FERROPLAST

FERROTERM

Geothermal System


FERROTERM
Geothermal System

content

01 Plásticos Ferro

Plásticos Ferro is a company belonging to **Group GPF**, leader in the Spanish plastic pipes and fittings sector with over 50 years of experience.

Plásticos Ferro manufactures and markets systems that offer integral solutions to any type of need in the field of piping and ducting, considering plastics as its basic materials and seeking, through constant research and innovation, total client satisfaction with products and services that meet their needs.

Being aware of the growing economic, social and environmental importance of renewable energies, and true to its commitment to continuous improvement and environmental protection, Plásticos Ferro has developed the new **“FERROTERM” GEOTHERMAL SYSTEM**. This system completes the product range with which the company has taken part in different projects within this field of application, thus providing an adequate technical and commercial alternative for current and future market needs.

With industrial and logistics facilities equipped with the most advanced technology, and with a highly qualified team of professionals devoted to this project, Plásticos Ferro’s commitment is to continue actively contributing to the sustainability of our energy model and to the growth and development of geothermal energy use, offering clients top quality and highly competitive solutions.

02
Quality & guarantees

Plásticos Ferro guarantees its FERROTERM Geothermal System against any manufacturing defect in any country in the world (except for the USA and Canada) for a period of TEN YEARS from the delivery date. Plásticos Ferro, through its Civil Liability Policy, guarantees any possible damages that faulty pipes and fittings systems may cause to third parties, up to a maximum of THREE MILLION EUROS.

PE-100 polyethylene pipes used in FERROTERM geothermal probes and heat collectors are manufactured according to the requirements and criteria of the **EN 12201** standard, their quality being continually controlled by carrying out all the tests specified in the relevant standard.

The probe foot used for the FERROTERM vertical catchment system is certified by the **SKZ** according to the HR 3.26: 2009-01 guideline.

All FERROTERM geothermal probes are tested in the factory, once the productive process has finished, and they are also regularly tested according to the DVS-2202-1 and DVS-2203-6 directives.

All the data relating to the welding appear on the label attached to each vertical probe, they are registered on each installation's **Guarantee Certificate** and they are filed by the Quality Department, guaranteeing complete traceability.

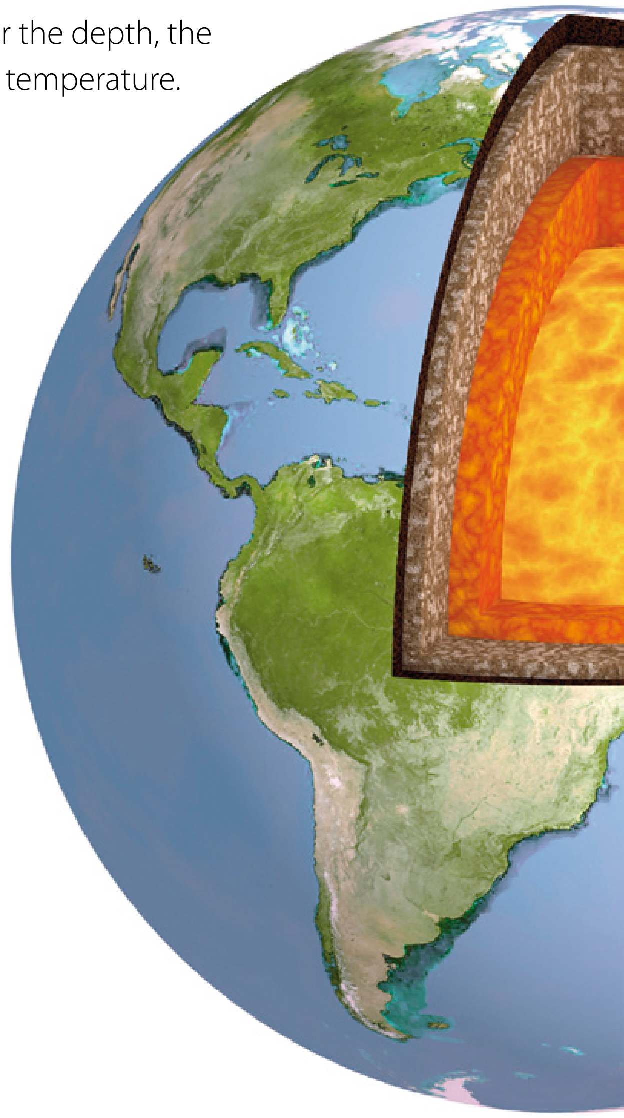
03
Geothermal energy

The conventional energy model, based on power generation from fossil fuels (oil, coal, gas) and with highly volatile prices, makes us increasingly vulnerable and dependent: they are limited resources, concentrated in specific areas.

The growing awareness of the need to protect the environment together with the threat of global climate change, have led to the search of a **future model that is more sustainable and independent**, safe, unlimited, competitive and which combines energy savings and respect for the environment.

Temperature of the Earth

The greater the depth, the higher the temperature.



03.1 Definition of geothermal energy

Geothermal energy is the **energy stored in the form of heat beneath the surface of the earth**. This energy can be used for the direct production of heat for electricity generation.

Geothermal energy comes from the upward flow of heat from the inside of the planet and, to a lesser extent, from solar radiation. The planet's thermal energy is not everlasting, but it is **inexhaustible**, making it a clean and renewable source of energy which is constantly being produced 24 hours a day, 365 days a year.

Enthalpy is the amount of thermal energy which a fluid or an object can exchange with its environment. It is expressed in kJ/Kg. or in Kcal/Kg. There is no equipment capable of measuring the enthalpy of a fluid beneath the earth's surface, but there are probes that measure the temperature, and since temperature and enthalpy are considered to be proportionate, the use of geothermal fluid temperature instead of its heat content has become widespread.

a. **High enthalpy geothermal energy** takes advantage of a geothermal resources found under certain pressure and high temperature conditions (**>150ºC**). The use of this resource can be done directly if the geological and climatic conditions for it are naturally available. If the appropriate geological and climatic conditions are available but there is no fluid, it could be injected to create a hot dry rock reservoir (stimulated geothermal energy).

b. **Low enthalpy geothermal energy** is based on the capacity for storing heat and maintaining a constant temperature found beneath the surface of our planet, at a depth of between 10 and 20 m, throughout the year and whatever the season. Considering that this heat is not sufficient for producing electrical power, resources with temperatures **<70ºC and even up to 15ºC** can be used for the production of domestic hot water and for climate control (heating and cooling), using a heat pump system.

TYPES OF GEOTHERMAL ENERGY

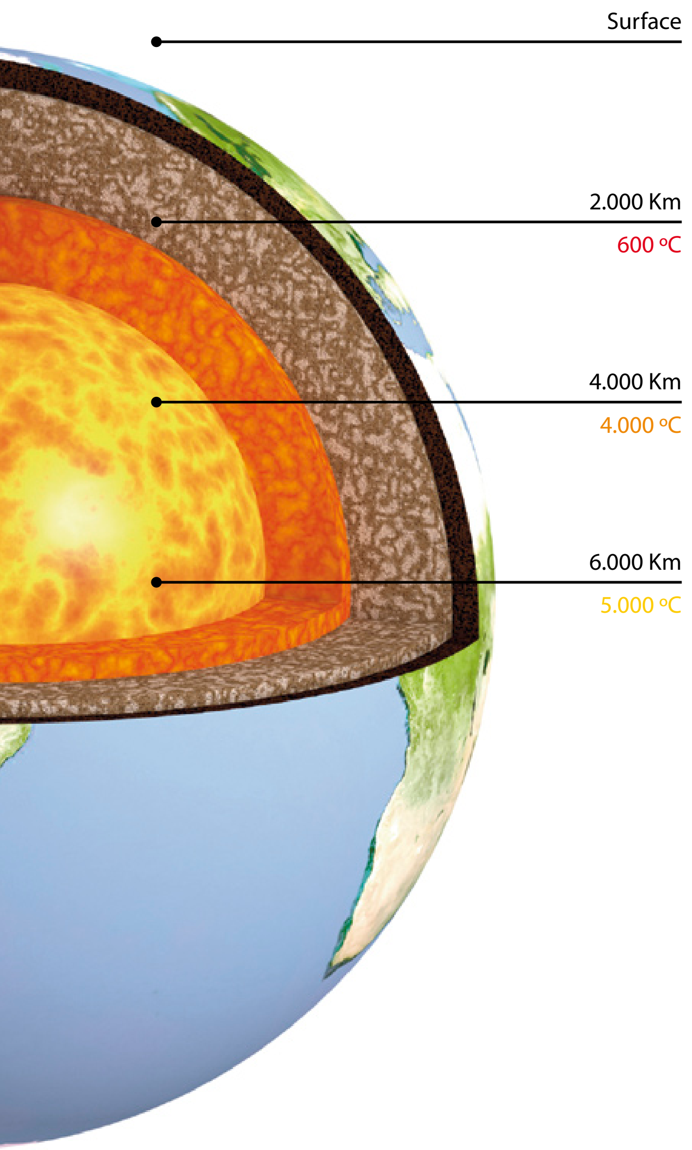
Four categories can be established:

- **High temperature (>150ºC):** helps to directly transform water steam into electrical power.

- **Medium temperature (between 80ºC and 150ºC):** enables electricity generation using a heat exchanger fluid, which is what supplies power plants.

- **Low temperature (between 30ºC and 80ºC):** insufficient heat content for electricity generation, but suitable for heating buildings and certain industrial and agricultural processes.

- **Very low temperature (<30ºC):** can be used for heating and cooling, requiring the use of a heat pump.



USES AND APPLICATIONS

The uses and applications of geothermal energy shall be determined according to its heat content (geothermal fluid temperature):

- **Electricity generation** (high enthalpy geothermal energy). Uses water steam under pressure to feed a turbine and generate electricity, either directly (open circuit), or by means of a heat exchanger (closed circuit).

- **Thermal applications.** For the direct applications of geothermal heat there is a secondary circuit through which a fluid flows with a temperature that depends on that of the geothermal resource flowing through the primary circuit, as well as on the efficiency of the heat exchanger. Such applications will depend on the resource's range of temperatures and they can even be used in cascade as the temperature decreases.

Domestic housing
- Heating, underfloor heating, cooling buildings and production of domestic hot water.
- Widely used for heating large surfaces — the volume of the complexes to be heated will depend on the capacity of the aquifer and on the number of boreholes, as well as on the extraction capacity via pumping.

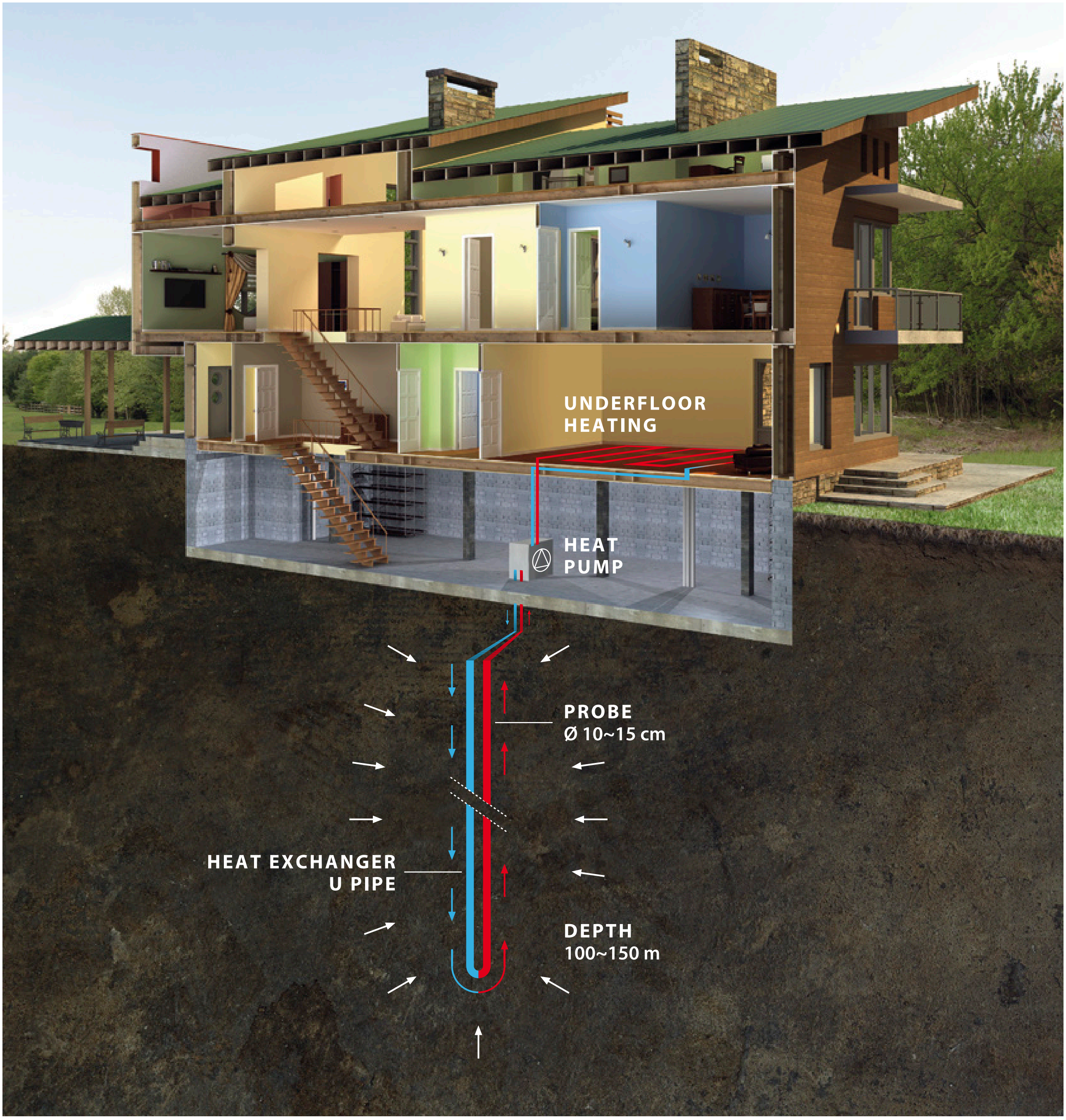
Public buildings
- Heating, underfloor heating, cooling buildings and production of domestic hot water.
- Particularly important in its use for climate and temperature control in spas, health resorts, swimming pools, etc.
- Underfloor heating in bridges and pavements.

Agriculture and aquaculture
- Heating of greenhouses, aquaculture, animal agricultural production, heating and irrigation of soils for crops, cultivation of fungi, production of biofuels.
- Significant use for growing plants in greenhouses, where the aim is to reproduce the ideal humidity and temperature conditions under environments that do not naturally have them.
- Geothermal resources improve the performance of farming and agricultural installations.
- Water temperature control in fish farms, river and lake systems as well as marine systems, for specific species.

Industrial processes
- In general, countless applications: all those requiring a heat treatment or water steam for their production, for example, handling cellulose paste in the paper industry, the necessary heat inputs in the drying and packaging industry for certain foods or, at higher temperatures, regular food processing in the canning industry.
- Hot water for washing machines, vehicle washing stations, absorption cooling at different temperatures, etc.
- Chemical industry.

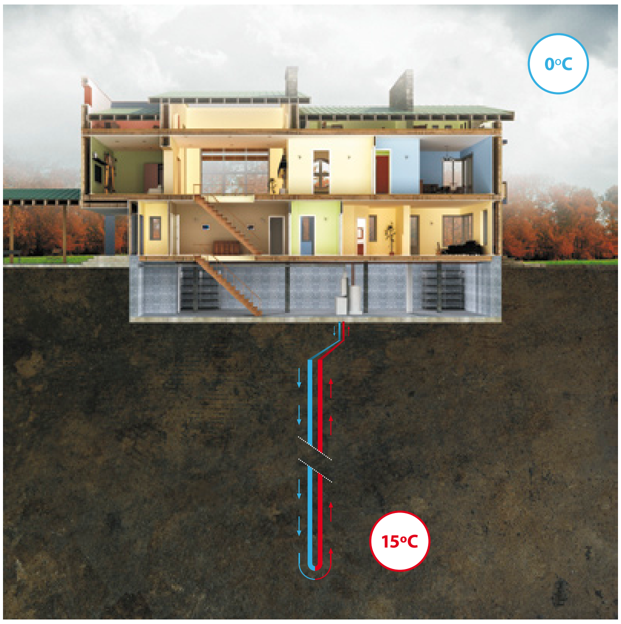
The **European Renewable Energy Directive 2009/28/CEE** establishes for Spain the mandatory target of covering **20% of the gross final energy consumption with efficient and renewable energies**, such as geothermal energy. The objective is to incorporate renewable systems, up until now under-exploited, thus laying down for geothermal energy important objectives to be accomplished within the 2011-2020 Renewable Energy Plan.

03.2
Geothermal energy with a closed very low-temperature system: **FERROTERM System**



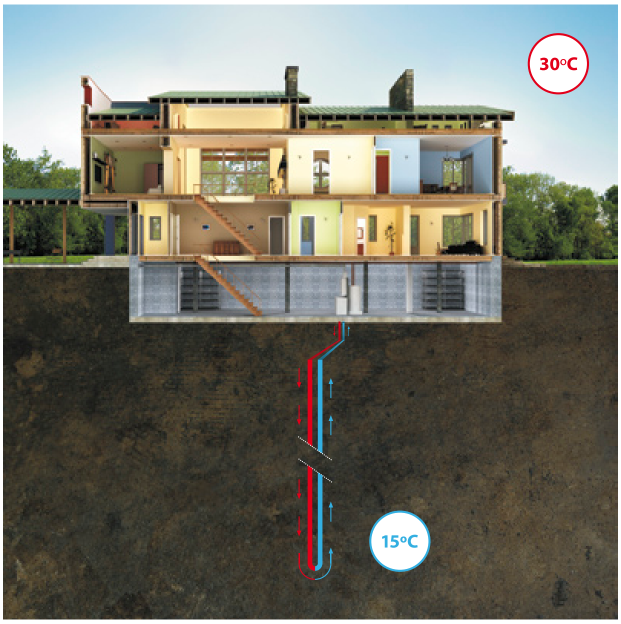
The **FERROTERM** geothermal system is a **closed low temperature system for geothermal heat pump applications** that uses horizontal and vertical heat collectors by means of polyethylene probes.

Winter



During the colder months of the year, heat is collected from the subsoil and transferred to the building.

Summer



During the warmer months, heat is collected from the building and transferred to the subsoil.

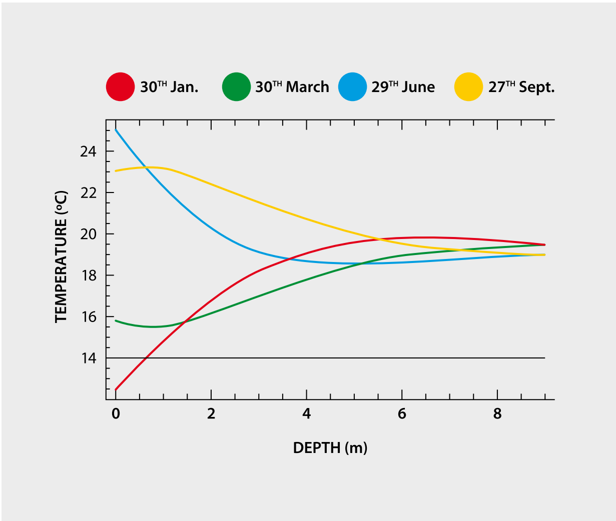
These types of geothermal systems are based on the fact that, in any corner of the planet, the interior of the earth, or **subsoil**, has a **more constant temperature** than the ambient air (the greater the depth, the fewer the temperature fluctuations). In winter the ground will be warmer than the outside environment, and in summer it will be cooler.

A **geothermal heat pump system** works in a similar way to a domestic fridge, and it can take advantage of the temperature differential that occurs when a fluid is transferred to the underground (3-5°C) to produce flow temperatures of up to 50°C for heating and 7°C for cooling.

For the first 15 metres underground, the ground temperature varies according to climatic conditions, **but from this depth on, the temperature remains virtually constant throughout the year**, increasing on average by approximately 3°C every 100 m.

In northern Europe, a ground temperature of 10ºC is common at depths of 20 m or above. In countries where there is a high solar radiation level, such as Spain, the ground temperature at a depth of 5 m is relatively high and stable: 15ºC are often reached, regardless of the season and/or weather conditions.

Changes in soil temperature



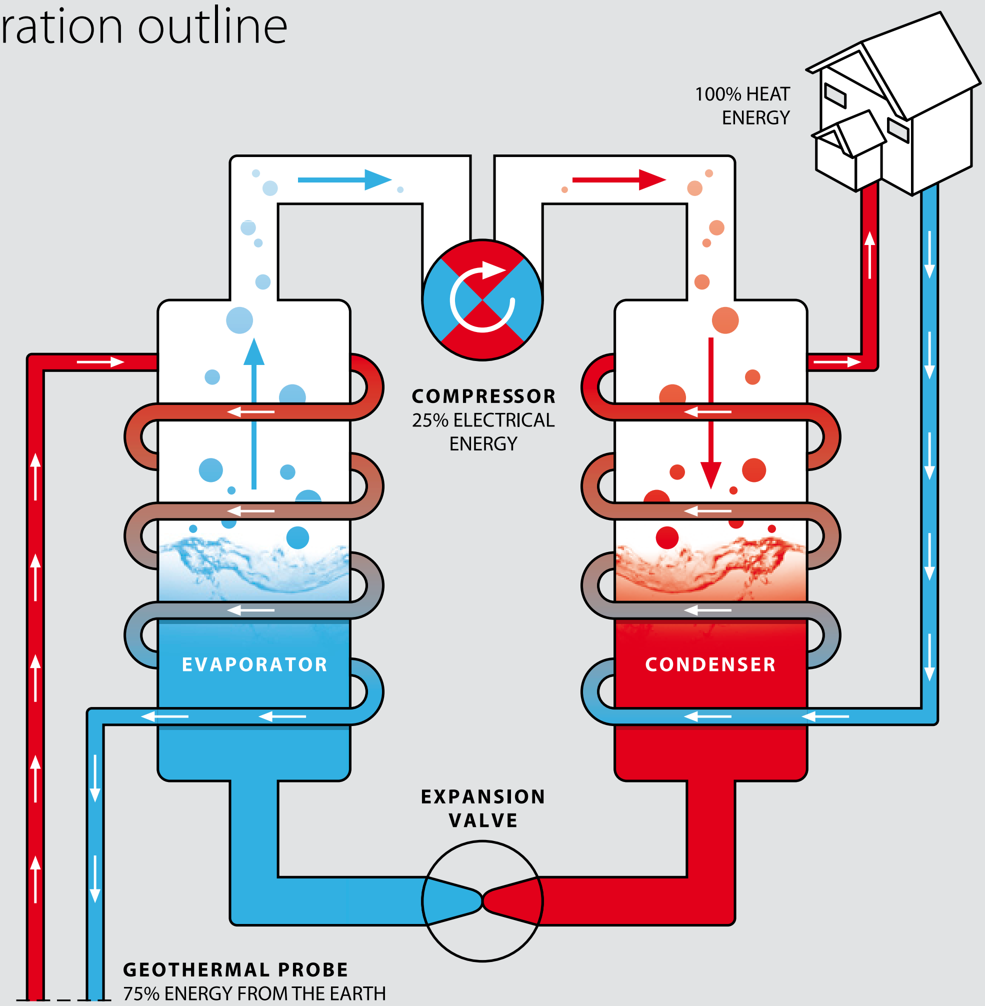
The graph shows soil temperature changes with depth on different days throughout the year.

Natural soil heat is absorbed by a **heat-carrier fluid** (generally glycol water) which circulates along the inside of the polyethylene probes. At the heat pump, the earth's heat is transferred to a refrigerant fluid that evaporates, is sucked in by an electric compressor which raises the pressure and temperature, moves on to a condenser and finally gives up heat in order for it to be used for heating (underfloor heating, low temperature radiators) or for the production of domestic hot water. Eventually the fluid passes through an expansion valve, reducing its temperature and pressure in order to restart the cycle. If the cycle is reversed, it allows for cooling applications, improving energy efficiency.

Systems using a geothermal heat pump have been widely used for over thirty years in Europe as heating systems, especially in northern countries.

Savings with geothermal heat pump systems are generated from **lower electricity consumption, lower maintenance costs** and a **longer service life than with other systems**. It is estimated that **energy savings, compared to conventional heating and cooling systems (oil, gas or electricity), can be between 30 and 70%**, for the electricity is used only for collecting, concentrating and supplying heat, not for producing it. Additionally, **the investment can be repaid in a period of around 6 to 12 years**, regardless of possible subsidies which could help shorten this period.

Heat pump
operation outline



03.3
Advantages of geothermal energy

RENEWABLE
It is a source of energy which has virtually inexhaustible resources and which is constantly being regenerated.

EFFICIENT
It makes it possible to achieve **energy savings** of 30 to 70% for heating and 20 to 50% for cooling.

CONSTANT
It is available 24 hours a day, 365 days a year, with practically no influence from seasonal climatic conditions, solar radiation or wind.

COST-EFFECTIVE
The investment is **paid off** in a period of around **6 to 12 years**. Operating and maintenance costs are very low.

ACCESSIBLE
It can be obtained and used in practically any location and everywhere in the world.

COMPATIBLE
It is complemented by other energy sources. The relationship between the earth's underground heat and its exploitation above ground is two-way, so that it is possible to adapt geothermal resources to different needs and vice versa.

AESTHETIC
It does not require placing different components on buildings' roofs or façades.

ENERGY MIX
It contributes to diversifying and optimising the basis of our current energy supply, reducing fossil fuel consumption and our dependence on imported energy, whilst ensuring a regular supply and reducing the energy losses that occur in the transmission and distribution of electricity.

CLEAN, SAFE & ENVIRONMENTALLY-FRIENDLY
It saves a great amount of primary energy and it does not contribute to greenhouse gas emission. There is also less waste production and pollution than with fuel transport.

SOCIAL
It offers new opportunities for the development of new industries and favours employment creation and local economic development.

In addition:

TECHNICAL BUILDING CODE (CTE): it meets the energy-saving requirements specified by the Spanish Technical Building Code.

SUPPORT from public administrations at both nacional and European level.

TOTAL CLIMATE CONTROL: with the correct catchment system and a geothermal heat pump, total climate control (heating and cooling) and domestic hot water can be supplied in a building or house: **maximum energy efficiency of the system**.

Lets build a more energy-efficient, sustainable society in harmony with our environment and with our future generations

04
FERROTERM System Range

04.1 Catchment systems

VERTICAL PROBES

Manufactured in high density polyethylene **PE-100** with nominal resistance to internal pressure **16 bar**.

They are **marked one in red and the other in blue** in order to distinguish flow and return, with end plugs in the same colours to protect the inside of the pipes.

They have an **excellent thermal conductivity coefficient** and a **high resistance to impact and scratches** that may occur when inserting them in boreholes.

The **probe foot is certified by the SKZ** and made up of a U shaped PE-100 fitting, with nominal pressure 16 bar, electrofusion. The **welding is carried out and individually tested at the factory**, giving it total operation guarantee.

They are supplied in coils as simple probes (2 Ø 40 pipes) or double probes (4 Ø 32 or Ø 40 pipes). In the case of double probes, a screw for assembly of the U fitting is included.

SIMPLE VERTICAL PE-100 GEOTHERMAL PROBE

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Probe length (m)	Weight (Kg)
246001	2	40	3,7	80	68
246002	2	40	3,7	100	84
246003	2	40	3,7	125	105
246004	2	40	3,7	150	126

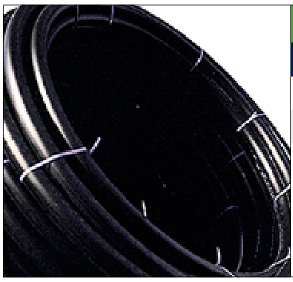
DOUBLE VERTICAL PE-100 GEOTHERMAL PROBE

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Probe length (m)	Weight (Kg)
246005	4	32	2,9	80	87
246006	4	32	2,9	100	109
246007	4	32	2,9	125	136
246008	4	32	2,9	150	163
246009	4	40	3,7	80	136
246010	4	40	3,7	100	168
246011	4	40	3,7	125	210
246012	4	40	3,7	150	252

For other measurements please contact us

HORIZONTAL HEAT COLLECTORS

Available in high density polyethylene **PE-100** with nominal resistance to internal pressure **16 bar**. They are marked in red (PE-100) or black (PE-X) and have red end plugs to protect the inside of the pipes. They have an **excellent thermal conductivity coefficient** and a **high resistance to friction**. They are also manufactured in crosslinked polyethylene **PE-X** according to the **EN ISO 15875** standard. PE-X offers **greater flexibility** and **withstands higher temperatures**.



SIMPLE HORIZONTAL PE-100 GEOTHERMAL HEAT COLLECTOR

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Probe length (m)	Weight (Kg)
246013	1	25	2,3	100	18
246014	1	32	2,9	100	28
246015	1	40	3,7	100	44

SIMPLE HORIZONTAL PE-Xb GEOTHERMAL HEAT COLLECTOR

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Probe length (m)	Weight (Kg)
246016	1	20	1,9	100	11
246017	1	25	2,3	50	8
246018	1	32	2,9	50	13
246019	1	40	3,7	50	21

For other measurements please contact us

04.2 Injection pipes

High density polyethylene **PE-100** black pipe with green stripes. For **injecting filling material** in vertical geothermal boreholes.

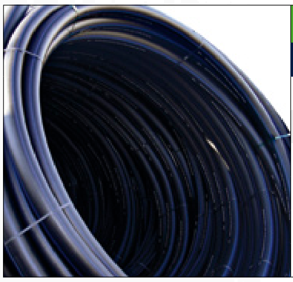
PE INJECTION PIPE

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Length (m)	Weight (Kg)
246020	1	25	2,0	80	12
246021	1	25	2,0	100	15
246022	1	25	2,0	125	19
246023	1	25	2,0	150	23
246024	1	32	2,0	80	15
246025	1	32	2,0	100	19
246026	1	32	2,0	125	24
246027	1	32	2,0	150	29

For other measurements please contact us

04.3 Pipes for connections

High density polyethylene **PE-100** black pipe with blue stripes. Manufactured according to the requirements and criteria of the **EN 12201** standard, with nominal resistance to internal pressure **16 bar**. Designed to **carry out connections** between the different elements of the installation.



PE-100 PIPE FOR CONNECTIONS

Code	No. Pipes	Pipe Ø (mm)	Thickness (mm)	Length (m)	Weight (Kg)
246028	1	40	3.7	100	44
246029	1	50	4.6	100	67
246030	1	63	5.8	50	53

For other measurements please contact us

04.4 Modular manifold

Modular distribution manifold manufactured with **bioriented polypropylene PPB**, for the **flow and return of catchment systems**. Available in diameters 40, 50 and 63. They consist of base modules with a tee-shape which are attached to form the number of male outlets required, and a final module with an elbow shape which is supplied with a screw to complete the inlet attachment to the manifold in the first base module.

MODULAR MANIFOLD	
Code	**Dimension**
346008	Modular tee 40 - 1-1/4" - 40
346009	Modular tee 50 - 1-1/4" - 50
346010	Modular tee 63 - 1-1/4" - 63
346011	End elbow 40 – 1-1/4”
346012	End elbow 50 – 1-1/4”
346013	End elbow 63 – 1-1/4”

04.5 Accessories

WEIGHT FOR VERTICAL PROBES		
Description	**Code**	**Weight (Kg)**
Ballast weights for inserting vertical probes in boreholes. The 25 Kg weight is made up of two 12,5 Kg weights and an attachment mechanism between both of them. They are connected to probes by means of the connection kits.	346001	12,5
	346002	25,0

CONNECTION KIT FOR VERTICAL PROBE WEIGHT		
Description	**Code**	**Probe Ø (mm)**
The connection kit for diameter 32 probes includes a threaded holder and a hexagonal screw M8 x 100 mm, a hexagonal nut and a spring washer. The connection kit for diameter 40 probes includes a threaded holder, a hexagonal screw M8 x 50 mm (for simple probes), a screw M8 x 110 mm (for double probes), a hexagonal nut and a spring washer.	346014	32
	346015	40

VERTICAL PROBE SPACER		
Description	**Code**	**Probe Ø (mm)**
Improves the geothermal heat exchanger, maintaining the distance between the probe pipes. It has a circular hollow in the middle for the injection pipe.	246031	32
	246032	40

“Y” JOINTING FOR DOUBLE VERTICAL PROBES		
Description	**Code**	**Ø (mm)**
Y electrofusion jointing for connecting the flows and returns in double vertical probes. PN-16.	246031	32
	246032	40

FIXING ACCESSORY FOR HORIZONTAL HEAT COLLECTORS		
Description	**Code**	**Ø (mm)**
Fixing components which are anchored to the soil, holding the probes that form horizontal heat collector circuits in place.	346005	25
	346006	32
	346007	40

ELECTROFUSION COUPLER		
Description	**Code**	**Pipe Ø (mm)**
PN-16 electrofusion welding coupler.	346024	25
	346025	32
	346026	40
	346027	50
	346028	63

Other Accessories

FERROPLAST, in its Polyethylene Pipes and Fittings Catalogue, offers a vast range of connection fittings: electrofusion from diameter 32 to 250, polypropylene compression fittings from diameter 20 to 110, metallic compression fittings from diameter 20 to 110. Transition fittings to electrofusion, reducers, valves…

For any other fitting or measurement please contact us.


(2) 1-3/4" X 11-7/8" LVL
FLUSH FRAMED
WALK-IN CLOSET
202
M

05
Design criteria, calculation & assembly

Information for the calculation and design of geothermal catchment systems is given here for pre-dimensioning purposes.

05.1 Material characteristics

QUALITY

During the entire manufacturing process, the most advanced processing technology and quality control systems and equipment are used, following the criteria and specifications relating to characteristics and test methods stated on the relevant standard.

Our Quality Department pays special attention to every stage of the manufacturing process, from the reception and control of raw materials up to the finished products, which are constantly and regularly being analysed by carrying out all the standardised tests described in the **Product Technical Specifications**.

ENVIRONMENT

Plasticos Ferro has amongst its primary objectives to **contribute to sustainable development** through actions that are respectful with the environment and nature. The high recyclability of polyethylene favours correct environmental management at every stage of the manufacturing process.

High density polyethylene (PE-100)

The marked increase in the use of polyethylene pipes in recent years is proof of their excellent technical suitability and competitiveness for all types of piping carrying pressurised fluids. With a long useful life and exceptional physical and chemical characteristics, **polyethylene pipes are the best current alternative for the production of geothermal probes**.

FERROTERM high density polyethylene **PE-100** probes have a nominal resistance to internal pressure of **16 bar**. Their **scratch resistance** has been improved and they have **high thermal conductivity**. For their manufacture, only first quality raw material is used, which comes directly from petrochemical plants and already incorporates the stabilisers, antioxidants and lamp black required for correct processing and in order to guarantee the quality of the final product.

Injection and connection pipes are also manufactured in PE-100 polyethylene.

FERROTERM high density polyethylene (PE-100) characteristics

- Withstands usual operating temperatures of 45ºC and exceptional ones of up to 80ºC.
- Resistance to high pressures.
- Long service life.
- They are not affected by corrosion or erosion.
- Lightness.
- Flexibility.
- Minimum head loss.
- No build-ups or adherences are produced.
- Maximum watertightness and waterproofing.
- They can carry glycol water.

Properties of FERROTERM high density polyethylene (PE-100)		
Mean density	> 0,95	gr/cm³
Coefficient of thermal linear expansion	0,22	mm/mºC
Thermal conductivity	0,40	Kcal/h mºC
Carbon black content	2-2,5	%
Carbon black dispersion	≤ grade 3	
Volatile matter content	<350	mg/Kg
Water content	<300	mg/Kg
Modulus of elasticity (short term)	1.000-1.200	MPa
Modulus of elasticity (long term)	160	MPa
Design stress (σ)	8,0	Mpa
Minimum security coefficient C	1,25	
Poisson coefficient (υ)	0,4	
Dielectric constant	2,5	
Hydraulic roughness	0,007	mm
Maximum use temperature	45	ºC

Crosslinked polyethylene (PE-X)

For horizontal heat collectors and geothermal energy piles, the use of crosslinked polyethylene (PE-X) probes is also possible, providing **greater flexibility and resistance to possible friction**, as well as withstanding **higher temperatures**. These are the pipes used for underfloor heating systems, which often complement geothermal heat pump installations due to the low flow temperatures that are needed.

Crosslinked polyethylene is manufactured using high density polyethylene, which is obtained using a process known as polymerisation, through which ethylene molecules join together to form a polyethylene chain. Crosslinking is based on the creation of connections between the polyethylene chains, making these pipes highly resistant to pressure and temperature.

FERROTERM crosslinked polyethylene (PE-X) characteristics

The majority of the characteristics are common to high density polyethylene, but in addition, the following can be added:

- Withstands high temperatures, usual operating temperatures of 95ºC and exceptional ones of up to 110ºC.
- High flexibility.
- Minimum radii of curvature.
- High resistance to chemical products, even at high temperatures.
- FERROTERM crosslinked polyethylene pipes are manufactured according to the EN ISO 15875 standard and they are certified by AENOR.

Properties of FERROTERM crosslinked polyethylene (PE-X)		
Density	> 0,95	gr/cm³
Roughness	0,007	mm
Tensile strength at 20ºC	>20	N/mm²
Tensile strength at 100ºC	>10	N/mm²
Modulus of elasticity at 20ºC	1.180	N/mm²
Modulus of elasticity at 80ºC	560	N/mm²
Elongation at break at 20ºC	300-450	%
Thermal conductivity coefficient	0,37	Kcal/h mºC
Linear expansion coefficient at 20ºC	0,14	mm/mºC
Linear expansion coefficient at 100ºC	0,205	mm/mºC
Softening temperature	133	ºC
Limit operating temperature	100	ºC

05.2
Design

Low temperature geothermal systems generally consist of:

• An **underground heat exchanger** (vertical probes, horizontal heat exchangers…) which, by means of a fluid that circulates inside them (glycol water) extracts heat from the subsoil or transfers heat from the building to the ground.

• A **heat pump** (normally water-water) that transfers heat between the exchanger and the building's distribution system, through a refrigerant fluid.

• A **distribution system** (underfloor heating, low temperature radiators…) that uses the heat or cold in the building.

The **heat pump** extracts thermal energy from the underground and, with that contribution, evaporates a very low pressure and low temperature refrigerant that is compressed through a compressor, increasing its temperature and pressure. Vapour moves on to the condenser and gives up heat to the space that is to be heated. Finally, the fluid passes through an expansion valve, reducing its temperature and pressure once again and re-starting the heat pump's refrigeration cycle. All this provides important **energy savings (30-70%) compared to conventional systems**.

Inside the earth, or subsoil, there is a more constant temperature than in the ambient air. In winter, the ground will have a higher temperature than that of the outside environment, and in summer it will be lower, also allowing for the reversal of the cycle so as to cool the building instead of heating it up: **increased energy efficiency thanks to this dual use for heating-cooling**.

To carry out this process, the heat pump consumes a small amount of electricity. The heat pump's efficiency is measured by the **COP** (Coefficient of Performance), which expresses the relationship between the thermal energy given up in the condenser (quantity of heat produced) and the electrical energy consumed in the compressor. On the other hand, the **EER** (Energy Efficient Ratio) is the ratio between the cooling energy generated in the evaporator (amount of cooling produced) and the electrical energy consumed in the compressor.

Geothermal catchment systems can be open or closed:

• **Open systems** are based on the use of underground waters as heat exchangers (the aquifer acts as the exchanger). These waters are pumped towards the heat pump by means of an inverted well and, once they have been used to give up the transported heat at the evaporator, they are sent back to the aquifer through another injection well.

• **Closed systems** are more common. In these, the heat carrier fluid flows along a closed circuit formed by a group of polyethylene pipes. This circuit exchanges heat with the ground, in vertical probes, in horizontal circuits or in the building's foundations (geothermal energy piles).

Vertical geothermal heat exchangers are made up of high density polyethylene probes with a simple or double U shape, placed inside vertical boreholes (perforations), with a depth varying from 50 to 150 m, filled with a special mortar that improves conductivity. Their installation requires a very small surface area and a shorter pipe length, for there is a greater heat transfer per linear meter of probe. These catchment systems are more expensive due to the need to drill boreholes, but at a depth of 15 m temperature is practically constant throughout the year (depending on the location, between 7 and 20ºC), therefore the heat pump's consumption is more regular.

Horizontal geothermal heat exchangers consist of high density polyethylene or crosslinked polyethylene (PE-X) probes that form circuits at a depth of 1,2 to 1,5 m, separated from each other by between 30 to 80 cm. A greater probe length and surface area are required for their installation, but the cost is lower thanks to their easy execution, as there is no need for deep drilling work. Ground temperature at this depth varies with climatic conditions. The ground surface must not be paved and it must be cleared of snow. Some vegetables can be grown to over the installation, but not trees with deep roots.

Geothermal energy piles are structural elements made out of concrete in which polyethylene pipes placed inside the building's foundations, piles, subterranean structures, retaining walls, slabs, etc… and attached to the concrete reinforcements are used as exchangers for capturing underground heat. They are cost-effective systems, for they take advantage of the installations required for the building's structure, however the exchange is less efficient in smaller sized constructions.

For installations with a thermal power of up 30 kW, the **VDI 4640** guideline "Thermal use of the underground" sets forth some simple dimensioning rules. The **IDAE's Technical Guide** "Design of Geothermal Heat Pump Systems" offers a series of formulae that allow for a more approximate calculation, although for larger installations or with a cooling use, ground survey is recommended as a basis for calculation, carrying out a TRT (soil response test). **The correct dimensioning of the catchment system is a key factor for these types of geothermal installations**.

05.3
Calculation

For the calculation of the installation, the first step is to determine the **power required** to cover the maximum simultaneous thermal needs, both for cooling and for heating, and to define the type of **heat pump** that must be installed. The power extracted from the ground is determined, following the guidelines of the VDI 4640, the SIA, the TRT, etc. The length of the horizontal or vertical collector is established, as is the surface area or number of boreholes and their depth. Finally, the hydraulic installation must be designed, its components, etc.

Therefore, first of all the **heat load calculation** is carried out in accordance with the design and dimensioning requirements specified in the Regulations for Thermal Installations in Buildings, and a suitable heat pump is chosen.

In order to calculate the ground's maximum and minimum temperatures during an annual cycle at a certain depth, we can use the following formulae:

$$T_L(X_s) := T_m - A_s \cdot e^{\left[-X_s \cdot \sqrt{\frac{\pi}{365 \cdot \alpha}}\right]}$$

$$T_H(X_s) := T_m - A_s \cdot e^{\left[-X_s \cdot \sqrt{\frac{\pi}{365 \cdot \alpha}}\right]}$$

Where:

$T_L(X_s)$ is the ground's minimum temperature.

$T_H(X_s)$ is the ground's maximum temperature.

T_m is the ground's average temperature in ºC. The location's average dry temperature can be used.

A_s is the location's average daily temperature in ºC. It is obtained from tabulated data for each geographical location. In the case of vertical exchangers it is considered that A_s=0.

X_s is the depth in cm.

α is the ground's thermal diffusivity in cm²/day. It depends on the type of soil.

For the temperature study, when the heat pump is working in heating mode (producing hot water to supply to the building between 45-55ºC), cold water is produced at the evaporator at around 5-15ºC, which is the one circulating through the buried exchanger. In cooling mode (producing cold between 7-12ºC) the exchange water from the condenser circulates through the exchanger pipes at around 25-35ºC. The water's outlet temperatures in cooling and heating modes can be determined from the data of the chosen heat pump:

$$T_{outlet,c} := T_{inlet,c} - \frac{1.000 \cdot P_c \cdot \frac{COP_c - 1}{COP_c}}{C_p (Q / 3.600)}$$

$$T_{outlet,f} := T_{inlet,f} + \frac{1.000 \cdot P_f \cdot \frac{COP_f + 1}{COP_f}}{C_p (Q / 3.600)}$$

Where:

$T_{outlet,c}$ is the outlet temperature in heating mode in ºC.

$T_{outlet,f}$ is the outlet temperature in cooling mode in ºC.

$T_{inlet,c}$ is the inlet temperature in heating mode in ºC (5-15ºC).

$T_{inlet,f}$ is the inlet temperature in cooling mode in ºC (25-35ºC).

P_c is the heat pump's power in heating mode in kW.

P_f is the heat pump's power in cooling mode in kW.

COP_c is the pump's coefficient of performance in heating mode.

COP_f is the pump's coefficient of performance in cooling mode.

C_p is the fluid's specific heat in J/Kg.

Q is the heat pump's flow in l/h.

The maximum temperature T_{MAX} will be the average between $T_{inlet,f}$ and $T_{outlet,f}$

The minimum temperature T_{MIN} will be the average between $T_{inlet,c}$ and $T_{outlet,c}$

The exchanger pipes' resistance to heat flow corresponds with:

$$R_p := \frac{1}{2 \cdot \pi \cdot K_p} \cdot L_N \left(\frac{D_0}{D_1} \right)$$

Where:

R_p is the thermal resistance in K m/W.

K_p is the pipe's thermal conductivity (FERROTERM = 0,43 W/m K).

L_N Napierian logarithm.

D_0 is the pipe's outside diameter in m.

D_1 is the pipe's inner diameter in m.

The ground's resistance Rs (K m/W) is the inverse of the ground's thermal conductivity.

Due to the fact that the heat pump is dimensioned taking into account the most unfavourable operating conditions, the pump will operate intermittently.

Both for heating and for cooling, we must take into consideration the fraction of time for which the heat pump is running, called the utilisation factor F, which is the ratio between a building's thermal demand for a period of time (heating or cooling) and the power of the pump.

There are energetic modelling software options available for the calculation of a building's annual energy demand, or tables with "bin hours" created using climate databases from the corresponding location.

With the above-mentioned information, the **lengths of horizontal or vertical exchangers can be determined** using the following formulae:

$$L_{HEATING} := \frac{Q_{heating} \cdot \frac{COP_{heating} - 1}{COP_{heating}} (R_p + R_s \cdot F_{heating})}{T_L - T_{MIN}}$$

$$L_{COOLING} := \frac{Q_{cooling} \cdot \frac{COP_{cooling} + 1}{COP_{cooling}} (R_p + R_s \cdot F_{cooling})}{T_{MAX} - T_H}$$

Where:

$L_{HEATING}$ is the exchanger length needed in heating mode in m.

$L_{COOLING}$ is the exchanger length needed in cooling mode in m.

For exchangers that work in both modes, the most unfavourable option must be chosen.

$Q_{heating} = 1000\ P_c$

$Q_{cooling} = 1000\ P_f$

Horizontal catchment system

Put more simply, for horizontal catchment systems in installations with less than 30 kW, it is possible to take the ground's heat extraction values from the VDI 4640–2. Horizontal heat collectors must be buried at a depth of 1,2 to 1,5 m, separated from each other by between 30 to 80 cm, and their length must not exceed 100 m per circuit for head loss reasons.

THERMAL EXTRACTION HORIZ. CATCHMENT SYSTEM	OPERATING HOURS PER YEAR	
TYPE OF SOIL	1.800 H	2.400 H
Dry. Non cohesive.	10 W/m^2	8 W/m^2
Damp. Cohesive.	20-30 W/m^2	16-24 W/m^2
Water-saturated. Cohesive.	40 W/m^2	32 W/m^2

The diameters of horizontal heat collectors also depend on the subsoil's thermal capacity. As a reference, the following can be considered:

TYPE OF SOIL	DIAMETER
Dry. Non cohesive.	20 mm
Damp. Cohesive.	25 mm
Water-saturated. Cohesive.	32 mm

Example for dimensioning a horizontal catchment system (according to VDI 4640)

A single-family household with thermal requirements for heating and domestic hot water, determined according to the type of construction, location and number of occupants, of 15 kW. Heating use is established at 1.800 hours/year. The geothermal heat pump's COP supplied by the manufacturer is 4. There is clay soil with water, according to the table 25 W/m^2.

- Total thermal power = ground's thermal power + power of the compressor.
- Ground's thermal power = total thermal power - power of the compressor.
  Ground's thermal power = 15 – 15 / 4 = 11,25 kW
- Catchment surface area = ground's thermal power / thermal extraction per m^2.
  Catchment surface area n = 11.250 / 25 = 450 m^2
- Horizontal heat collector length = catchment surface area / separation between pipes.
  Horizontal heat collector length = 450 / 0,75 = 600 m

The result is 6 circuits with a length of 100 m, with geothermal heat collectors for horizontal catchment, each 100 m long and with a 25 mm diameter.

Vertical catchment system

For vertical catchment systems in installations with less than 30 kW and probe lengths of up to 100 m, it is possible to take the ground's heat extraction values from the VDI 4640–2. Vertical probes must be placed at a distance from buildings of at least 3 m, and boreholes must be separated from each other by a minimum of 6 m.

THERMAL EXTRACTION VERTICAL CATCHMENT SYSTEM	OPERATING HOURS PER YEAR	
TYPE OF SOIL – GENERAL VALUES	**1.800 H**	**2.400 H**
Inappropriate. Dry sediment. Conductivity λ<1,5 W/mK	25 W/m	20 W/m
Normal. Consolidated rock. Sediment saturated with water. Conductivity λ<3,0 W/mK	60 W/m	50 W/m
Consolidated rock. High thermal conductivity. Conductivity λ>3,0 W/mK	84 W/m	70 W/m
TYPE OF SOIL		
Gravel, sand. Dry.	<25 W/m	<20 W/m
Gravel, sand. With water.	65-80 W/m	55-85 W/m
Phreatic area through gravel and sand.	80-100 W/m	55-85 W/m
Clay, mud. Damp.	35-50 W/m	30-40 W/m
Limestone.	55-70 W/m	45-60 W/m
Sandstone	65-80 W/m	55-65 W/m
Granite	65-85 W/m	55-70 W/m
Basalt	40-65 W/m	35-55 W/m
Gneiss	70-85 W/m	60-70 W/m

The probe diameters or the use of simple or double probes are decided depending on the type of soil and on the depth of the boreholes.

Example for dimensioning a vertical catchment system (according to VDI 4640)

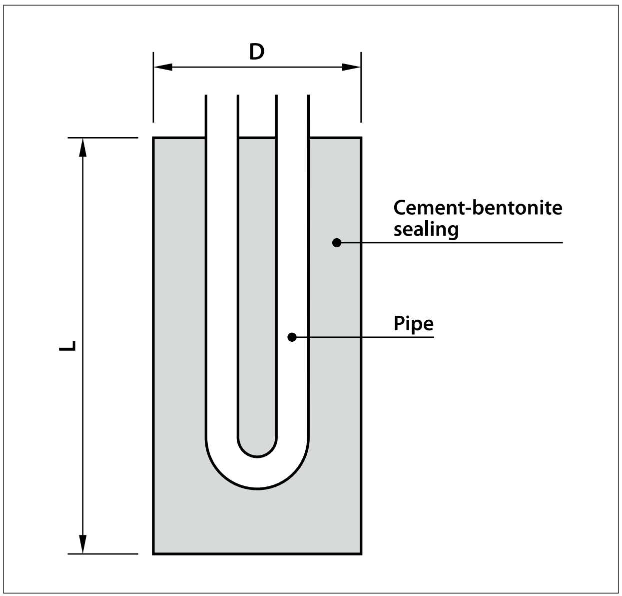
A single-family household with thermal requirements for heating and domestic hot water, determined according to the type of construction, location and number of occupants, of 15 kW. Heating use is established at 1.800 hours/year. The geothermal heat pump's COP supplied by the manufacturer is 4. There is damp soil with λ<3,0 W/mK, according to the table 60 W/m.

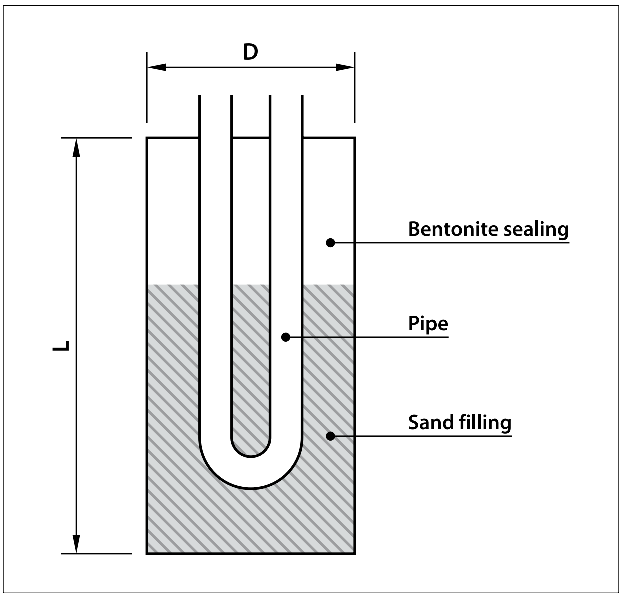
- Total thermal power = ground's thermal power + power of the compressor.
- Ground's thermal power = total thermal power - power of the compressor.
  Ground's thermal power = 15 – 15 / 4 = 11,25 kW
- Vertical probe length = ground's thermal power / thermal extraction per m.
  Vertical probe length = 11.250 / 60 = 187,5 m

The result is 2 boreholes with a depth of 95 m for two double U shaped probes with a 32x3,0 mm diameter.

05.4
Assembly

Examples of different sections of a vertical heat exchanger





Vertical heat exchangers

When carrying out vertical heat exchangers, boreholes shall be located and their section, their depth, the aquifers crossed and the type of filling shall be determined.

The **borehole** must be carried out by a specialised company, using the most appropriate technology for each type of soil and mainly with diameters ranging from 110 to 165 mm. Wells must be at a distance from buildings of at least 3 m, and 1 m away from other installations, and they must be separated from each other by a minimum of 6 m.

When **introducing the vertical probe in the borehole**, a decoiler or unwinding element is frequently used and a weight is placed on the probe's U in order to help with the introduction. It is advisable to introduce probes filled up so as to prevent them from collapsing. Once the vertical probe has been introduced, and before the filling of the borehole, a **pressure and fluid circulation test** is carried out on the probe.

The **injection pipe** is introduced at the same time as the probe in order to be able to fill up the borehole with a **special high conductivity mortar** from the borehole's bottom up to its surface. After this filling, the relevant tests must be carried out once again.

Until the relevant pressure tests are carried out, pipe ends shall be **protected with end plugs** in order to prevent any foreign particles from entering.

It will be necessary to **dig up trenches** in order to install connection branches for the flows and returns of the vertical exchangers and with the distribution manifold. The topsoil shall be removed and the trench shall be dug up and cleaned, removing any rocks found on the bottom part in order to prevent any damage to the pipes. The pipes shall be placed over a sand bed, filling up with sand until the pipes are completely covered. The area shall be signposted with a plastic tape and it shall be filled with excavation materials which have previously been selected (with no sharp edges, with diameters under 5 cm, etc.). Layers shall be added with a reduced thickness in order to obtain a greater degree of compaction (25-30 cm).

Wherever possible, horizontal sections must not be placed in areas affected by other buried services. Where this is not possible, when overlapping with other services, the geothermal installation must be placed below and at a distance of over 40 cm. In the case of parallel services, a distance of over 40 cm must also be maintained.

Horizontal heat exchangers

When carrying out horizontal heat exchangers, there are different configurations, the most common one being the installation of **buried pipes forming a spiral or coil circuit** on a horizontal plane at a depth of 1,2 to 1,5 m and with a separation of between 30 to 80 cm.

They cannot be placed under waterproofed surfaces. The surface where the horizontal exchanger is placed must not be paved or have concrete poured on it, with the objective of ensuring a good heat exchange. The **maximum recommended length** per circuit is **100 m**, for head loss reasons. It is not advisable to install collectors over gravel that creates air bubbles which could diminish the ground's conductivity.

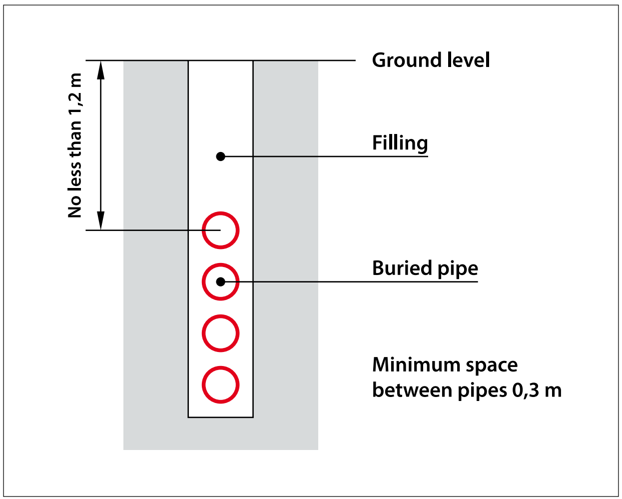
If there is sufficient space, it is advisable to carry out **the earthworks as a whole**. Once the pressure test has been carried out, the area surrounding the pipes shall be filled with fine sand in order to facilitate heat conduction, and the rest of the areas with the extraction material which has the appropriate characteristics (with no sharp edges, with diameters under 5 cm, etc.).

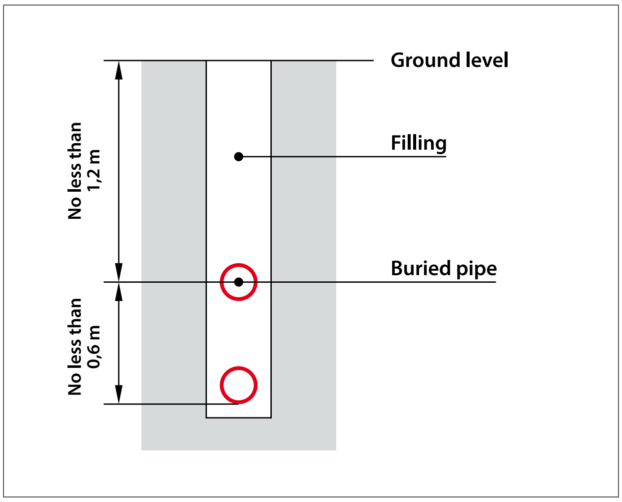
It is possible to **grow vegetables on the surface**, but not to plant deep-rooted trees. The laying of the circuits must be done **taking into account the radii of curvature** of the probe material, and **they shall be fixed to the ground** whenever necessary, with auxiliary elements or with the filling material or sand.

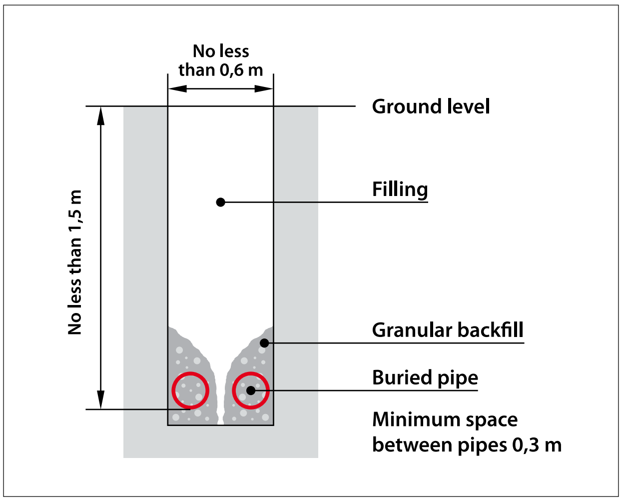
The **distribution manifolds** must be arranged in such a way that they are situated at the highest point of the installation.

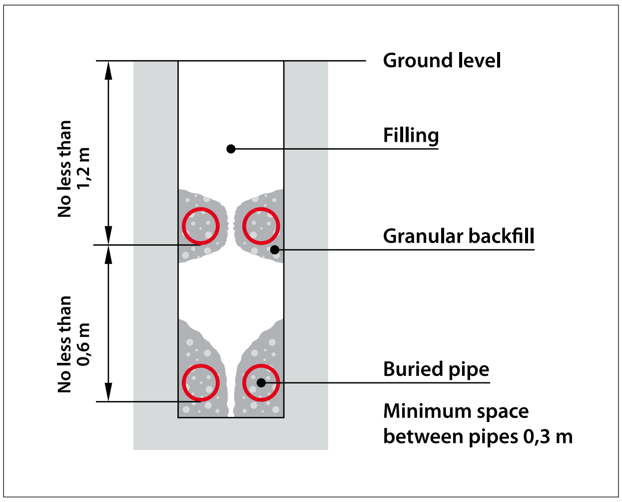
The **machine room** must have a free wall for the location of the heat pump and the inlet and outlet manifolds with all their elements, hung on the wall.

Both the heat pump and the manifolds and accessories must remain easily **accessible for maintenance and repair work**, leaving at least the distances specified in the heat pump manufacturer's catalogue. **In general, all that is specified on the Regulations for Thermal Installations in Buildings must be fully complied with**.









05.4.1 Pressure tests on vertical probes

Once the pressure probes have been introduced in the boreholes, and before their filling, **purging** shall be carried out. This requires the speed of the water in the pipes to be at least 0,6 m/s, with the following implications on flow rates depending on the probe diameters used:

DN (mm)	Q (m^3/h)
25	0,7
32	1,2
40	1,8

Purging flow rates (PE100 16 bar pipes)

After the purging, a **leak tightness and stress test** is carried out on each geothermal probe based on the following premises:

- The test pressure shall be at least 3 times the operating pressure and no more than 80% of the pipe's nominal pressure.
- The duration of the test shall be 1 hour.
- The maximum allowable pressure drop shall be 3%.

During the first few minutes of the test, one must wait for the **correct stabilisation of the manometer**, injecting pressure if necessary until the agreed minimum pressure has been reached.

Once each borehole has been filled, the test shall be repeated.

05.4.2 Pressure tests on horizontal heat collectors

It is necessary to carry out tests on the horizontal connection branches between the machine room and the vertical geothermal probes and to the pipes which make up a horizontal heat exchanger.

Purging shall be carried out by circulating pressurised water at a minimum speed of 0,6 m/s at any point in the installation. The flow rate injected will depend on the configuration and diameter of the horizontal collectors.

For the purpose of carrying out the test, the installation shall be kept at a **minimum pressure 3 times the operating pressure for two hours** and the pressure drop during this time must be verified to be below 0,2 bar.

At the beginning of the test, one must wait for the **correct stabilisation of the manometer**, for in the very first moments of the test there could be a loss in pressure. If this happens, the circuit must be pressurised until the minimum test pressure is reached.

In **installations with a larger size**, carrying out these tests in sections is advisable, doing them as the set-up of each one of them comes to an end. In these cases, once the tests have been validated, the trench shall be covered, leaving connections uncovered until a test on the whole ensemble is carried out, which involves:

- Circulating water along the installation at a speed of 6 m/s for 15 minutes.
- Maintaining the installation at 6 bar for 30 minutes.

05.4.3 System leak tightness and pressure tests

Once the whole system has been connected, filled with the heat-carrier fluid (which is generally water containing a percentage of antifreeze) and purged, a **preliminary leak tightness test to the filling pressure** must be carried out in order to confirm the continuity of the network and to verify that the connections are leak-proof. Then, the installation shall be subjected to a test pressure 1,5 times the maximum effective operating pressure with a minimum of 6 bar.

06
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Head Office:

A CORUÑA
Tel.: +34 981 900 900. Fax: +34 981 900 901
Paseo Marítimo Alcde. Fco. Vázquez – Pza. interior, 63
15002 A Coruña (Spain)
e-mail: admincor@ferroplast.es

Factories and offices:

GRANADA
Tel.: +34 958 438 611. Fax: +34 958 438 700
Ctra. Atarfe a Sta. Fe, s/n
18230 Atarfe, Granada (Spain)
e-mail: ventasgranada@ferroplast.es

LUGO
Tel.: +34 982 500 000. Fax: +34 982 500 101
Rua José Ferro Rodeiro, 4
27836 Muras, Lugo (Spain)
e-mail: ventasmuras@ferroplast.es

MOROCCO
FERROPLAST MAROC, S.A.R.L.
Tel.: +212 (0) 520 22 56 56
Fax: +212 (0) 520 22 56 57
Km. 5,6 – RS. 107,
Tit Mellil vers Médiouna
B.P. 181, Tit Mellil
Casablanca (Morocco)
e-mail: commercial@ferroplastmaroc.com

Regional offices:

BARCELONA
Tel.: +34 937 703 000. Fax: +34 937 703 120
Pol. Ind. Sant Ermengol
c/ Progrés, 7
08630 Abrera, Barcelona (Spain)
e-mail: ventasbarcelona@ferroplast.es

VALENCIA
Tel.: +34 961 322 615. Fax: +34 961 322 064
c/ Ciudad de Barcelona, 54
46988 Fuente del Jarro, Valencia (Spain)
e-mail: ventasvalencia@ferroplast.es

VIZCAYA
Tel.: +34 944 576 014. Fax: +34 944 575 139
Pol. Ind. Martiartu, nivel 3, nº9
48480 Arrigorriaga, Vizcaya (Spain)
e-mail: ventasbizcaia@ferroplast.es

Distribuído em Portugal pela Ferroplast:

PONTEVEDRA
Tel.: +34 986 663 023. Fax: +34 986 663 024
Pol. Ind. Rivadil
36880 La Cañiza, Pontevedra (Spain)
e-mail: encomendas@ferroplast.es

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