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**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*

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## Foreword

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

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](http://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](http://www.iso.org/patents)).

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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).

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# 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.

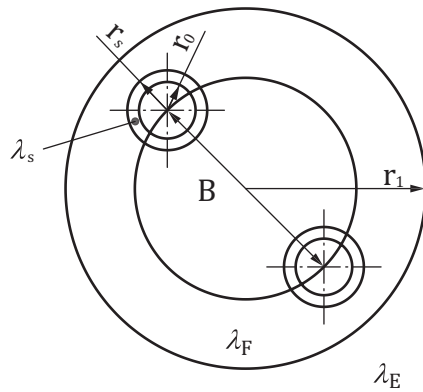
### 3.1

#### **borehole heat exchanger**

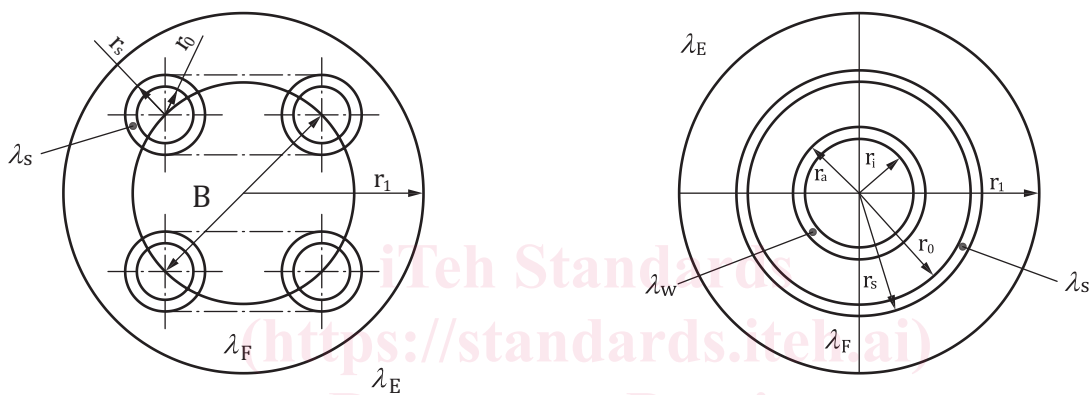
#### **BHE**

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



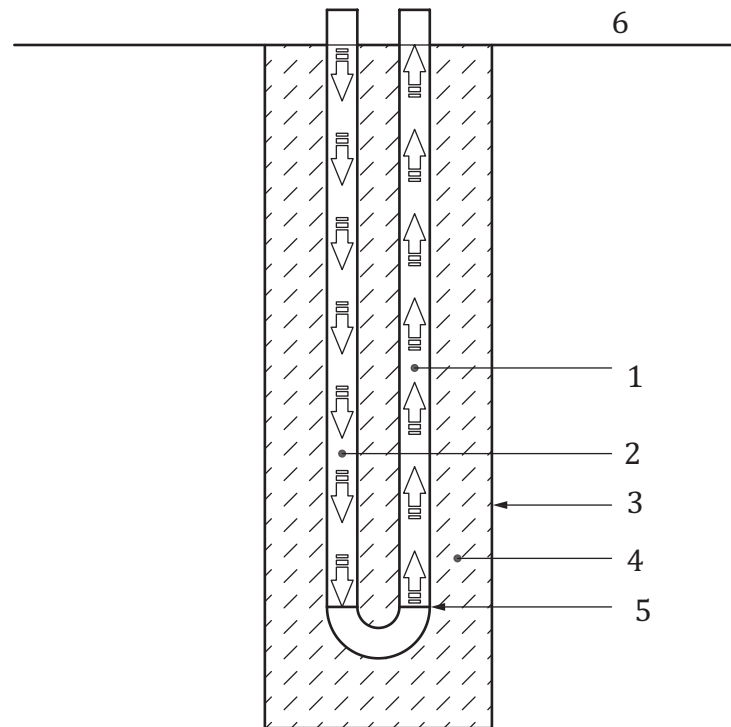
b) double U-tube

c) coaxial tube

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$r_1$	borehole radius	$\lambda_F$	thermal conductivity of the annular space filling
$r_i$	inner radius	$\lambda_w$	thermal conductivity of the inner borehole tube
$r_a$	outer radius	$\lambda_s$	thermal conductivity of the outer borehole tube
$r_o$	inner radius of the outer tube	$\lambda_E$	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

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<https://standards.itih.ai/standards/iso/17628:2015>**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 <sup>2</sup>
$B$	tube spacing	m
$H$	length of the borehole heat exchanger	m
$k$	slope	
$m$	mass of a substance	kg
$\rho c_p$	volume related thermal capacity	J/m <sup>3</sup> /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
$\lambda$	thermal conductivity	W/m/K
$\lambda_E$	thermal conductivity of the ground	W/m/K
$\lambda_{eff}$	effective thermal conductivity	W/m/K
$\lambda_{est}$	estimated thermal conductivity	W/m/K
$\lambda_F$	thermal conductivity of the annular space filling	W/m/K
$\lambda_s$	thermal conductivity of the outer borehole tube	W/m/K
$\lambda_w$	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.