 Where samples are placed in plastic bags they should be wrapped as tight as possible.

9.2.6 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 shall be airtight. Glass jars additionally need sealing rings for air tightness.

9.2.7 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.

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

9.2.8 Cylindrical, cube or other soil and rock samples wrapped in plastic film should be further protected with three coats of wax.

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

9.3 Labelling of samples

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

9.3.2 The label shall show the following information:

a) identification of the project;

b) identification of trial pit, borehole etc.;

c) date of sampling;

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d) identification of sample;

e) depth of the sample from the reference level;

f) where samples contain contaminants or hazards the sample label or container shall be clearly marked to identify the hazard.

NOTE Digital identification codes can be added.

9.3.3 The samples shall be marked, so that there is no doubt about the upper and lower end of the sample.

9.4 Transport and storage of samples

9.4.1 General considerations

As part of the planning of a ground investigation, consideration should be given to the storage arrangements for all the samples that will be produced by the various techniques used. Both the short-term storage (on site during the investigation), as well as the long-term storage (fixed premises) arrangements will need to be considered. In addition, how samples are stored during transport should be considered as part of the overall sample storage strategy.

9.4.2 Sampling category A

9.4.2.1 General

The samples shall be protected against vibration and shocks.

Both soil and rock samples obtained according to sampling category A shall be stored with the presumption that laboratory testing for strength, settlement and deformation will be undertaken on the samples. This means that no reduction of the quality is permitted following extraction from the ground. As such the samples (and any subsamples that have been taken) will require to be stored in an environment that protects the sample from physical disturbance as well as from the effects of temperature extremes.

9.4.2.2 Storage on site and at fixed premises

All tube and block samples obtained in soft or very soft fine soils shall be stored in a vertical orientation so as to prevent slumping of the material and destruction of any bedding within the sample container.

All tube, block, liner, and core samples obtained in firm, stiff or very stiff fine soils and samples of rock, may be stored horizontally in such a manner that individual samples are prevented from rolling. This is best achieved by means of racking and shelving, although core samples may be stored within the core boxes.

The environment within which these samples are stored should be temperature-controlled such that extremes of temperature are avoided. The temperature range should be between 5 °C and 25 °C.

NOTE Below 5 °C samples become prone to freezing and the effects of ice damage, whilst above 25 °C samples are liable to undergo significant water content loss. Both of these conditions can have significant detrimental effects on material properties.

9.4.2.3 Storage during transport

Precautions should be taken to ensure that during the transport of samples from a site to fixed premises and/or to a laboratory, the same general storage arrangements are applied to the samples. Samples identified to be stored in an upright orientation should be transported in the same manner. All other samples may be transported horizontally, but in such a manner so at to prevent any movement of the samples.

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Temperature control should to be maintained during transport, such that specific measures should be taken if samples are to be transported when the temperature is below 5 °C or above 25 °C.

9.4.3 Sampling category B to E

9.4.3.1 General

For both soil and rock samples obtained according to sampling categories B to E inclusive, the presumption is that no laboratory machine testing (testing to obtain strength, settlement or deformation characteristics) will be required. The storage of such samples is therefore less onerous than for category A samples. However, it should be noted that where tube samples have been obtained using sampling category B, there is the possibility that laboratory machine testing could be undertaken, with the results suitably caveated in the report. In view of this, it is sensible to treat all tube samples as if they were obtained by sampling category A and to store them in accordance with the requirements of 9.4.2.

If the structure is to remain intact for soil identification and index testing, the samples should be placed in airtight containers or bags immediately after collecting to minimise oxidation.

If the structure and texture is to remain intact, the samples should be placed in containers of sufficient thickness and strength to prevent breakage and moisture loss.

If the structure, texture and consistency is to remain intact, the samples should be placed in containers protected against vibration and shock and protected from extreme heat or cold.

9.4.3.2 Storage on site and at fixed premises

Samples obtained as sampling category B to E inclusive, may be stored in a different manner to those samples obtained by sampling category A, with the exception of the tube samples noted in 9.4.3. Samples recovered in plastic tubs and bulk bags may be stored in an environment where the temperature is not maintained within the 5 °C to 25 °C range. Similarly, there is no requirement to store such samples in a particular orientation or on shelving etc.

NOTE Where water content determinations are required on small disturbed samples (plastic tubs) or core samples, loss of water content will occur if such samples are not sealed immediately.

Core samples of soil or rock obtained within these categories and required for laboratory testing shall be sealed immediately.

9.4.3.3 Storage during transport

The transport of samples obtained by sampling categories B to E inclusive should be such that no further deterioration of sample quality takes place.

9.4.4 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 and be transported within a temperature range of 4 °C and 12 °C.

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10 Report

10.1 Field report

10.1.1 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 10.1.2);

b) drilling record (see 10.1.3);

c) sampling record (see 10.1.4);

d) record of identification and description of soil and rock (see 10.1.5);

e) backfilling record (see 10.1.6);

f) daily report (see 10.1.8).

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

10.1.2 Summary log

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

a) general information:

   1) name of enterprise performing the sampling;

   2) name of client or representative;

   3) date of sampling;

   4) identification of the project;

   5) number of borehole, trial pit, heading or shaft;

b) information on the project site:

   1) position and elevation of 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;

   3) information on any attached records;

   4) name and signature of the qualified operator.

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

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10.1.3 Drilling record

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

a) general information:
   1) name of enterprise performing the drilling;
   2) name of 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 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: name and signature of the qualified operator.

10.1.4 Sampling record

The sampling record shall be clear and accurate, and it may not only contain the data required for determination of the soil and rock strata and the location (x, y, z) of the samples obtained but also of 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 information, if applicable (see also Table B.3):

a) general information:
   1) name of enterprise performing the sampling;
   2) name of client or representative;
   3) number of sample;

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4) date of sampling;

5) identification of the project;

6) identification of 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) disturbance of the sample;

5) sample container filled up;

6) number of liners or other identification of the sample;

7) ramming used during cutting of the sample;

8) sampling methods;

d) other information:

1) preliminary identification of soil or rock type (including IC, RQD, SCR, TC and TCR);

2) for water samples: temperature, pH-value fixing agents, sampling operations;

3) name and signature of the qualified operator.

All unsuccessful sampling operations shall be recorded.

10.1.5 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 information, if applicable (see also Table B.4):

a) name of enterprise performing the sampling;

b) name of client or representative;

c) date of sampling;

d) identification of the project;

e) identification of borehole, trial pit, heading or shaft;

f) orientation and diameter of the borehole;

g) sampling methods;

h) preliminary identification and description of soil and rock based on the visual examination according to ISO 14688-1 and ISO 14689;

i) photographic documentation of the obtained cores/samples;

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j) name and signature of the qualified operator.

10.1.6 Backfilling record

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

a) name of enterprise performing the backfilling;

b) name of client or representative;

c) date of backfilling;

d) identification of project;

e) identification of borehole, trial pit, heading or shaft;

f) backfilling material;

g) sections of backfilling;

h) name and signature of the qualified operator.

10.1.7 Record of groundwater measurements during drilling and sampling

10.1.7.1 The record of groundwater measurements shall be attached to the summary log and include the following essential information, if applicable:

a) general information:
   1) name of enterprise performing the drilling and sampling;
   2) name of client or representative;
   3) date of groundwater measurements;
   4) identification of the project;
   5) identification of the borehole;

b) information on the measurement:
   1) time for each separate groundwater measurement;
   2) measured values;
   3) comments on observations or performed checks of importance for the interpretation;

c) other information: name and signature of the qualified operator.

10.1.8 Daily record

See Table B.6.

10.2 Report of the results

The report of the results shall include the following 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;

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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) 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

An example a form for the preliminary information on the intended sampling is given in Table A.1.

Table A.1 — Preliminary information on the intended sampling and groundwater measurements

Preliminary information on the intended sampling and groundwater measurements		
Project		
Location		
Number of borehole, excavation etc. and/or groundwater measurement		
Orientation, inclination and acceptable deviations in bore-holes		
Surveying requirements and expected geological and hydrogeological conditions		
Required accuracy and uncertainty of measurements		
Frequency of measurements		
Environmental and safety risk (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 _____ _____	

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Page 2	Preliminary information on the intended sampling and groundwater measurements
Planned depth of the borehole or excavation	
Sampling category	☐ A ☐ B ☐ C ☐ D ☐ E ☐ groundwater
Sampling method(s)	
Sample handling	
Sample storage	
Sample transport	
Intended field 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 ☐ inclinometer installation ☐ extensometer 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	

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Annex B
(informative)

Field reports

Table B.1 — Summary log

Summary log	Name of the enterprise		
Investigation type: borehole/trial pit/shaft/head[a]	Name of the client		
Name of project		No. of 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[b]	☐ drilling record ☐ sampling record ☐ backfilling record ☐ record of identification and description of soil and rock ☐ record of the installation of groundwater measuring stations ☐ record of the installation of inclinometers ☐ record of the installation of extensometers ☐ record of groundwater measurements ☐ others, such as		
Remarks (interruptions, obstructions, difficulties etc.)			
Name of the qualified operator			
Signature of the responsible driller			

[a] Delete if not applicable.

[b] Tick as applicable.

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Table B.2 — Drilling record

Drilling record				Name of the enterprise									
				Name of the client									
Name of project								No. of the project					
Date of drilling:								Identification of the borehole					
Drill rig (type, manufacturing year)								End depth of borehole					
Method of pre-drilling*[a]								Ramming [a]					
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 diame-ter mm	Outer diameter mm	Depth mm	Pres-sure	Circulated volume	
Remarks (interruptions, obstructions, difficulties etc.)													
Name of the qualified operator													
Signature of the qualified operator													
[a] If used.													

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Table B.3 — Sampling record

Sampling record	Name of the enterprise								
	Name of the client								
Name of project				No. of the project					
Date of sampling				Identification of the borehole etc.					
Identification of the sample									

Depth/core run m		Sample		Rock quality and core recovery			Sampler		Remarks — Core lifter used — disturbance — soil/rock type — ramming used
		Length mm	Diameter mm	TCR	RQD	SCR	Specifications	Type	
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	

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

Name of the enterprise: *Name of the client:* *Drilling method:* *Date:* *Diameter:* *Inclination:* *Project name:*	**Record of identification and description of soil and rock according to ISO 14688-1 and ISO 14689** *Name and signature of the qualified operator:*	*Page:* *Trial pit:* *Project number:*

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* — *No.* — *depth*	**Remarks** — *seepage / flushing medium* — *drilling tools / casing* — *core loss* — *core length*

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Table B.4 *(continued)*

Page 2

1	2	3	4	5	6	7
Depth m	***Identification of soil or rock type*** *Additional remarks* *Geological designation/stratigraphy*	**Colour** **Carbonate content**	**Description of the sample** — *Consistency, plasticity, hardness, strength- - - Particle shape, matrix* — *Weathering, discontinuities etc.*	**Description of drilling progress** — *drillability / core shape* — *use of chisel* — *observations etc.*	**Samples tests** — *type* — *No.* — *depth*	**Remarks** — *seepage / flushing medium* — *drilling tools / casing* — *core loss* — *core length*

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Table B.5 — Backfilling record

Backfilling record		Name of the enterprise					
		Name of the client					
Name of project				No. 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		
Remarks							
Name of the qualified operator							
Signature of the qualified operator							

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Table B.6 — Daily report

Daily Report Company and address

Project Project-No. Date

Borehole No	Type of drilling tool or casing	Ø mm	Type of ground	Drill length From	Drill length To	Drill Length m	Core length m

Flushing loss or influx Litre at depth	Groundwater level morning m below ground level evening m Groundwater reached m	Achieved depth		
		Depth previous day		
		Daily output		

Name of operator		Work hour	Travel Hour	Work sequence	Time	
Total time						
	Executed work	○ contract work • non-contractual				
	Loading and transport	○ h				
	Intermediary transport	○ h				
	Rigging and de-rigging	○ h				
	Drilling and sampling	○ h				
	Borehole widening, re-drilling	○ h				
	Installation of pipes	○ h		Material consumption		
	Grouting	○ h				
	Cable detection pit	○ h				
	Repairing	○ h				
	Operating hours	○ h		External service		
	Waiting hours	○ h				
	Work by the hour	○ h				
	Total time	○ h				

Operational data:		Weather:	Temperature:
Pressure/torque	kg/bar	Core recovery	%
Drive	rpm	Casing mm Ø	m

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Name of operator		Work hour	Travel Hour	Work sequence		Time
Pressure mud pump			bar	Casing	mm Ø	m
Engine running			hours	Casing	mm Ø	m
Power or fuel	kW/h		liter	Casing	mm Ø	m

Remarks:

Visitor:

Name and signature of the operator

accepted, client:

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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 (see Figures C.1 to C.39 and Tables C.1 to C.20) of the most frequently and universally used equipment for drilling and sampling in soils and rock. This 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 document.

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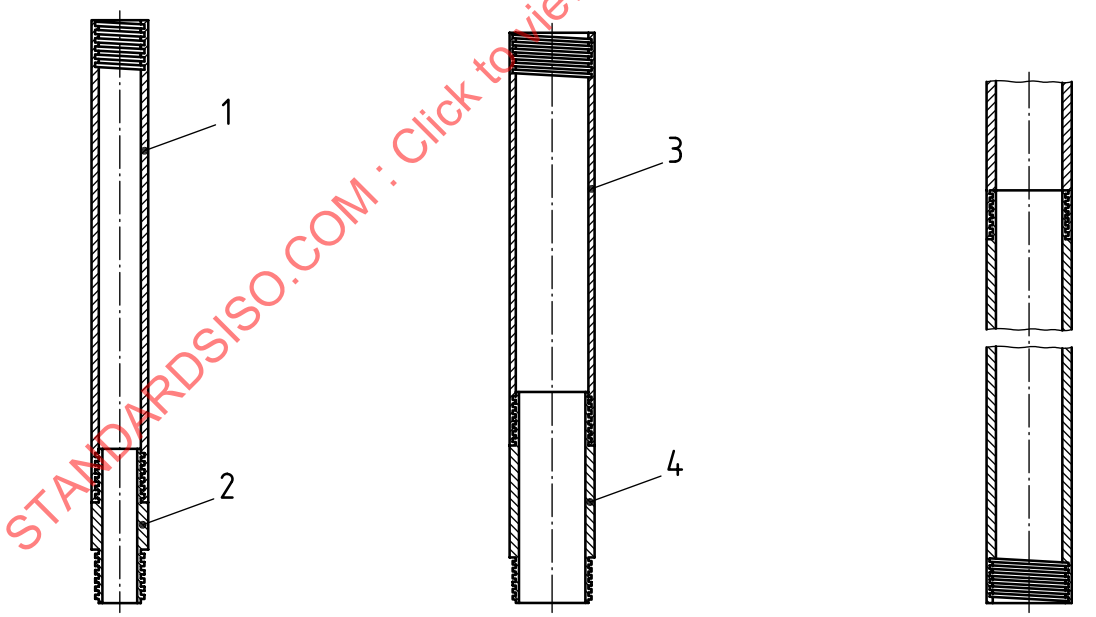
C.2 Drill rods and casing

C.2.1 General



a) Flush-coupled drill rod **b) Flush-coupled casing** **c) Flush-jointed casing**

Key

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

Figure C.1 — Drill rods and casing

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C.2.2 Drill rods and casing 'W'-series according to ISO 3551-1

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 coupling	Casing flush jointed	Casing		Casing reaming shell	Casing bit		Casing shoe	
	OD	ID		OD	ID		OD	ID	Set OD	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	47,75 47,50	35,81 35,56	47,75 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

Key

OD outer diameter

ID inner diameter

not required

C.2.3 Drill rods and casing 'metric' series according to ISO 3552-1

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

Key

OD outer diameter

ID inner diameter

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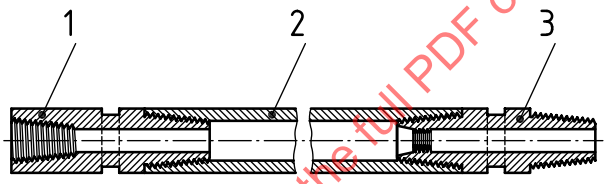
Table C.2 *(continued)*

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
			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
Key OD outer diameter ID inner diameter									

C.2.4 Drill rods taper threaded 'Y' series



Key

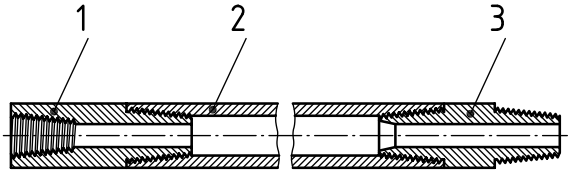
1 tool joint-box
2 rod tube
3 tool joint-pin

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	
Key OD outer diameter ID Inner diameter											

C.2.5 Drill rods taper threaded 'J' series



Key

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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	

Key
OD outer diameter
ID inner diameter

C.3 Core barrel data

C.3.1 General

For schematic illustrations of core barrel types, see also C.4.

C.3.2 Core barrels 'W' series according to ISO 3551-1

Table C.5 — Core barrels 'W' series

Core barrel designs				Coring bits		Reaming shells	Kerf width	Kerf area	Core area	Hole area	Core to hole area	Nominal core size	Nominal 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

Key
OD outer diameter
ID inner diameter
NOTE 1 WT and WG are single tube core barrel types.
NOTE 2 WF, WG and WM are double tube core barrel types.

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Table C.5 *(continued)*

Core barrel 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	%		
	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

Key

OD outer diameter

ID inner diameter

NOTE 1 WT and WG are single tube core barrel types.

NOTE 2 WF, WG and WM are double tube core barrel types.

C.3.3 Core barrels 'metric' series according to ISO 3552-1

Table C.6 — Core barrels 'metric' series according to ISO 3552-1

Core barrel type			Coring bits		Rea-ming 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

Key

OD Outer diameter

ID Inner diameter

NOTE 1 B and Z are single tube core barrel types.

NOTE 2 T is the double tube core barrel type.

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Table C.6 *(continued)*

Core barrel type			Coring bits		Rea-ming 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	%
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

Key

OD Outer diameter

ID Inner diameter

NOTE 1 B and Z are single tube core barrel types.

NOTE 2 T is the double tube core barrel type.

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C.3.4 Core barrels air flush

Table C.7 — Core barrels air flush

Bit set	HWAF		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 core barrels are also suitable for use with air flush by the incorporation of an air flush type core bit.

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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	Weight kg/m	mm	Type	Core Ø mm	Type	Core Ø mm	Type	Core Ø mm	OD Ø mm	OD Ø "	Cplg. inside mm	weight kg/m
	508	480	101,5	508							PR 244,0		190,0	80,2
	419	394	126	419							TS 194,0		90,0	62,6
	343	318	102	343							PR 146,0		127,0	36,0
	324	299	85,3	324							140,0		125,5	26,0
	311	286	91,3	311										
	298	273	88,8	298			F-273	248,0			140,0		125,5	26,0
	273	248	80,9	273										
	254	232	74,7	254										
	244	223	69,6	246/244			F 246	220,0			140,0		125,5	26,0
ZW	219	199	51,6	222										
219,1	203	183	47,6	219			F 222	196,0			140,0		125,5	26,0
203,1				202/199	SF 219	190,0					140,0		125,5	26,0
UW							F 202	178,0			73,0		32,0	17,0
193,7	194	174	45,3	198	SF 199	170,0	Z	186,0			140,0		125,5	26,0
177,7											172,0		151,0	42,0
	178	163	30	182			F 182	158,0			73,0		32,0	17,0
											140,0		125,5	26,0
											172,0		151,0	42,0
SW					SF-179	150,0					73,0		32,0	17,0
168,3	168	154	28,3	176/179	K3	140,0	Z	146,0	SK		140,0		125,5	26,0
152,3									176,0	132,0	172,0		151,0	42,0
PW					T 6	123,0					73,0		32,0	17,0
139,7	143	134	16,3	146/150	T 6 S	116,0	B	132,0						
127				SQ	K 3	116,0	Z	120,0	SK		140,0		125,5	26,0
					D	122,0			146,0	102,0				
					T 6	108,0					73,0		32,0	17,0
					T 6 S	101,0	B	117,0			HW			
	128	119	14,4	131	K 3	101,0	Z	105,0			88,9	3 1/2	60,3	12,6
					D	110,0								
					F	101,0								
HW					T 6	93,0					73,0		32,0	17,0
114,7	113	104	12,7	122,6 (PQ/CP)	T 6 S	86,0	B	102,0						
101					K 3	86,0	Z	60,0	PQ		117,8		103,2	19,0
				116	D	96,0			122,6	85,0				
NW					T 2	84,0					73,0		32,0	17,0
88,9	98	89	10,4		T 6	79,0								
				101	T 6 S	72,0	B	87,0			HW			
76,2					K 3	72,0	Z	75,0			88,9	3 1/2	60,3	12,6
					D	81,0								
	84	77	7	96 HQ					HQ		88,9	3 1/2	60,3	12,6
									96,0	63,5				
				99,2 HW	HWG				HXB		90,0		76,0	14,3
					99,2	76,2			92,8	61,2				
	84	77	7	86	T 2	72,0	B	72,0			50,0		22,0	6,9
					T6	67,0	Z	62,0			88,9	3 1/2	60,3	12,6
					D	66,0					63,5		25,0	12,0
BW					T 2	62,0	B	62,0			50,0		22,0	6,9
73	74	67	6,1	76	T6	57,0	Z	54,0			88,7	3 1/2	60,3	12,6
					D	56,0					63,5		25,0	12,0
60,3	74	67	6,1								66,7		34,9	12,5
				75,7 NQ	NWG				NQ		69,9		60,3	7,7
				NW	75,8	54,7			75,7	47,6	73,0		32,0	17,0
									NXB					
	64	57	5,2	66	T 2	52,0								
					T6	47,0	B	52,0			53,0		22,0	4,1
					D	46,0	Z	44,0			50,0		22,0	6,9
											51,0		15,0	9,7
AW				60 BQ	BWG						54,0		19,0	9,5
57,4	54	47	4,4	BW	60,0	42,0			BQ		55,6		46,0	6,0
48,4									60,0	36,3				
	54	47	4,4	56	TT	45,5	B	42,0			53,0		22,0	4,1
					T2	42,0					50,0		22,0	6,9
											51,0		15,0	9,7
EW				AQ	AWG						43,7		15,9	5,7
46,3	44	37	3,5	48	48,0	30,1			AQ		44,5		34,9	4,7
38,1				AW					48,0	27,0				
	44	37	3,5	46	TT	35,6	B	32,0			43,0		22,0	2,5
					T2	32,0					42,0		22,0	4,4
											33,0		15,0	1,7
											33,5		15,0	3,3
				37,7 EW	EWG						HW			
					37,7	21,5					34,9		11,1	4,5
RW					T	22,0					33,0		15,0	1,7
36,6				36	RWT		B	22,0			33,5		15,0	3,3
30,2					29,8	18,6					27,7		10,3	2,9

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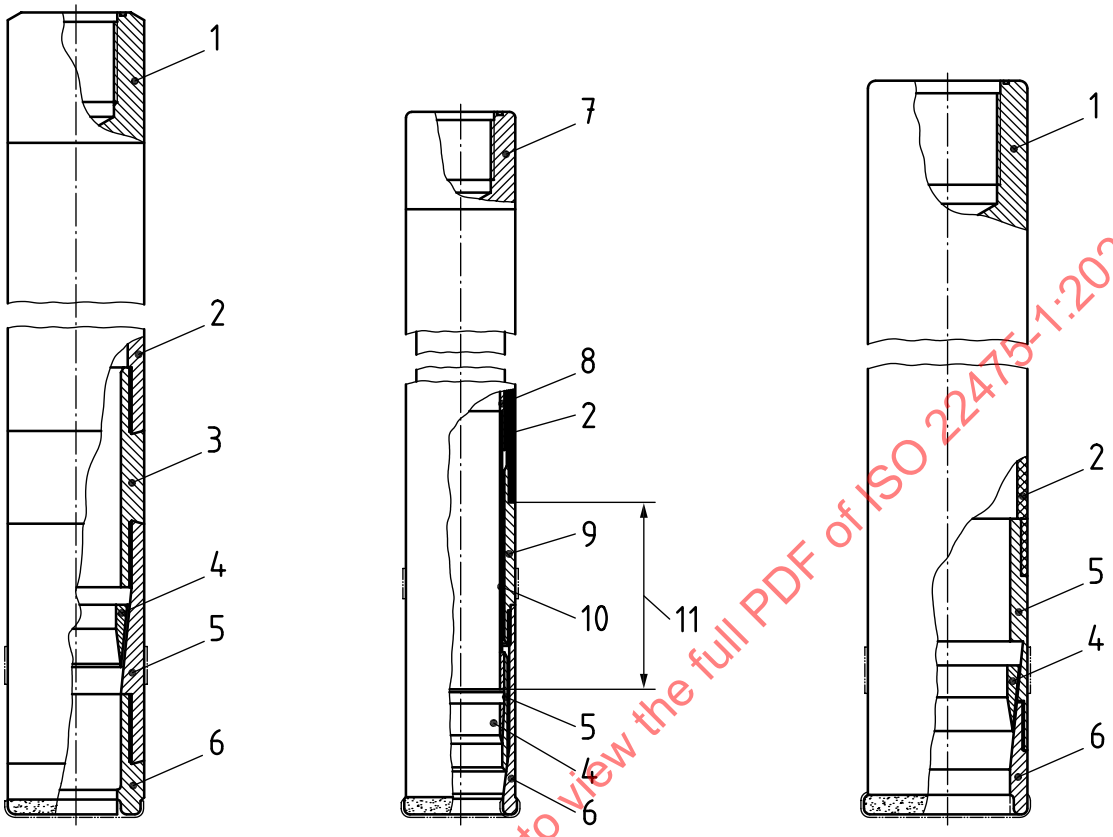
C.4 Schematic illustrations of single and double-tube core barrels

C.4.1 Core barrels 'metric' series according to ISO 3552-1



a) Core barrel, type Z - Assembly

b) Double-tube core barrel, type T - bottom-discharge and swivel type - Assembly

c) Core barrel, type B - Assembly

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Key

1 head
2 outer tube
3 core-lifter coupling
4 core lifter
5 core-lifter case
6 bit
7 core barrel head [only the thread (right-hand thread) for connection to drill rod is standardised]
8 inner tube
9 reaming shell
10 extension tube
11 projecting part of inner tube

Figure C.4 — Core barrels 'metric' series according to ISO 3552-1

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Table C.9 — Core barrels 'metric' series according to ISO 3552-1

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

C.4.2 Core barrels 'W' series according to ISO 3551-1

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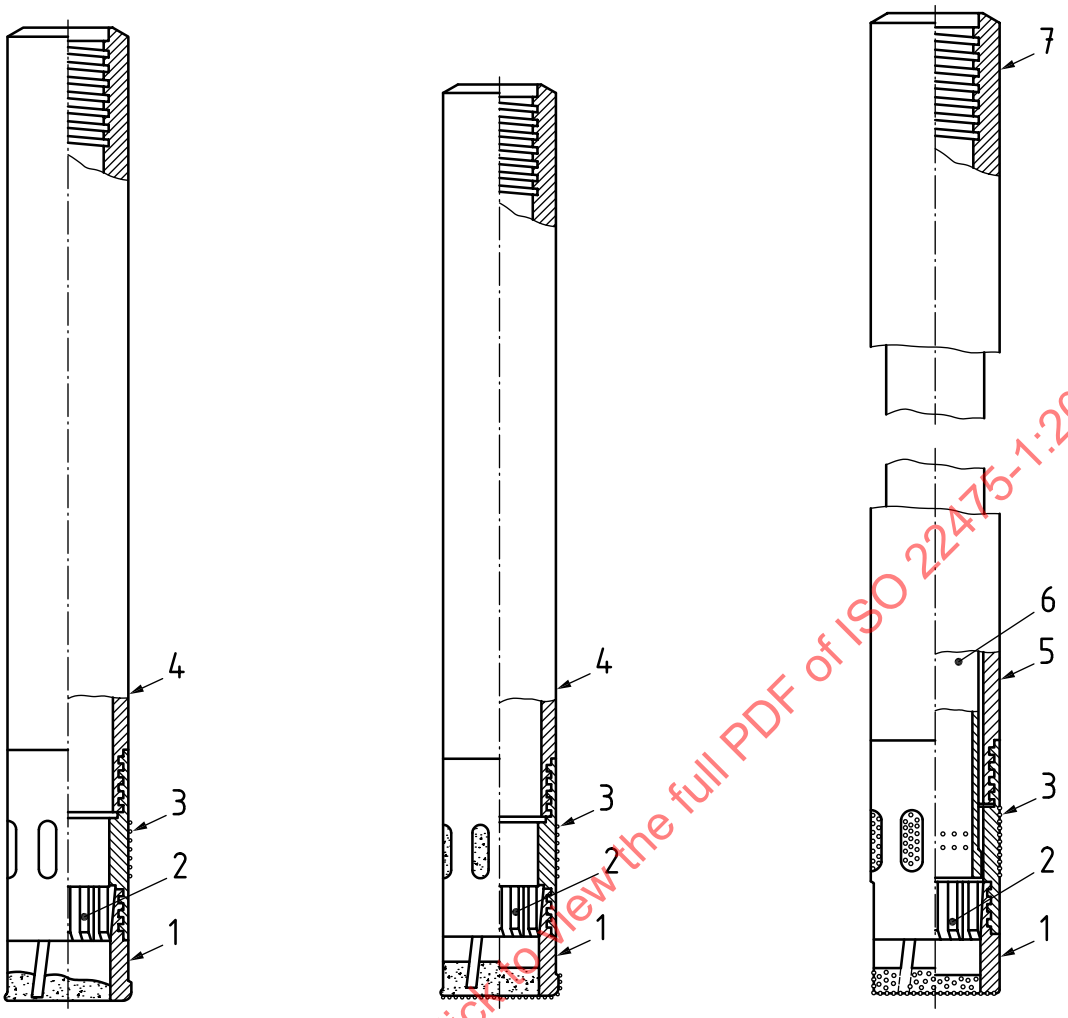

a) 'WG' design single-tube core barrel - Assembly[a]

b) 'WT' design single-tube core barrel - Assembly[a]

c) 'WG' design double-tube core barrel - Assembly[b]

Key

1 core bit
2 core lifter
3 reaming shell
4 tube
5 outer tube
6 inner tube
7 head (rigid or swivel)

[a] Bits and core springs are interchangeable with double-tube barrels.

[b] Bits and core springs are interchangeable with single-tube barrels.

Figure C.5 — Core barrels 'W' series according to ISO 3551-1

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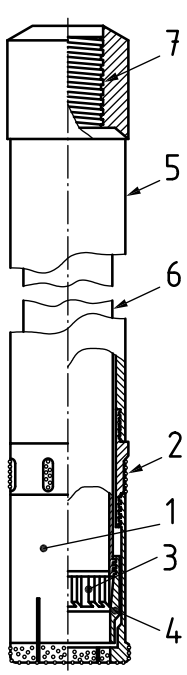
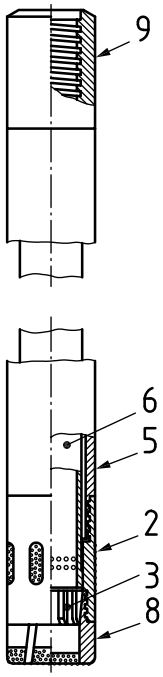
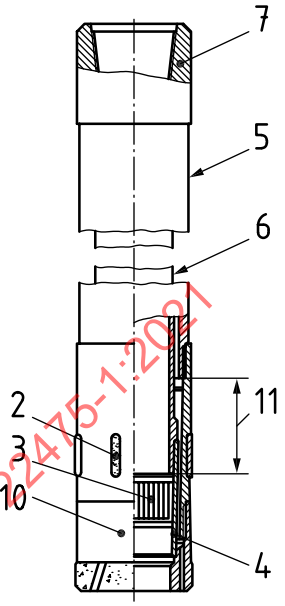


a) 'WM' design double-tube core barrel - Assembly[a]



b) 'WT' design double-tube core barrel - Assembly[c,d]



c) 'WF' design double-tube core barrel - Swivel type[b]

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 core barrel lengths are 1,5 m and 3 m (lengths refer to core capacity).

[b] Standard 'WF' design core barrel 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 core barrel lengths are 1,5 m and 3 m (lengths refer to core capacity).

Figure C.6 — Core barrels 'W' series according to ISO 3551-1

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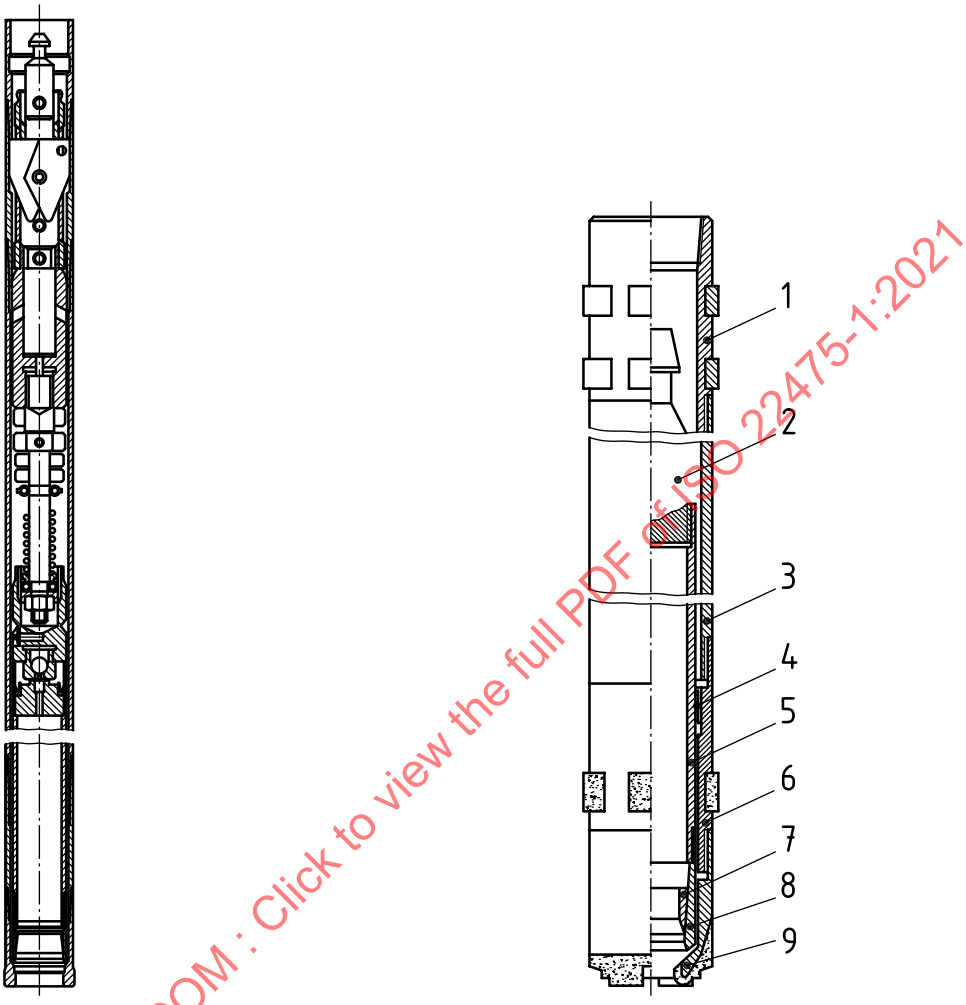
C.5 Schematic illustrations of wireline and geotechnical wireline core barrels

C.5.1 Wireline core barrel assembly



a) Typical wireline core barrel **b) Parts standardised in ISO 10097-1[a]**

Key

1 head (not standardised)
2 bearing unit (not standardised)
3 outer core barrel
4 stabiliser (not standardised)
5 retractable innertube 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 core barrel assembly

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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 core barrel 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

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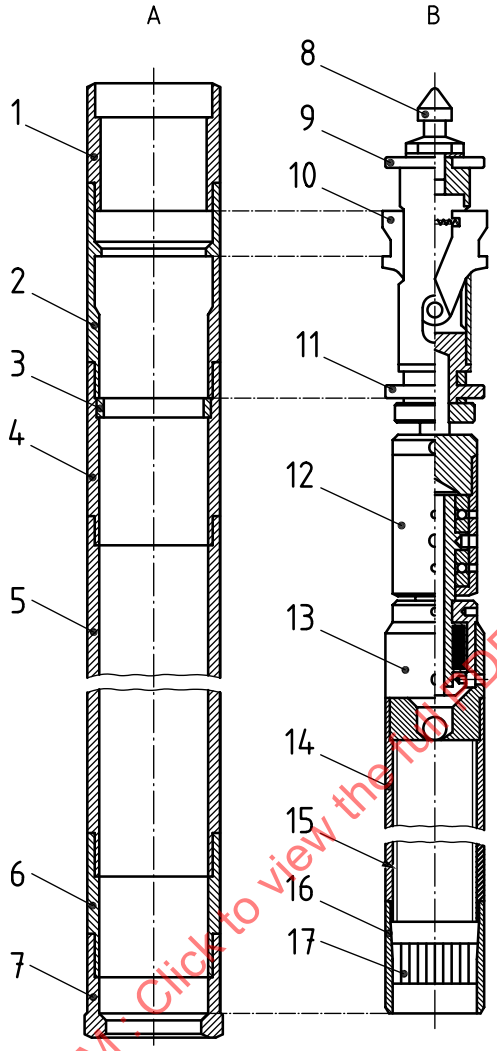
C.5.2 Geotechnical wireline core barrel



Key

A	outer tube assembly	B	Inner tube assembly
1	drill and coupling	8	lifting spear
2	locking coupling	9	upper stabiliser
3	landing ring	10	latches
4	adapter coupling	11	lower stabiliser
5	outer tube	12	bearing assembly
6	blank reaming shell	13	inner tube bung
7	core bit (not included)	14	outer tube
		15	plastic coreliner
		16	core-lifter case
		17	core lifter

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

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Table C.12 — Geotechnical wireline core barrel drill pipe dimensions

Equipment	P size Flush jointed mm	P size Flush coupled mm	S size Flush jointed mm	S size Flush coupled 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 core barrel 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.		

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C.6 Water-well casing

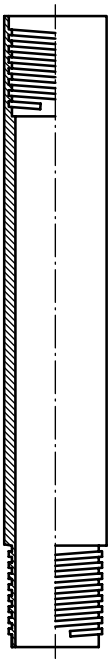

Figure C.9 — Water-well casing with flush butt joints according to BS 879

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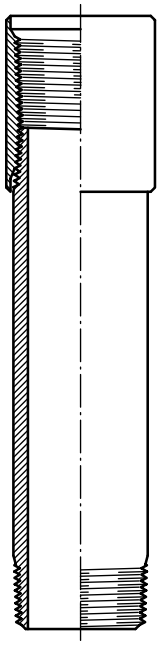

Figure C.10 — Water-well casing with screwed and socketed joints according to BS 879

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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	

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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	

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C.7 Bit selection chart

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Table C.16 — Bit selection chart

Group	Rock description	Hardness abrasivity	TU	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 Shale Chalk Soft Limestone Gypsum Volcanic Tuff	Soft															
2	Sand Loose Sandstone Shale Marble Medium Limestone Salt	Soft to medium															
3	Soft Sandstone Sandy Shale Claystone Sandy Limestone Soft Schist	Med-hard low abrasivity															

Key

TU tungsten carbide set

GTS geotechnical saw-tooth carbide set

PCD polycrystalline diamond set

TSP thermally stable polycrystalline set

2 for abrasive or fractured softer formations

4 for medium hard and abrasive formations

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

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Table C.16 *(continued)*

Group	Rock description	Hardness abrasivity	TU	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
4	Medium Sandstone Siltstone Calcitic Limestone Medium Limestone Hard Shales	Med-hard high abrasivity															

Key

TU tungsten carbide set

GTS geotechnical saw-tooth carbide set

PCD polycrystalline diamond set

TSP thermally stable polycrystalline set

2 for abrasive or fractured softer formations

4 for medium hard and abrasive formations

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

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Table C.16 *(continued)*

Group	Rock description	Hardness abrasivity	TU	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
5	Hard Limestone Dolomitic Limestone Schist Serpentine Dolomite Marble Syenite Andesite Pegmatite Hematite Magnetite	Hard, low abrasivity															
6	Gneiss Granite Basalt Gabbro Rhyolite	Very hard, medium abrasivity															

Key

TU tungsten carbide set

GTS geotechnical saw-tooth carbide set

PCD polycrystalline diamond set

TSP thermally stable polycrystalline set

2 for abrasive or fractured softer formations

4 for medium hard and abrasive formations

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

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Table C.16 *(continued)*

Group	Rock description	Hardness abrasivity	TU	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
***	Abrasive sandstone Pyritic Formations Banded Hematite Conglomerate Taconite							Carbonado									

Key

TU tungsten carbide set

GTS geotechnical saw-tooth carbide set

PCD polycrystalline diamond set

TSP thermally stable polycrystalline set

2 for abrasive or fractured softer formations

4 for medium hard and abrasive formations

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

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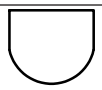
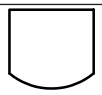
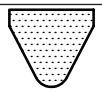
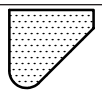
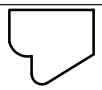
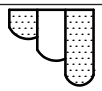
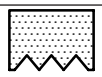
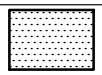
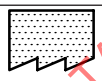
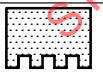
C.8 Core bit profiles

Table C.17 — Core bit profiles - Diamond set, impregnated, TU 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)**

NOTE 1 Flush alternatives are CF (channel flush), which is standard core bit flush design, and ECF (expanded channel flush).

NOTE 2 Optional flush on request can be FD (face discharge flush), which is standard with oval holes, and SCAL (scallop), a combination of FD and CF.

NOTE 3 Core bits with face discharge are used in loose formations where the flushing medium can destroy the core.

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C.9 Rock bit types and sizes

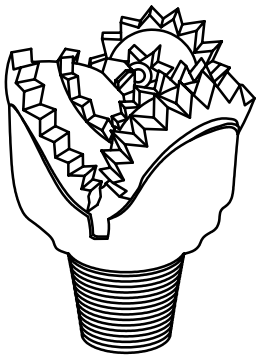

Figure C.11 — Three-cone milled tooth rock bit

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

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Table C.18 *(continued)*

Bit size		Thread	Approx. weight	
inch	mm		lb	kg
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

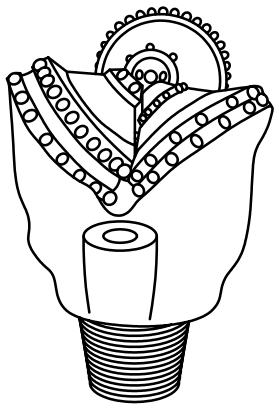

Figure C.12 — Tungsten carbide button bit

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

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Table C.19 *(continued)*

Bit size		Thread	Approx. weight	
inch	mm		lb	kg
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

C.10.1 General

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

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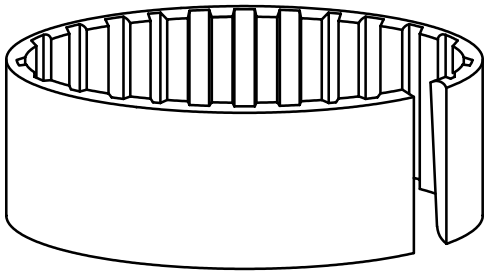
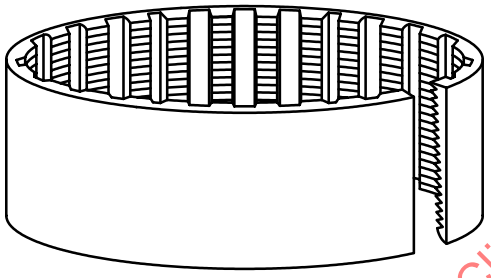
C.10.2 Typical core barrel lifters

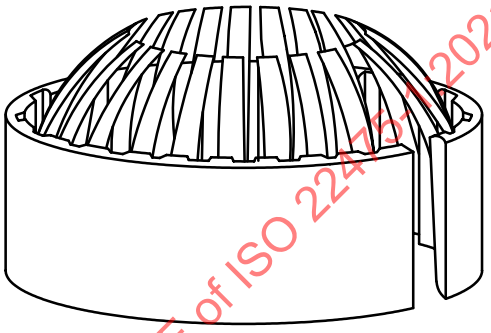
a) Plain



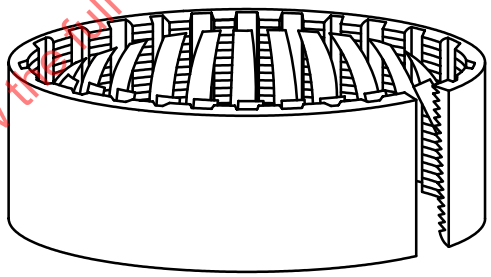
b) Internal slotted



c) Internal slotted and serrated



d) Internal slotted with basket fingers



e) Internal slotted and serrated with basket fingers

Figure C.13 — Typical core barrel lifters

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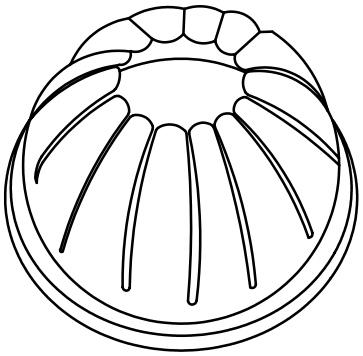
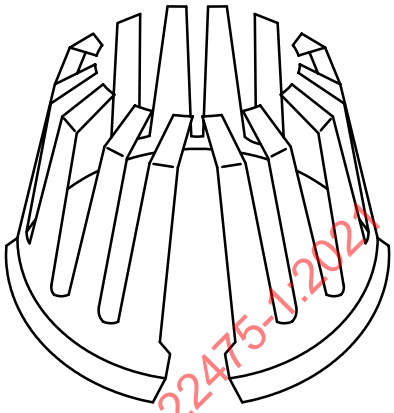
C.10.3 Typical sampler retainers

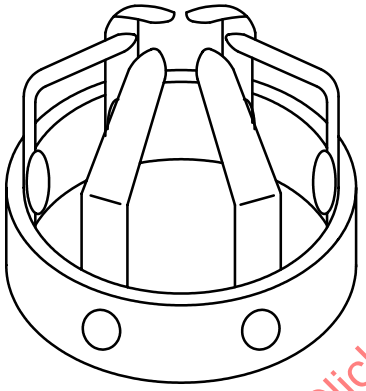
Sample retainers are used to retain the soil sample within the sampling tube as the sample tube is withdrawn to the surface. Figure C.14 is showing a few examples of the most popular.



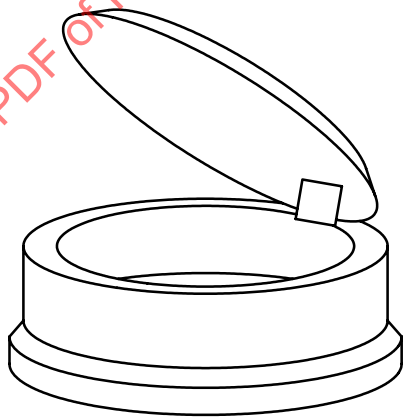
a) Basket retainer of plastic or steel



b) Spring retainer (light duty)



c) Basket retainer (heavy duty)



d) Flap valve

Figure C.14 — Typical sampler retainers

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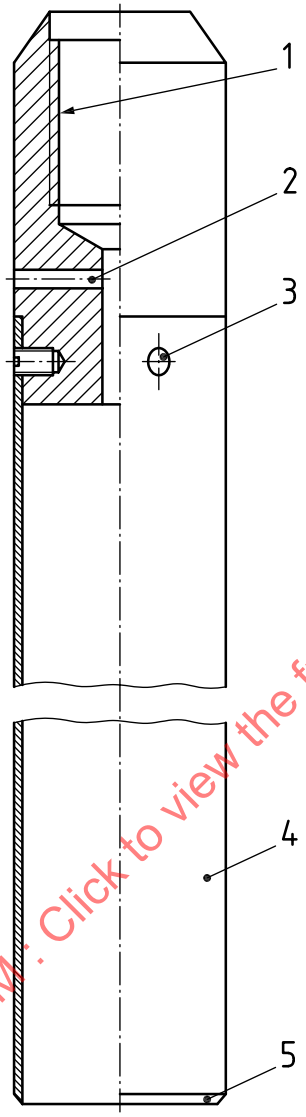
C.11 Sampling equipment

C.11.1 Thin-walled sampler (Shelby tube)



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-walled sampler (Shelby tube)

C.11.2 Hydraulic piston sampler

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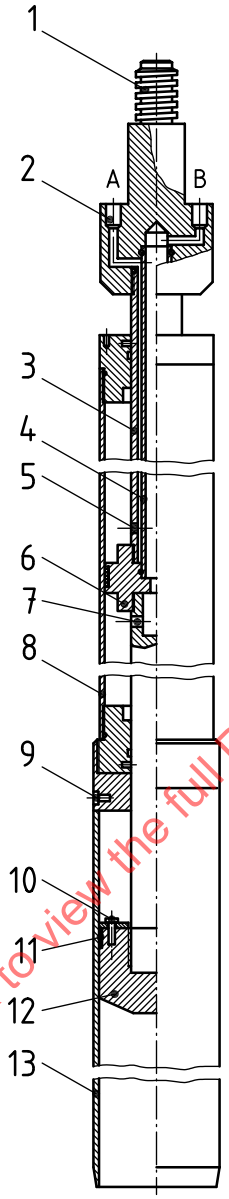

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Key

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 liter)
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

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In Figure C.17 a stationary piston sampler with a liner of 50 mm diameter is shown for taking samples in soft to stiff fine soils and silts (sampling category A).

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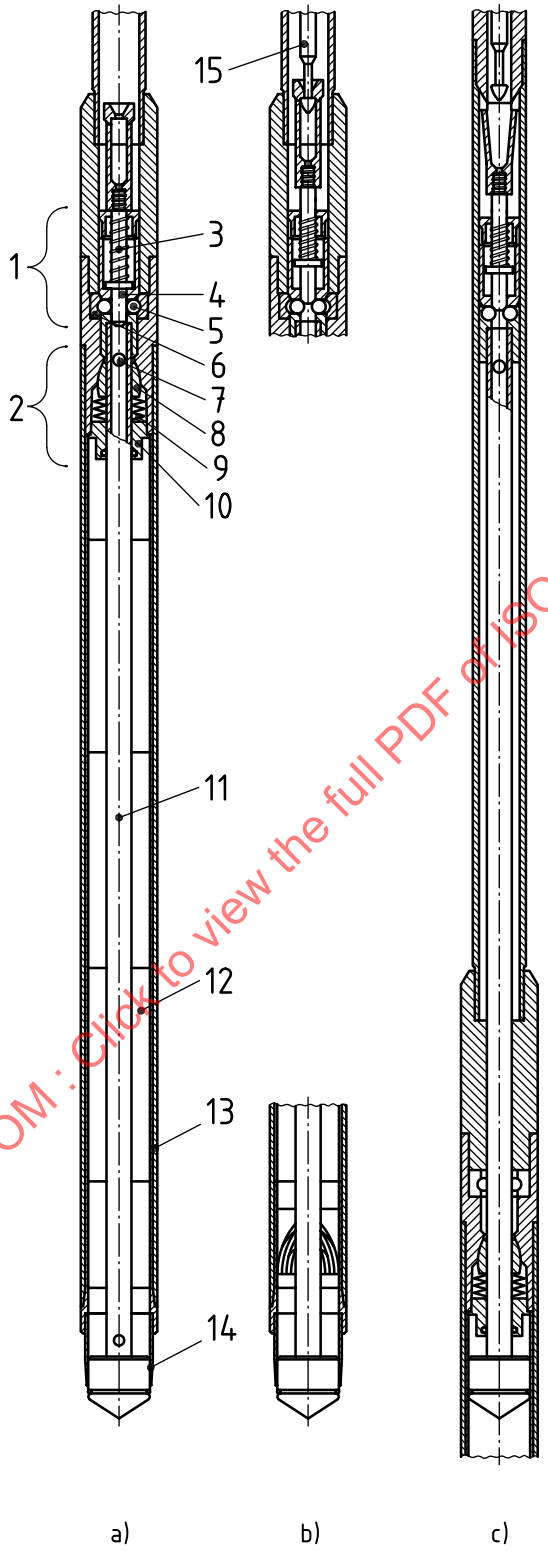

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Key

a) sampler before punching
b) after releasing the lock; alternative with shutter
c) when pushing is finished and rod is released
1 lock
2 brake
3 spring

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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

Figure C.17 — Stationary piston sampler with a liner of 50 mm diameter for taking samples in soft to stiff fine soils and silts (sampling category A)

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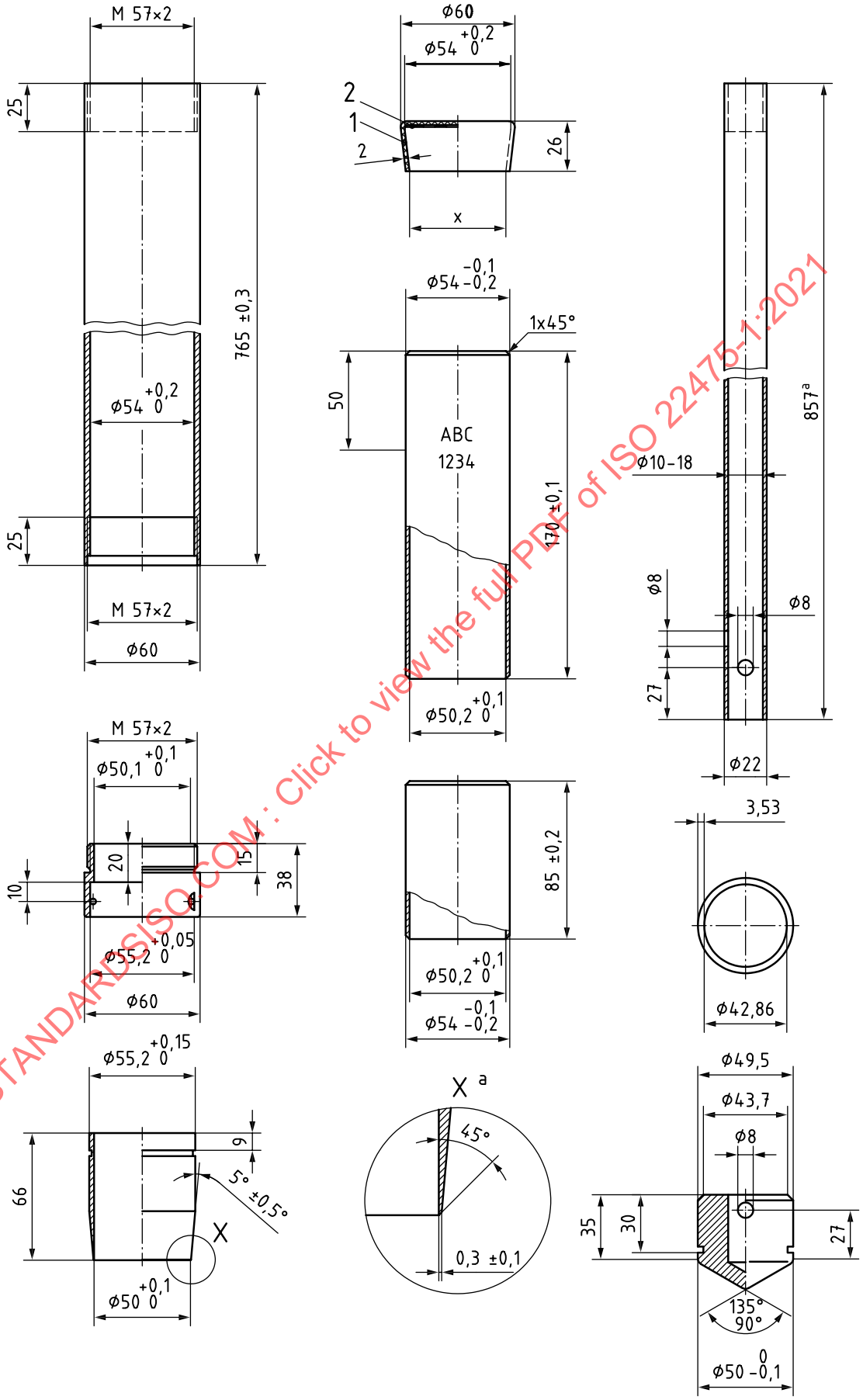
Dimensions in millimetres



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[a] To be adjusted after material.

Figure C.18 — Stationary piston sampler with liner 50 mm — Parts

In Figure C.19 a stationary piston sampler with a liner of 50 mm diameter is shown for taking samples in soft to stiff fine soils and silts (sampling category A and B). The samples are cut by rotating the inner rod system. This sampling principle is also used for taking samples in cohesionless soils with liners of 25 mm, 34 mm and 50 mm diameters (sampling category B).

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Dimensions in millimetres

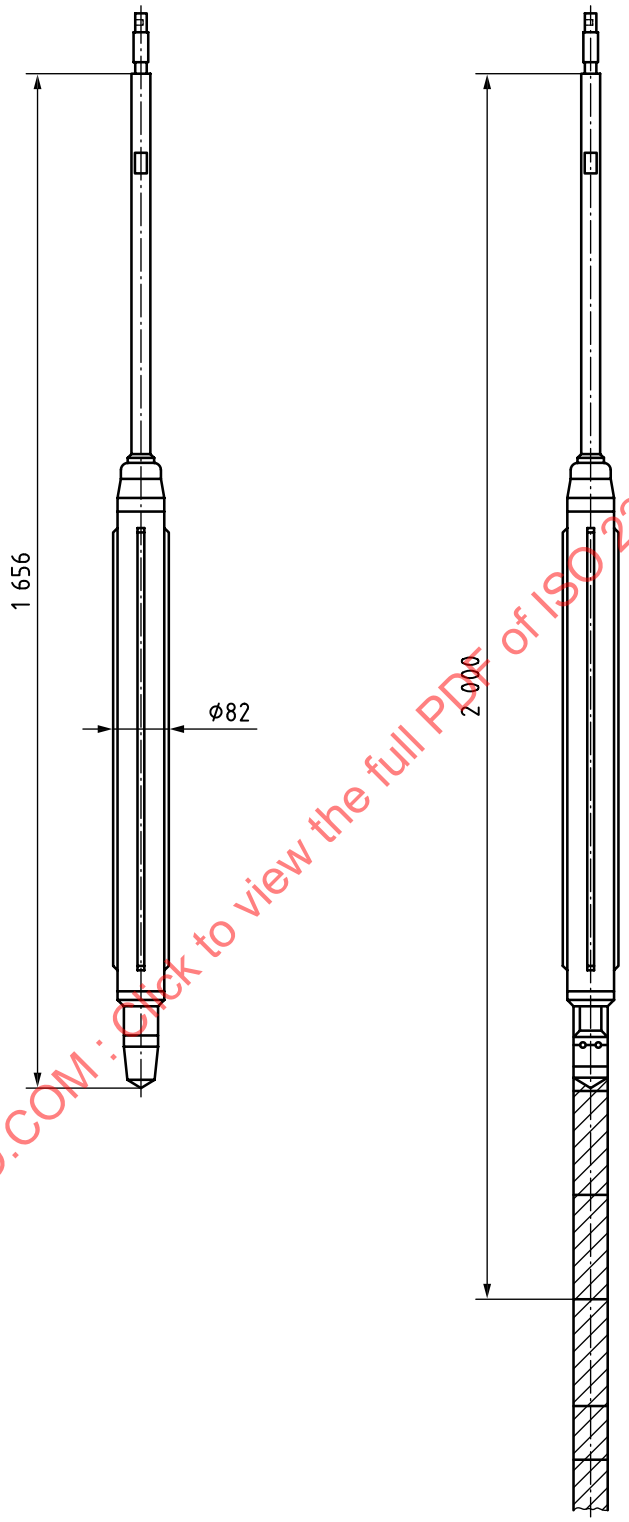

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Figure C.19 — Stationary piston sampler with a liner of 50 mm diameter for taking samples in fine soils with very low to high undrained shear strength (sampling category A and B)

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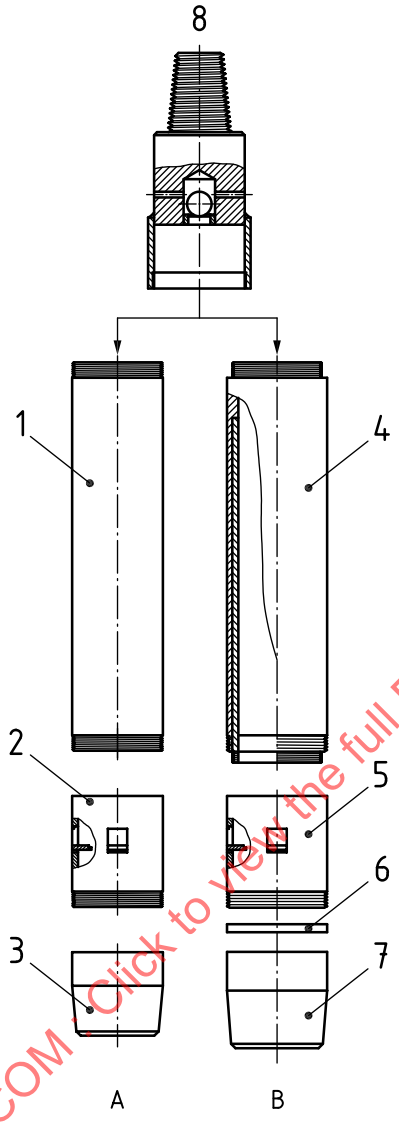
C.11.3 U100 Sampler



Key

A Standard system
B Plastic liner system
1 sample tube (cadmium-plated steel or aluminium)
2 core catcher (optional)
3 cutting shoe (plain or serrated edge)
4 steel body tube (enclosing plastic liner)
5 core catcher (optional)
6 spacing ring
7 cutting shoe (plain or serrated edge)
8 U100 drive head (bell housing)

Figure C.20 — U100 Sampler

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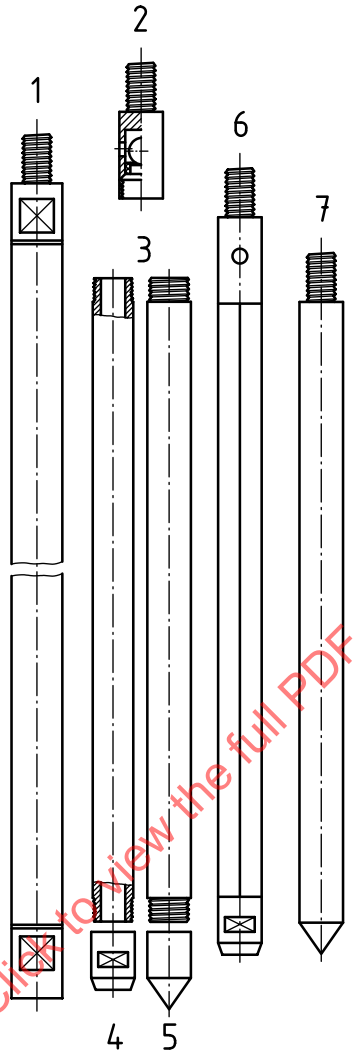
C.11.4 Standard penetration test (SPT) samplers



Key

1 SPT rod
2 top adaptor
3 split spoon sampler
4 SPT shoe
5 SPT solid cone
6 SPT assembly complete
7 SPT solid rod

Figure C.21 — Standard penetration test (SPT) samplers

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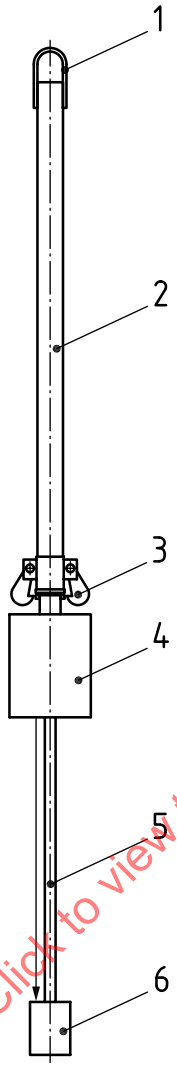
C.11.5 Typical automatic trip hammer



Key

1 lifting eye
2 outer tube
3 lifting pawls with springs
4 drive weight
5 guide rod
6 anvil

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Figure C.22 — Typical automatic trip hammer

C.11.6 Window and windowless samplers

In Figure C.23 b) a window sampler is shown for taking samples in coarse soils (sampling category C). Opening of the window is made by rotating the rod system. Alternatively, tubes with a fixed open window may be used.

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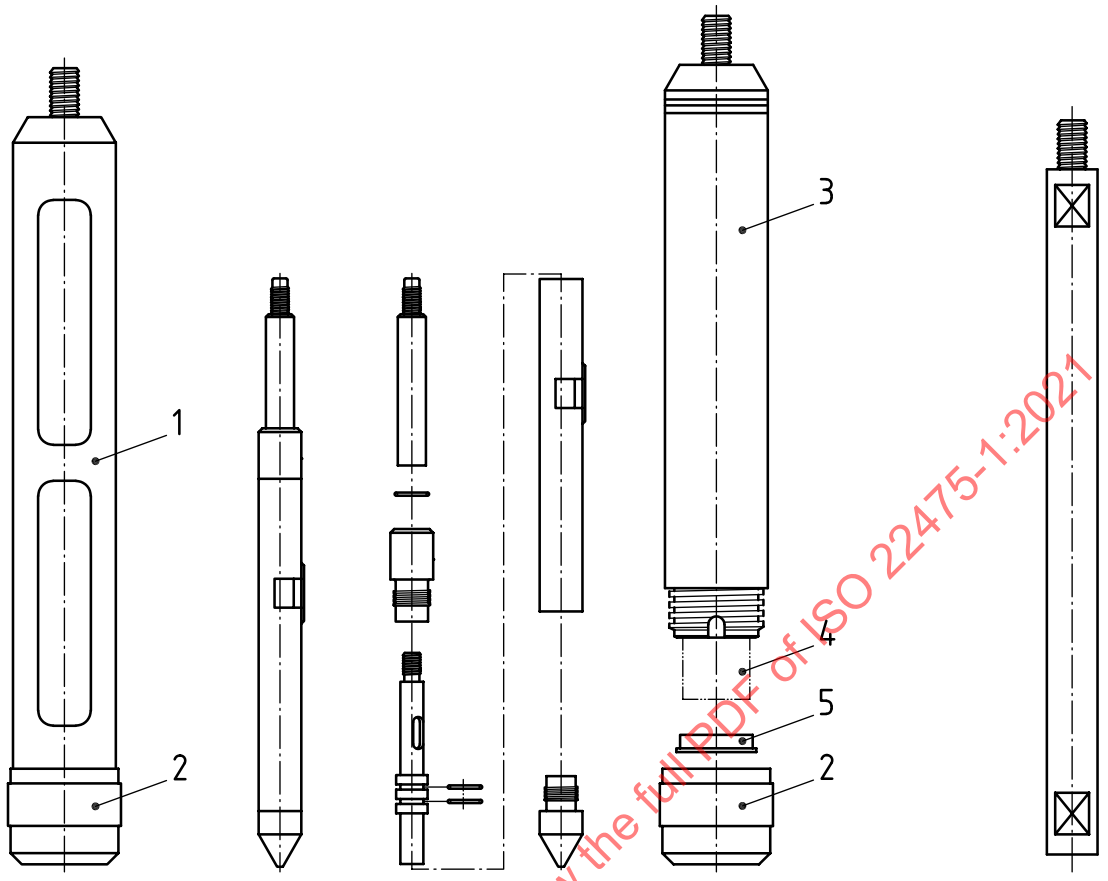

a) Window sampler b) Window sampler with 35 mm and 50 mm diameter c) Windowless sampler d) Driving rod

Key

1 sample tube-window
2 shoe
3 sample tube
4 plastic liner
5 retainer

Figure C.23 — Window and windowless samplers

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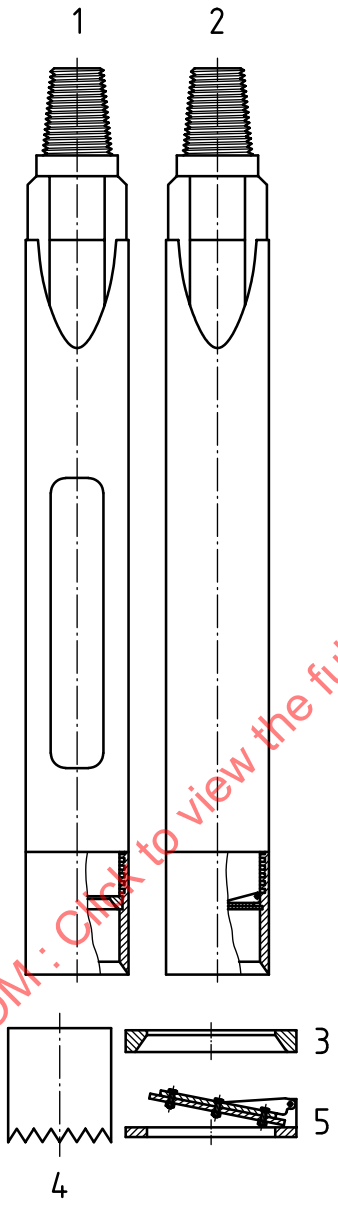
C.12 Cable percussion drilling tools

C.12.1 Clay cutter and shell (bailer)



Key

1 clay cutter
2 shell or bailer
3 clay cutter ring
4 serrated tool shoe
5 leather clack

Figure C.24 — Clay cutter and shell (bailer)

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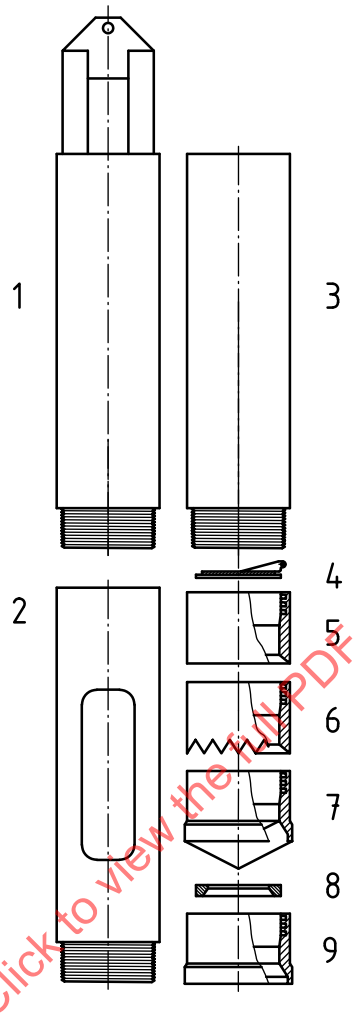
C.12.2 Sectional shell



Key

1 hanger section
2 window section
3 plain section
4 clack
5 plain shoe
6 serrated shoe
7 chisel shoe
8 clay cutter ring
9 clay cutter shoe

Figure C.25 — Sectional shell

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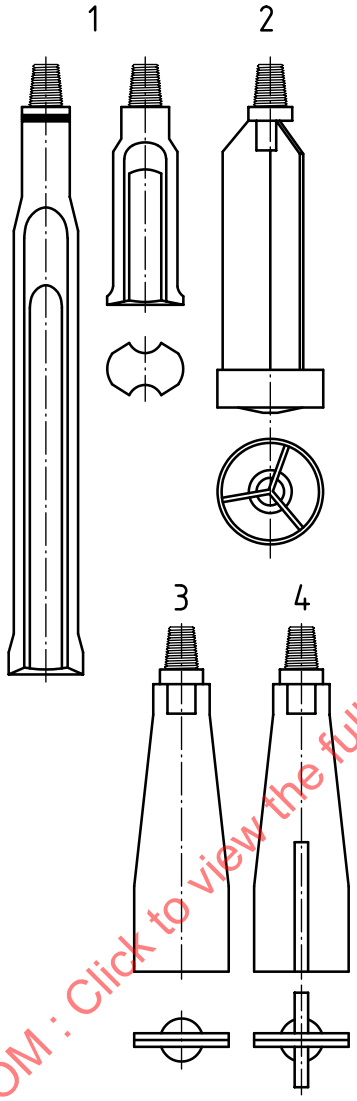
C.12.3 Chisels and stubber



Key

1 California chisels
2 stubber
3 flat chisel
4 cross chisel

Figure C.26 — Chisels and stubber

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C.13 Types of augers

C.13.1 Continuous flight auger

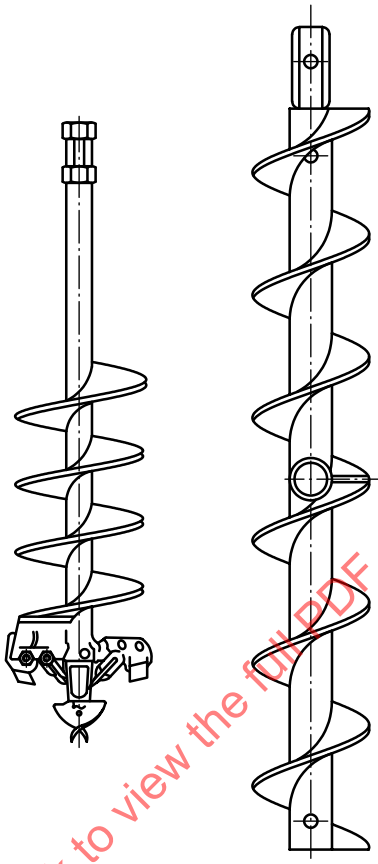

Figure C.27 — Continuous flight auger

In Figure C.28 an auger is shown with a diameter between 36 mm and 80 mm for taking samples in cohesive soils and cohesionless soils above groundwater level (sampling category E).

Table C.20 — Augers with diameters between 36 mm and 80 mm for taking samples in cohesive soils and coarse soils above groundwater level (sampling category E)

Diameters mm	Flight length mm	Flight thread	Overall length mm
36	250	right hand	300
40	500	right hand	1 000
50	500	right hand	1 000
50	1 000	right hand	1 250
75	500	right hand	1 000
60	1 000	left hand	1 220

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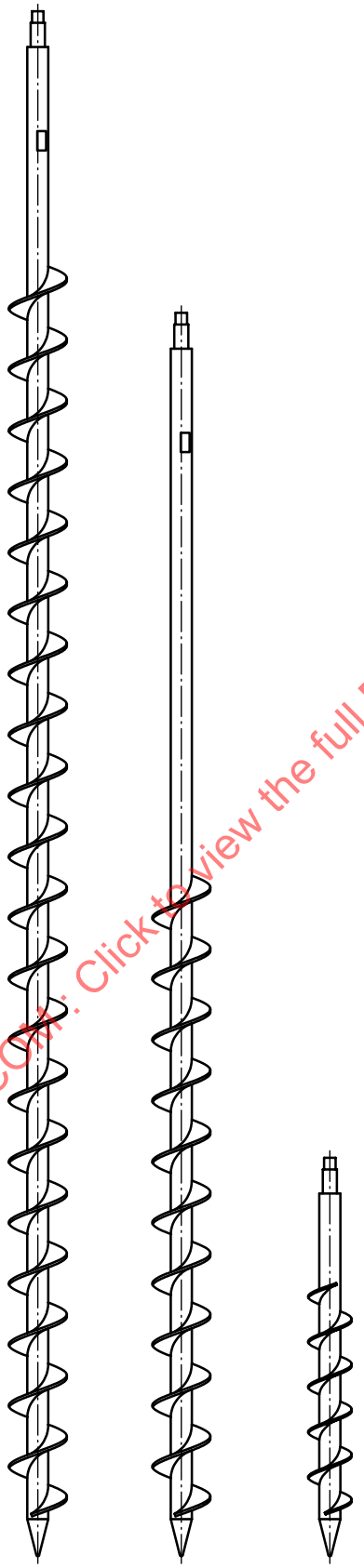

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Figure C.28 — Augers with diameters between 36 mm and 80 mm for taking samples in cohesive soils and coarse soils above groundwater level (sampling category E)

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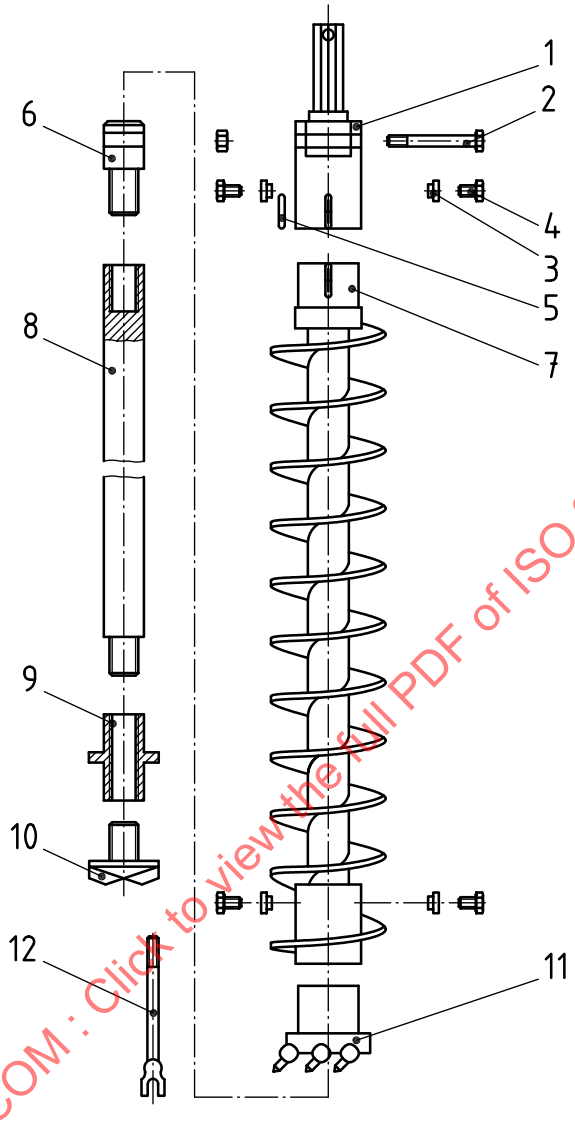
C.13.2 Hollow stem auger



Key

1	drive cap	7	hollow stern auger
2	nut and bolt for rod to cap adaptor	8	drill rod
3	bushing nut	9	pilot bit connector
4	lock nut	10	pilot bit
5	drive key	11	cutter head
6	rod to cap adaptor	12	knock-out wrench

Figure C.29 — Hollow stem auger

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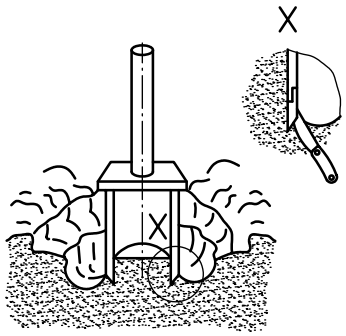
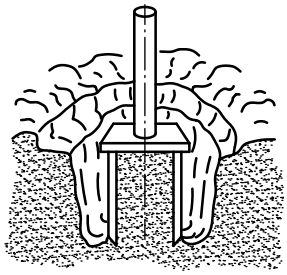
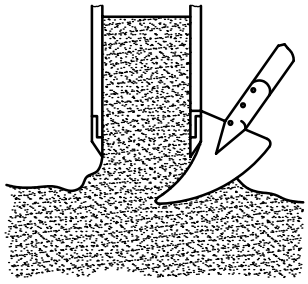
C.14 Method of recovering samples from trial pits



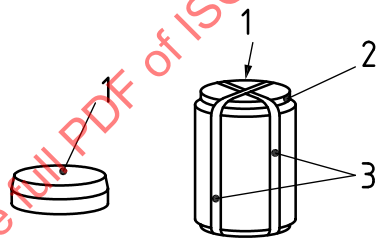
a) The cylindrical sampler tube should be placed on a prepared surface and be pushed into the soil. The soil should be removed around the sampler tube down to the cutting edge.



b) The sampler tube should then be vertically pushed further into the soil. The soil around the sampler should be removed down to the cutting edge.



c) The sampler should be removed from the soil.



d) Sealing of the sample.

Key

1 waterproof cap
2 paraffin or water proof seal
3 strong tape

Figure C.30 — Examples of sampling from trial pits

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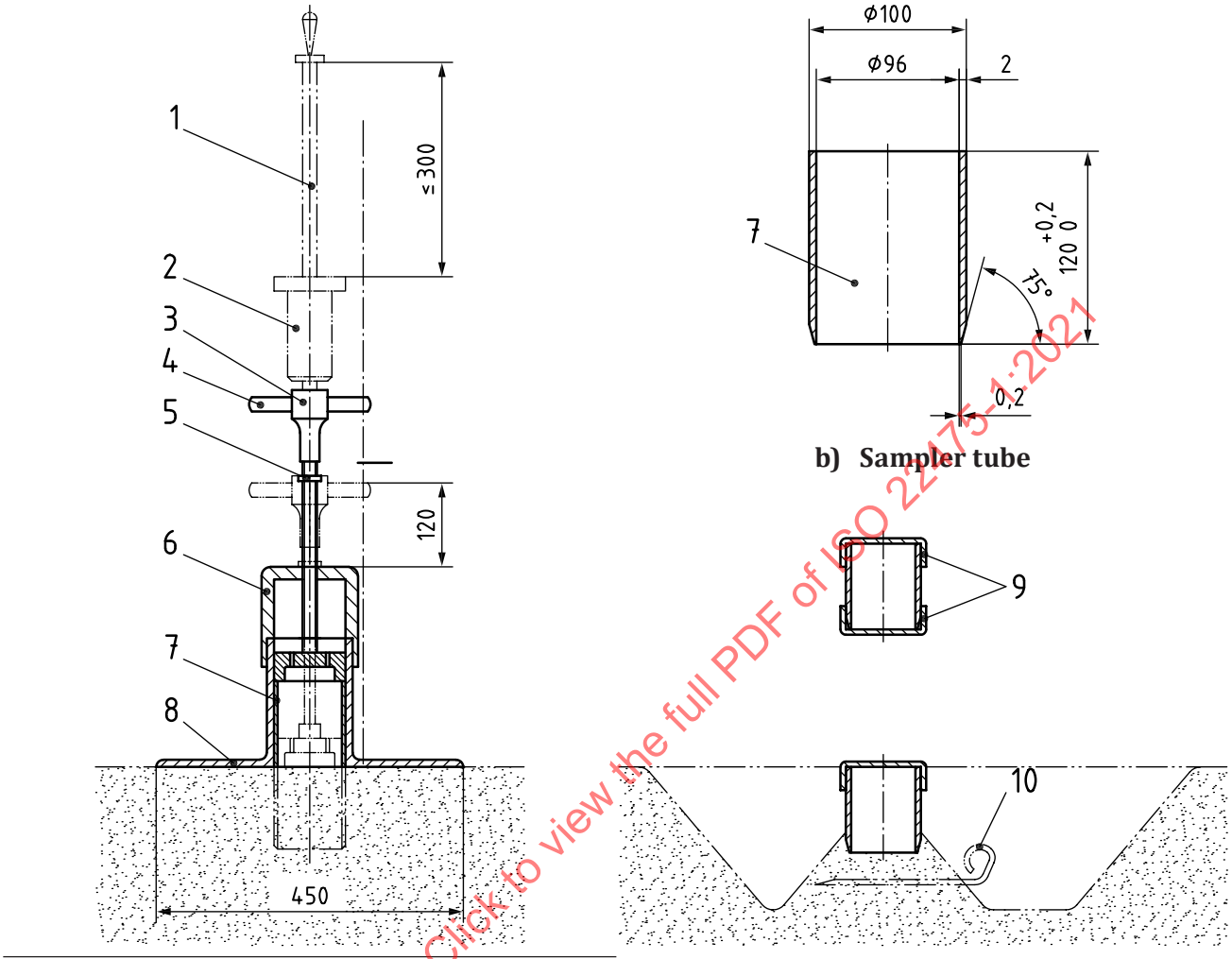
Dimensions in millimetres



a) Arrangement of sampler

b) Sampler tube

c) Sampling process

Key

1 percussion drill rods
2 drop weight
3 anvil
4 driving device
5 ring mark
6 guide hood
7 sampler tube
8 guide plate
9 end caps (sealed with adhesive tape)
10 metal plate for limiting depth of penetration

Figure C.31 — Examples of recovering samples from trial pits

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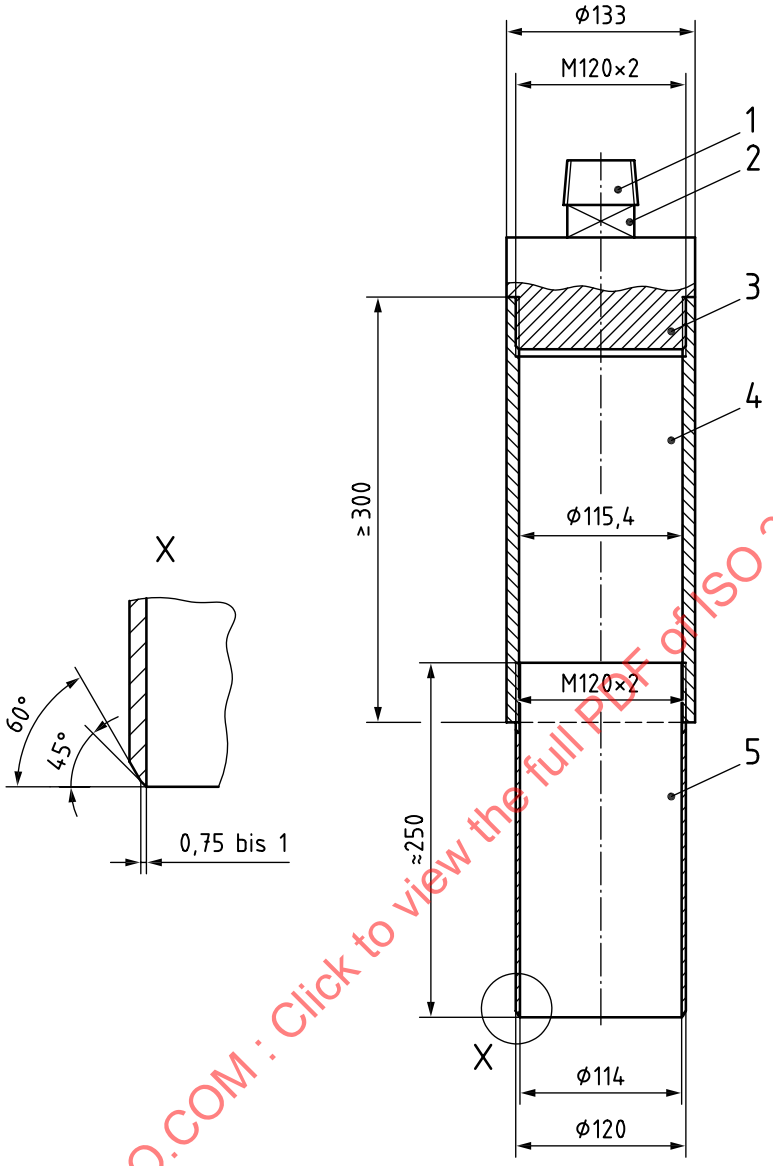
Dimensions in millimetres



Key

1 pipe thread
2 width across flats
3 sampler head with non-return valve (not shown)
4 overdrive space
5 sampler tube

Figure C.32 — Example for a thin-walled open-tube sampler

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