INTERNATIONAL STANDARD

ISO 17628

First edition
2015-07-15

Geotechnical investigation and testing — Geothermal testing — Determination of thermal conductivity of soil and rock using a borehole heat exchanger

Reconnaissance et essais géotechniques — Essais géothermiques — Détermination de la conductivité thermique des sols et des roches dans les sondes géothermiques

Reference number
ISO 17628:2015(E)

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

Contents

Page

Foreword

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

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

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

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

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

ISO 17628 was prepared by European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical investigation and testing*, in collaboration with ISO Technical Committee ISO/TC 182, *Geotechnics*, Subcommittee SC 1, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Geotechnical investigation and testing — Geothermal testing — Determination of thermal conductivity of soil and rock using a borehole heat exchanger

1 Scope

This International Standard specifies requirements for the Geothermal Response Test (GRT). This test comprises the *in situ* determination of the thermal conductivity in saturated and unsaturated soil and rock in a heat exchanger installed in a borehole. For this test, liquid heat transfer media not subjected to phase changes are used.

The thermal conductivity is an important parameter used in the design of thermal storage and thermal exchange systems.

A Geothermal Response Test measures the temperature response to a thermal energy forcing of a borehole heat exchanger (BHE) or the extraction of thermal energy from a borehole. The temperature response is related to the thermal parameters of the ground and borehole filling material, such as thermal conductivity and borehole resistivity, and is therefore used to obtain estimated or derived values of these parameters.

This International Standard applies to heat exchangers installed in vertical or inclined boreholes with length up to e.g. 400 m and with a diameter of up to 200 mm.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

ISO 22475-1, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution*

EN 16228-1, *Drilling and foundation equipment - Safety - Part 1: Common requirements*

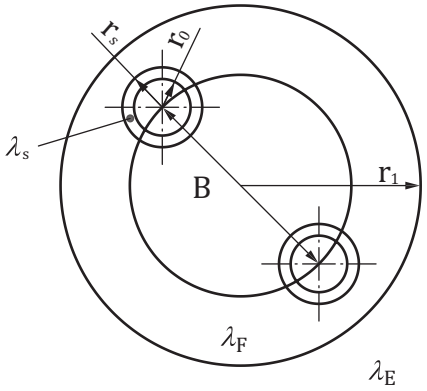
EN 16228-2, *Drilling and foundation equipment - Safety - Part 2: Mobile drill rigs for civil and geotechnical engineering, quarrying and mining*

3 Terms and definitions

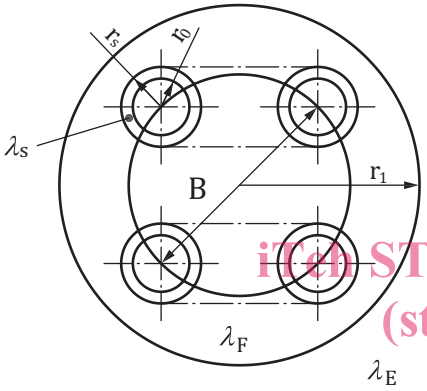
For the purposes of this document, the terms and definitions given in ISO 22475-1 and the following apply.

3.1
borehole heat exchanger
BHE
one or two U-tubes or one coaxial tube in a borehole through which the exchanger fluid circulates

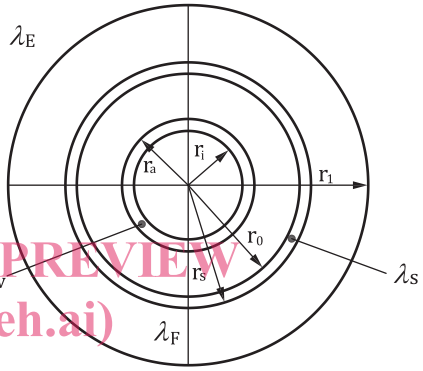
Note 1 to entry: See Figure 1 and Figure 2.



a) single U-tube



b) double U-tube

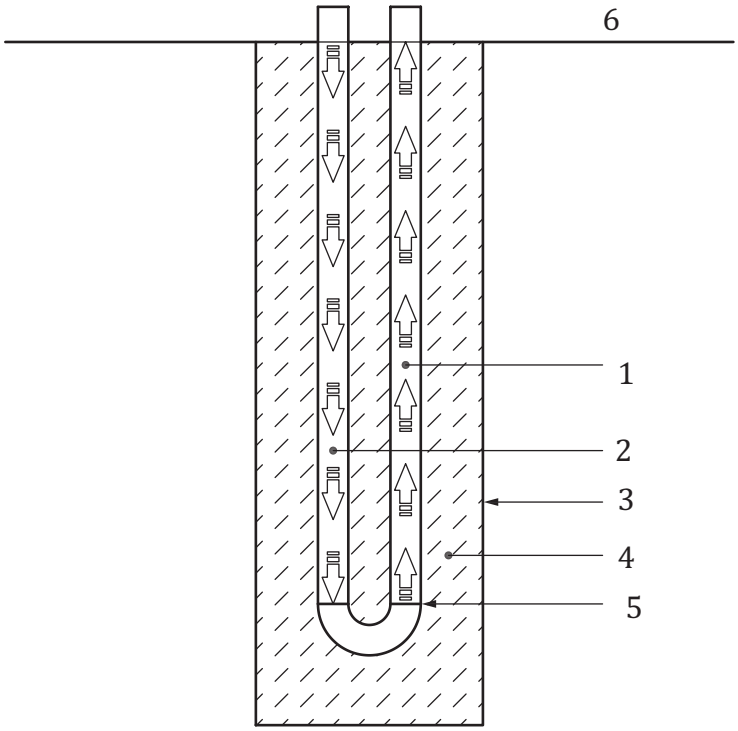


c) coaxial tube

Key

r_1	borehole radius	λ_F	thermal conductivity of the annular space filling
r_i	inner radius	λ_w	thermal conductivity of the inner borehole tube
r_a	outer radius	λ_s	thermal conductivity of the outer borehole tube
r_o	inner radius of the outer tube	λ_E	thermal conductivity of the ground
r_s	outer radius of the outer tube	B	tube spacing

Figure 1 — Cross-section of examples of borehole heat exchanger tubes



Key

1 heat exchanger outlet
2 heat exchanger inlet
3 borehole wall
4 annular space filling
5 connection
6 ground level

Figure 2 — Example of a borehole heat exchanger including annular space filling

3.2
geothermal response test
test to obtain the thermal conductivity

4 Symbols and abbreviations

Table 1 — List of symbols and abbreviations

Symbol	Designation	Unit
A	total cross sectional area of a conducting surface	m^2
B	tube spacing	m
H	length of the borehole heat exchanger	m
k	slope	
m	mass of a substance	kg
ρc_p	volume related thermal capacity	$J/m^3/K$
Q	heat supply	W
r_0	borehole radius	m
r_i	inner radius	m

Table 1 *(continued)*

Symbol	Designation	Unit
r_a	outer radius	m
r_o	inner radius of the outer tube	m
r_s	outer radius of the outer tube	m
Re	Reynold's number	
R_b	borehole resistance	
T	temperature	°C
T_0	undisturbed ground temperature	°C
T_f	fluid temperature at time t	°C
t_1	minimum test duration	
x	thickness of the conducting surface separating two different temperatures	m
λ	thermal conductivity	W/m/K
λ_E	thermal conductivity of the ground	W/m/K
λ_{eff}	effective thermal conductivity	W/m/K
λ_{est}	estimated thermal conductivity	W/m/K
λ_F	thermal conductivity of the annular space filling	W/m/K
λ_s	thermal conductivity of the outer borehole tube	W/m/K
λ_w	thermal conductivity of the inner borehole tube	W/m/K

5 Installation of borehole heat exchangers

5.1 Drilling rigs and ancillary equipment

5.1.1 General

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

5.1.2 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 depth and stability of the borehole can be achieved.

The drilling rig and equipment shall allow all drilling functions to be adjusted accurately.

When specified, the following drilling parameters should be measured and recorded against depth:

a) penetration rate (m/min);

b) drilled length (m);

c) flushing medium recovery rate (l/min);

d) azimuth and inclination (degree);

e) borehole diameter (mm);

f) casing and casing length (m);

g) flush medium.

5.2 Borehole heat exchangers, filling, and annular space filling materials

5.2.1 Borehole heat exchanger material

The material of the borehole heat exchanger tubes and bottom concerning the following shall be selected related to the purpose and the design:

a) quality;

b) durability;

c) corrosion;

d) thermal resistance;

e) impact resistance;

f) hydraulic resistance;

g) compressive strength;

h) resistance to deformation;

i) safety, related to contamination of the ground and ground water;

j) dimensions (diameter, wall thickness, and distance).

Plastic tubes shall have the quality of at least PE 100 black pipe for non-potable underground use and should be made of the same material as the borehole heat exchanger which will be installed for the later BHE-array.

Tube spacers shall be attached to U-tubes in order to avoid thermal shortcuts. The minimum spacer distance shall be at least 2 m.

Beginning at the bottom of the borehole heat exchanger, the tubes shall possess length marks every meter in numerical order starting at zero and increasing to the end of the tubes to check the installed length at all times.

5.2.2 Heat transfer fluid of the borehole heat exchanger tubes

The heat transfer fluid of the borehole heat exchanger tubes shall fulfil the requirements of the test design and the environmental regulations.

Water or de-ionized water should be used because of its good hydrodynamic properties and it does not endanger the ground and the groundwater, if a leakage of the borehole heat exchanger occurs.

The specific thermal capacity of the heat transfer fluid shall be known.

The use of antifreeze additives shall be justified. If used, the annular space filling has to be adapted to freezing and thawing conditions in order to avoid cracks.

The design shall take into account the minimum temperature of the heat transfer fluid.

5.2.3 Annular space filling material

The annular space filling material shall provide the thermal transport from the ground to the borehole heat exchanger and vice versa. It shall seal the borehole to the ground level to prevent contaminants from entering and aquifers that might have been penetrated. The filling material shall ensure a durable, physically and chemically stable incorporation of the borehole heat exchanger in the ground. It shall be suited for all the respective deployment temperatures.

The filling material shall be selected according to expected thermal conductivity of the surrounding ground and ground water.

Thermally improved filling materials with a thermal conductivity of > 2 W/mK should be used.

The material shall be chemically harmless for the environment and health.

5.3 General requirements prior to installation

5.3.1 Requirements on the drilling and installation site

Drilling points shall be marked on the site before drilling commences. Their location and elevation shall be surveyed correctly and in accordance with site conditions and entered in a site plan on completion of the installation.

Drilling and installation sites shall be investigated with respect to relevant hazards, underground utilities, former or current underground mining activities, natural cavities, and unexpected, unexploded ordnance and, if necessary, appropriate actions have to be taken. Installation locations on contaminated ground have to be dealt with by special procedures.

The environmental impact of drilling and installation shall be considered. Special principles have to be applied in

— water supply areas,

— areas with artesian or confined groundwater conditions,

— areas with multiple aquifers, and

— grounds with swellable or collapsible rocks or soils.

The distance to existing buildings should be at least 2 m; the stability may not be jeopardized.

5.3.2 Selection of drilling techniques and installation methods

The techniques and methods for drilling and installation shall be selected according to the purpose of the borehole heat exchanger in relation to the expected geological and hydrogeological conditions.

If installation in unstable ground is necessary, stable or stabilized boreholes are required using casings or suitable flushing media.

Sampling techniques, sample transportation, and storage procedures shall be selected according to ISO 22475-1 on the basis of the required sample quality class.

The knowledge of the geological and hydrogeological conditions is necessary for the interpretation of the results of the Geothermal response test and for the selection of the annular space filling material.

5.3.3 Preliminary information needed before starting drilling and installation

The following preliminary information shall be available before starting drilling and installation:

a) location of the planned borehole heat exchanger;

b) requirements on numbering of boreholes;

c) identification and planned depths of boreholes based on the outline design;

d) orientation, inclination, and acceptable deviations in boreholes;

e) installation plan of the borehole heat exchanger including the annular space filling;

f) tolerances of borehole depth and installation length;

g) expected geology and hydrogeology;

h) space requirements, accessibility of the drilling site, transport routes;

i) environmental and safety risks associated with, e.g. flushing media or additives intended to be used as well as regulations for their use;

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

k) preparation of the disposal of drilling mud and cuttings;

l) supply of auxiliary materials, water and energy;

m) sampling method and sampling category intended;

n) sample handling, storage, and transport intended according to ISO 22475-1;

o) requirements concerning planned measurements in the borehole heat exchanger;

p) required accuracy and uncertainty of measurements;

q) frequency of measurements;

r) *in situ* tests intended;

s) site reinstatement;

t) environmental care;

u) emergency arrangements;

v) clarification of necessary permissions;

w) name of contact person;

x) planned flow of information.

5.3.4 Environmental requirements

Regarding nuisance and environmental protection, for each particular situation, the respective national standards, specifications or statutory requirements or respective international standards shall be applied.

5.3.5 Safety requirements

Regarding safety on the site and safety of the working practices, the respective national standards, specifications or statutory requirements or respective international standards shall be applied.

Drill rigs shall be in accordance with EN 16228-1 and EN 16228-2.

Every borehole shall be fenced or temporarily capped in a safe manner until the installation has been finished.

5.4 Execution

5.4.1 Drilling

The drilling methods have to be selected according to the expected geology and hydrogeology. In the case that the borehole is not stable, it shall be stabilized by a supporting liquid (e.g. bentonite suspension) or by casing.

NOTE In suitable soils, a push-in technique can be used instead of drilling. Where required, the inclination of the casing and the borehole can be checked by an inclinometer measurement.

A possibility for sampling of cuttings shall be provided. If more than one drill rig is working at the same site, the rigs shall keep a sufficient distance from another to minimize the interaction during drilling and grouting.

5.4.2 Installation of borehole heat exchangers

The borehole heat exchanger shall be prefabricated to avoid welding at the installation site. It shall have a pressure test certificate. Mechanical damages during transport, storage, and installation shall be avoided.

The borehole heat exchanger tubes shall be filled with water and pressure-tight capped before installation. It shall be predetermined whether an additional weight is required at the bottom of the borehole heat exchanger tubes. The density of the flushing media, if used, shall be checked to ensure its compliance with the selected predetermined weight. The borehole heat exchanger shall be held back initially when placed into the borehole to avoid it from sliding in too quickly. The tubes cannot be pushed from the ground level. The tubes can only be drawn in a straight position by a suitable device that applies any force directly at the bottom of the borehole heat exchanger. The meter marks on the tubes shall be reported.

In circumstances where the borehole is dry, the BHE tube should not be filled with water until after installation.

The tremie pipes for filling the annular space should be placed together with borehole heat exchanger in the borehole considering the dimensions of the left space. Several tremie pipes can be required depending on the borehole depth to ensure continuous grouting. The number and lengths of the tremie pipes shall have been defined by the design in advance. The tremie pipes shall be clearly marked, i.e. the depth or length of the respective tremie pipe shall be recognizable at the ground level.

During prolonged frost periods, the tubes can also be filled with an antifreeze fluid that is compatible with ground array design.

The installation shall be recorded according to 7.1.2.

5.4.3 Annular space filling

After the installation of the borehole heat exchanger, the annular space shall be filled with materials whose permeability after hardening is equal or less than that of the surrounding ground, e.g. in order to stabilize the borehole, to provide a good thermal transfer, and to prevent contamination and connections between aquifers and vertical drainage along the borehole heat exchanger tubes.

The grout shall be placed by means of a tremie lowered to the bottom of the borehole. The tremie should remain in the borehole. If it is removed, this should not happen until the infill material flows out at the surface with a density equal to the density at which it was injected. The injection operation shall be continued during removal.

If there is an influence of the ground and groundwater conditions on the filling process, special technical requirements for filling shall be specified in advance. Voids shall not occur during the placement of the filling material in the borehole.

Due to certain conditions, e.g. hydrogeological and geological conditions, more than one grouting tube can be required to ensure the filling of the annular space from the bottom to the top.

When withdrawing the grouting tube, the outlet shall always be below the current filled level to prevent entrapped air. A grouting tube that remains in the borehole shall remain filled with suspension.

The annular space shall be infilled, consolidated, and capped in such a manner that there will be no subsequent depression at ground level due to the settlement to the infill material. After one or two days, the level of annular space filling shall be checked. Any depressions shall be equalized.

The properties and the preparation of the filling material shall be recorded.

