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Konstruiranje in izdelava vrtinskih toplotnih izmenjevalnikov

Design and construction of borehole heat exchangers

Planung und Bau von Erdwärmesonden

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Design and construction of borehole heat exchangers

Planung und Bau von Erdwärmesonden

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (prEN 17522:2020) has been prepared by Technical Committee CEN/TC 451 “Water wells and borehole heat exchangers”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

1 Scope

This document covers standardization in the field of geological and environmental aspects, design, drilling, construction, completion, operation, monitoring, maintenance, rehabilitation and decommissioning of borehole heat exchangers for uses of geothermal energy.

The direct expansion and thermal syphon techniques are excluded from this document

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.

EN 12201-1:2011, *Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 1: General*

EN 12201-2:2011, *Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 2: Pipes*

EN 12201-3:2011, *Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 3: Fittings*

EN 12201-5:2011, *Plastics piping systems for water supply, and for drainage and sewerage under pressure - Polyethylene (PE) - Part 5: Fitness for purpose of the system*

EN ISO 15875-1:2003, *Plastics piping systems for hot and cold water installations - Crosslinked polyethylene (PE-X) - Part 1: General (ISO 15875-1:2003)*

EN ISO 15494, *Plastics piping systems for industrial applications - Polybutene (PB), polyethylene (PE), polyethylene of raised temperature resistance (PE-RT), crosslinked polyethylene (PE-X), polypropylene (PP) - Metric series for specifications for components and the system (ISO 15494:2015)*

EN ISO 22391-1, *Plastics piping systems for hot and cold water installations - Polyethylene of raised temperature resistance (PE-RT) - Part 1: General (ISO 22391-1:2009)*

EN 1057, *Copper and copper alloys - Seamless, round copper tubes for water and gas in sanitary and heating applications*

EN 12449, *Copper and copper alloys - Seamless, round tubes for general purposes*

EN 1965-2, *Structural adhesives - Corrosion - Part 2: Determination and classification of corrosion to a brass substrate*

EN 12168, *Copper and copper alloys - Hollow rod for free machining purposes*

EN ISO 1127, *Stainless steel tubes - Dimensions, tolerances and conventional masses per unit length (ISO 1127:1992)*

EN 10216-5, *Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 5: Stainless steel tubes*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
aquifer
underground geological formations containing water that can be partially mobilised by gravity and which of permeable and/or cracked or fractured rocks that allow enough transmission of groundwater to create a significant flow and catchment of a significant amount of water

Note 1 to entry: An aquifer can be fully or partly saturated.

Note 2 to entry: Its upper limit is called the "top of the aquifer" and its base is called the "bottom of the aquifer"

3.2
aquitard
body of rock or stratum of sediment that retards but does not prevent the flow of groundwater from one aquifer to another

3.3
borehole heat exchanger
BHE
consists of the borehole with a loop, to circulate a heat transfer fluid, and a borehole filling

3.4
BHE loop
part of the pipe system in the borehole, which contains the fluid for heat transfer

3.5
heat transfer fluid
HTF
fluid circulated through the BHE for the heat transport

3.6
BHE system
one or more BHE connected in one hydraulic circulation system

Note 1 to entry: It does not include the heat pump or circulation pump

3.7
ground source heat pump system
GSHPS
BHE system including the horizontal piping, manifolds, the heat pump and circulation pump

3.8
BHE field
area with several BHEs systems that are not connected in the same hydraulic circulation system

3.9
backfill
material used for refilling any borehole or trench

3.10
grout
backfilling material composed of cement and water mixture and other additional components (clay minerals, etc.)

3.11
fluid
gas, vapour, liquid or combinations thereof

4 Geological and Environmental aspects

4.1 General

The design shall check whether the location of the planned installation is situated in any areas defined in spatial planning documents. These could be areas of special protection of natural resources (water protection, nature protection) or areas of specific risks (endangered areas, landslides, contaminated sites, etc.).

If the installation would be situated on such protected areas, it shall be verified that the design is in accordance with the specific geological conditions.

It shall be checked whether there are hydrogeological conditions (artesian aquifers, shallow groundwater table, perched groundwater, etc.) that could require special consideration or even impact or risk assessments.

The designer shall assess whether the available geological and hydrogeological information is sufficient for the project in question.

4.2 Geological and hydrogeological risks

4.2.1 Artesian aquifers

When the drilling penetrates into an artesian aquifer, the groundwater level rises over the orifice of the borehole. Uncontrolled upwelling and pressure loss would occur from use of improper drilling techniques or equipment selection. In certain cases, the upwelling (into shallower aquifers) might not be directly evident. This represents the main risks when artesian aquifer is penetrated.

Drilling in the artesian aquifer is a risk. Special specifications regarding drilling methods and BHE construction shall be implemented.

4.2.2 Stacked aquifers with different groundwater potential

Drilling through sealing layers between aquifers could result in leakage from one aquifer to another and result in impact on chemical characteristics of groundwater or hydraulic conditions. This could also cause an undesired drop or increase of groundwater level in one or more aquifers. Consequences could be decreased productivity of water sources or deteriorated formation conditions.

Groundwater flow conditions and qualities can also be affected adversely where drilling penetrates two or more groundwater layers. In this case, the possibility of uncontrolled water exchange between the individual aquifers via the borehole needs to be taken into account. A hydraulic short circuit should be avoided for groundwater protection reasons, especially where one of the penetrated layers contains highly mineralized or contaminated groundwater.

If drilling would cross through several aquifers, at least the aquitards shall be sealed.

4.2.3 Groundwater and soil chemistry

The chemical composition of the groundwater (high sulphate concentration, high salinity, etc.) could adversely affect the sealing properties and stability of the backfilling.

Drilling or excavating near mineral water springs or wells could adversely affect the mineralogical composition of groundwater.

4.2.4 Gas occurrence

Under certain geological conditions, gas of geogenic origin can accumulate in cavities and trap structures in the subsurface. When drilling in these areas, the gas could leak uncontrollably through the borehole and pose a safety risk (toxic or explosive gases) or an environmental risk (greenhouse gases). Gas deposits could occur in areas with volcanic activity or above geological layers containing coal, peat, hydrocarbons, sulphides, etc. If the risk of drilling gas at the project site is known or can be predicted based on geological research, certain safety measures (e.g. explosion protection concept, special backfill material) are required or the drilling depth shall be limited or the drilling shall be terminated.

4.2.5 Ground stability

Unstable ground could be found especially in the following geological situations:

— intensively fissured, faulted and breccia zones, provoking formation of natural or anthropogenic cavities;

— soft fragile rocks representing unstable ground (e.g. volcanic or sedimentary rocks).

4.2.6 Swelling and shrinking minerals or soils

Presence of evaporates or swelling clays presents a risk of subsidence or swelling in the case of connection of shallow or deep aquifers with evaporitic or clay layers because of unsuitable or hardly feasible underground operations.

4.2.7 Contrasting geological sequence (Alternated bedding)

Geology is highly diverse, and could range from structures represented by unconsolidated sand, clay and gravel going to very complex situations including unconsolidated or consolidated sedimentary (sandstone, limestone – fissured and frequently karstified) or crystalline (metamorphic and igneous) rocks. An adequate knowledge of the geological conditions and associated hydrodynamic properties of the selected site represents the base for any BHE drilling project. Adequate prior analysis of site conditions raises the probability of an efficient and long-lasting product; this also contributes to the management and protection of groundwater resources (quantity and quality) to be exploited through future projects (e.g. water wells of different purposes and configurations).

The lithological description of the geological sequence be drilled and the structural characterization of the site area are both compulsory in order to provide sufficient information for the preparation of a BHE design and provision of adequate drilling machineries and auxiliary equipment for efficient construction works; whilst avoiding, minimizing and/or controlling the potential geologic risks during drilling.

Depending on the complexity of the project and of the geological conditions, the standard set of topics to be described should refer to the following aspects (if appropriate):

— occurrence and description of the regional geologic structure(s) - sedimentary basin, folded structures and/or faults;

— the lithological (specific) description (from bottom to top or reverse) of the litho-stratigraphic units (formations, beds, layers, or horizons) to be drilled;

— occurrence and characterization of local tectonic (structural) discontinuities – faults, fissures, fractures (particularly in case of hard rocks);

— occurrence and characterization of dissolution voids and channels (in case of carbonate and evaporite rocks);

— hydrological aspects (groundwater chemistry, redox potential, depth of sweet/salt level, level of phreatic groundwater, regional groundwater flow for every aquifer, hydraulic conductivity, porosity / thermal parameters);

— inventory of other users in the vicinity (groundwater extraction wells, groundwater energy wells, borehole heat exchangers).

4.2.8 Karst geology

Karstified zones can represent strong heterogeneity of the ground and risk of caverns. High probability of occurrence of caverns leads to several risks: collapsing of borehole, subsidence of the ground, losses of drilling fluids, problems with backfilling, turbidity and solids in groundwater, unstable temperature of groundwater (too low in winter, too high in summer), hardly predictable, unreliable modelling.

Geological and hydrogeological conditions in the depth of karst area are often not sufficiently known to make a reliable prediction without additional investigation.

4.2.9 Frost susceptibility

Because the temperature of the fluid in the BHE can be below 0 °C, there could be a risk of freezing the soil causing upheaval of the horizontal part and affect the sealing properties of the borehole filling and the natural sealing layers around the borehole.”

The sealing grout of the borehole heat exchanger should be adapted to the actual physiochemical conditions, naturally occurring or due to operation of the system. It should not be negatively affected by freezing and should withstand a negative temperature of the heat transfer fluid that returns to the geothermal heat exchangers up to −3 °C, keeping its physiochemical and mechanical properties intact.

4.2.10 Groundwater protection area

The risk of BHE in groundwater protection areas is the degradation of the groundwater quality due to:

— introduction of pollutants from the surface;

— leakages of the heat transfer fluid;

— mixing of groundwater of different quality;

— changing the biological composition of the groundwater.

Areas of interest to drinking water supply can be protected areas. In such areas, installations could require special authorisations.

4.3 Anthropogenic risks

Interactions between the built environment and the subsoil could impose constraints on the realization of borehole heat exchangers. Also, underground structures can impact the groundwater flow.

When planning a borehole heat exchanger, the potential risks and impacts of sites should be evaluated, such as presence of:

— areas of archaeological interest;

— nature protection areas;

— unexploded ordnance;

— contaminated soil;

— mining areas.

Drilling impacts on the piezometric level of the groundwater should be assessed. The presence of thermal anomalies (geothermal gradient, hot spot) shall be evaluated in order to adapt the dimensioning of the BHE and the materials used for the drilling and construction of the BHE.

4.4 Environmental aspects

4.4.1 General

Environmental aspects shall be considered throughout the whole construction process.

4.4.2 Influence on groundwater

Regulations and the regional planning targets shall be complied with during planning, construction and operation of ground source heat pump systems.

Within the scope of the applicable water law and – to the extent required – mining law procedures, the desired uses should be harmonized with the water management targets with respect to the local situation by imposing usage terms.

Groundwater should be managed in a way to avoid adverse changes to its quantity and chemical composition. From this, it follows that:

— groundwater should be treated carefully;

— hazardous substances should not be allowed to enter the ground or penetrate into the groundwater zone;

— thermal use of the underground in drinking water protection areas, in catchment areas of drinking water aquifers and in protection areas of mineral springs is generally prohibited. Exceptions shall be examined according to the relevant circumstances;

— in groundwater protection areas or other designated zones, the drinking water supply takes priority over any thermal use of groundwater layers. This principle applies also for registered domestic wells not covered by an official protection area. Exceptions shall be examined according to the local regulations;

— the backfill of the borehole has to use suitable materials (in accordance with local regulations). This may include sealing clays and/or grout depending on the risk to the aquifer. Suitable materials are described in Clause 6.

4.4.3 Environmental Impact Due to Construction Works

4.4.3.1 General

Environmental aspects shall be considered throughout the entire construction process. Systems for the thermal use of the underground should be constructed and operated without adverse impact on the environment. Any harmful effects shall be avoided. Such consequence could be caused by unsuitable materials/fluids of the drilling process or the thermal impact on the ground/groundwater due to the operation of the heat exchanger.

4.4.3.2 Materials

Materials installed underground shall be rated non-harmful to groundwater and environment and non-corroding. Pipes, backfill materials, etc. should be suitable for use in groundwater.

When using metal pipes in borehole heat exchangers in exceptional cases, attention should be paid to sufficient wall thickness, metal quality and corrosion prevention, and the chemical composition of the groundwater shall be considered. Attention should be paid to the consequences where heat transfer media or working fluids could leak into the air, soil or groundwater.

If water/anti-freeze mix is used as heat transfer fluid, it shall be considered that, in case of leakage, corrosion inhibitor or other additives can have negative impacts on the environment.

4.4.3.3 Drilling Process

Drilling companies involved in BHE projects shall make sure that qualified staff is operating any drilling activities and warrant that equipment conforms to health and safety standards and is regularly maintained and checked. This can be warranted through a recent maintenance certificate. Drill rigs, drilling rods, accessories and materials should not cause contaminants to enter the underground/soil. Appropriate precautions should be taken to prevent contamination and similar. Pollution of surface water due to dumping of drilling mud or highly mineralized groundwater shall be avoided. The use of mud additives with clearance certificates is permitted in accordance with any conditions imposed by the authorities. Only mud additives [5] may be used that do not cause chemical/biological changes in the underground. National guidelines shall be applied. The quality of the discharge water shall comply with the required quality of the responsible sewage water company.

Pollution of natural greens, roads, buildings or other infrastructure due to dirt, fluids, oil spill or unnecessary noise and vibration of the drilling process shall be avoided.

5 System description

5.1 General

The BHE system can be divided into four subsystems (Figure 1):

1) Borehole heat exchanger

2) Horizontal piping

3) Manifold

4) Thermal plant (technical room) with heat pump installation

NOTE The heating system, in the house including the heat pump, is not discussed in the text.

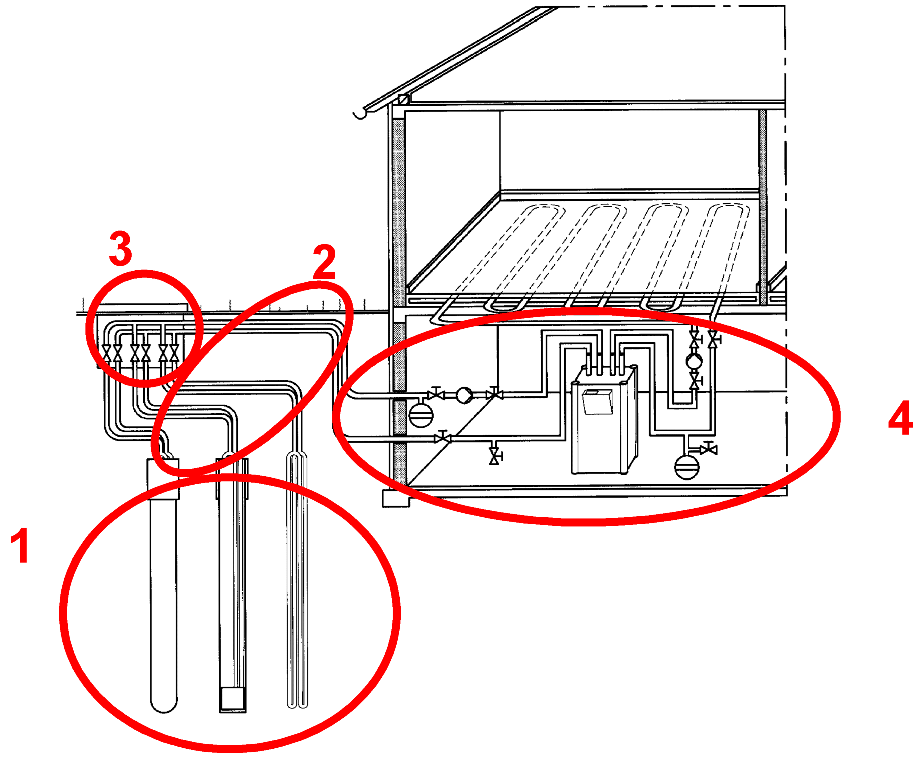


Figure 1 — Example of a GSHPS with BHE

The BHE represents the heat source (heating mode) or heat sink (cooling mode) for the system. BHE are made in various versions (see Figure 2) each with different properties.

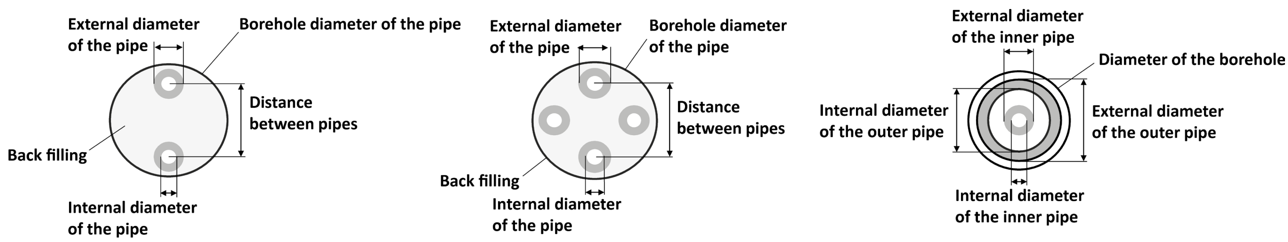
5.2 Borehole heat exchanger

There are several possibilities to configure loops of BHE. The most common types of BHE are the following three:

— single U loop (Figure 2a);

— double or Multiple U loop (in Figure 2b a double U loop is shown);

— co-axial loop (Figure 2c).



a b c

Figure 2 — Types of typical BHE: single U loop (a), double U loop (b), co-axial (c) loop

The BHE is characterized by the average borehole diameter and the depth.

The BHE loops are characterized by their pipe material and their inner and outer diameters. For U-loop heat exchangers, the average distance between the pipe centres results from the geometries of the pipes, their installation arrangement and the borehole. This is called shank spacing. The space between the pipe and the borehole wall is filled with a backfill material (6.2).

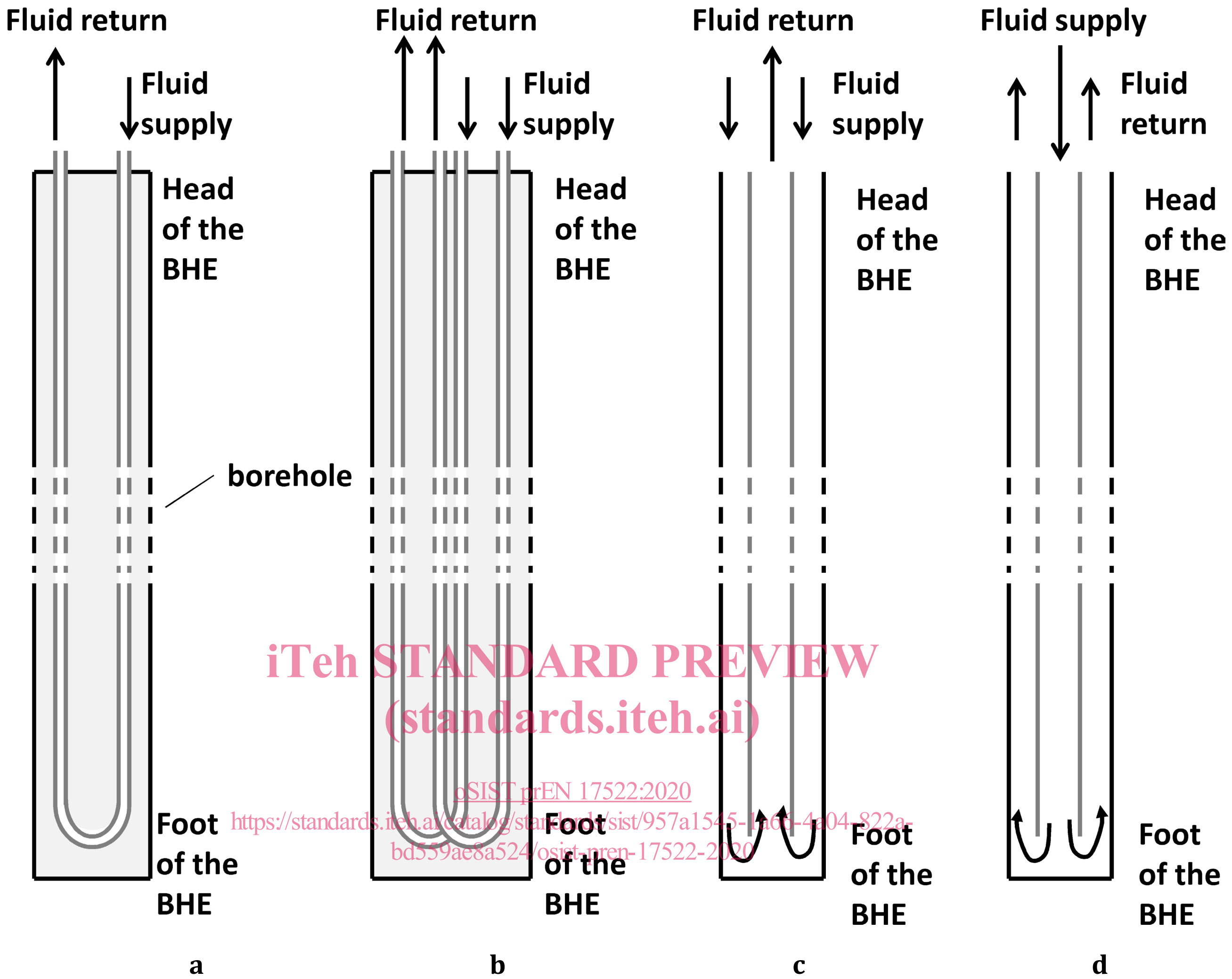


Figure 3 — Types of typical vertical BHE: single U pipe (a), double U pipe (b), co-axial with water supply in the annular section (c), co-axial with water supply in the central pipe (d)

The design shall meet environmental (see Clause 4) and construction (see Clause 8) aspects of this document.

The quality and operational life of the heat exchanger loop depends on the pressure class, the wall thickness and operating temperature. The internal and/or external hydraulic pressure along the length of the BHE shall be considered during all construction and operation phases.

5.3 Horizontal piping

The horizontal piping is the circuit connecting the BHEs, to the manifolds and to the thermal plant. Annex A is giving information on the insulation of horizontal piping.

5.4 Manifolds

The purpose of the manifolds is to connect all individual horizontal pipes into one hydraulic circuit and to ensure and control the volume flow of the fluid in the individual BHEs.