US 20110011558A1

(19) United States

(12) Patent Application Publication

DORRIAN et al.

(10) Pub. No.: US 2011/0011558 A1

(43) Pub. Date: Jan. 20, 2011

(54) **THERMAL CONDUCTIVITY PIPE FOR GEOTHERMAL APPLICATIONS**

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(21) Appl. No.: **12/835,404**

(22) Filed: **Jul. 13, 2010**

Related U.S. Application Data

(60) Provisional application No. 61/225,815, filed on Jul. 15, 2009.

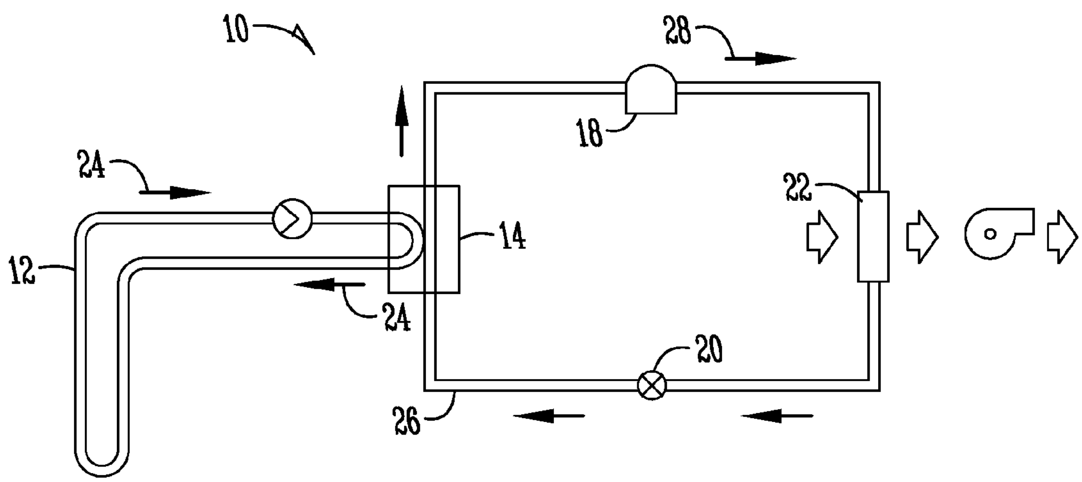
Publication Classification

(51) **Int. Cl.**
F24J 3/08 (2006.01)

(52) **U.S. Cl.** **165/45**

(57) **ABSTRACT**

An improved geothermal system for heating and cooling a building includes a fluid loop installed in the ground with opposite ends connected to a heat pump or other heat exchanger. The fluid loop comprises a plastic pipe embedded with heat transfer particles. The pipe is a thermoplastic or thermoset elastomer modified polymer having a modulus of elasticity less than 200,000 psi.



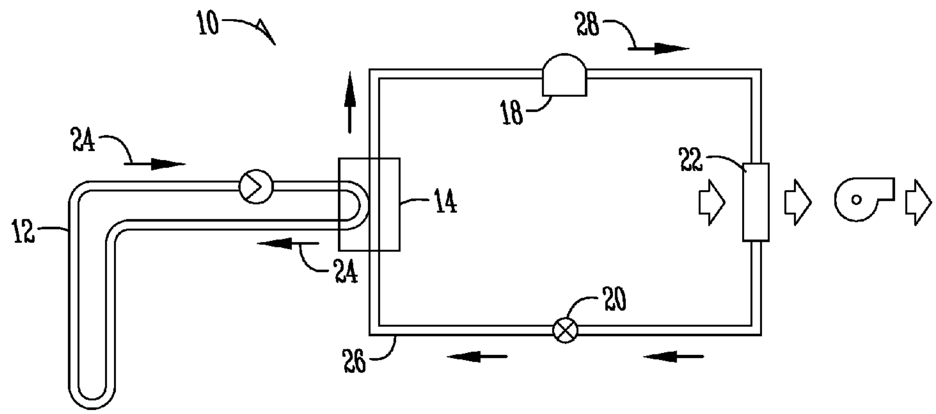


Fig.1

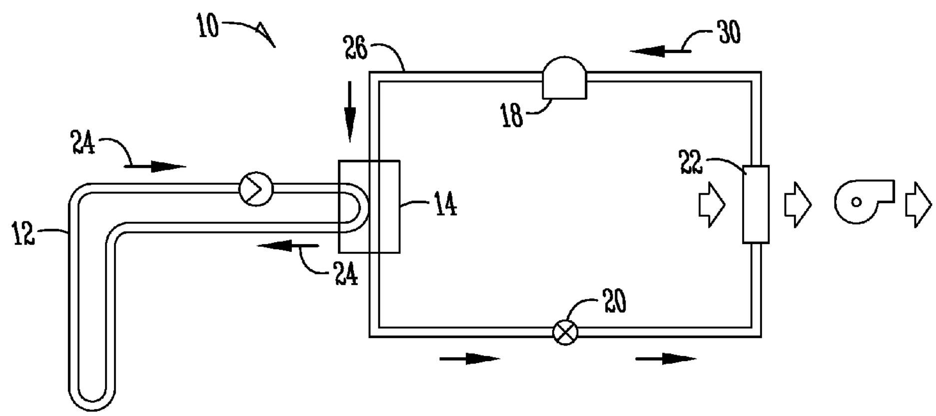


Fig.2

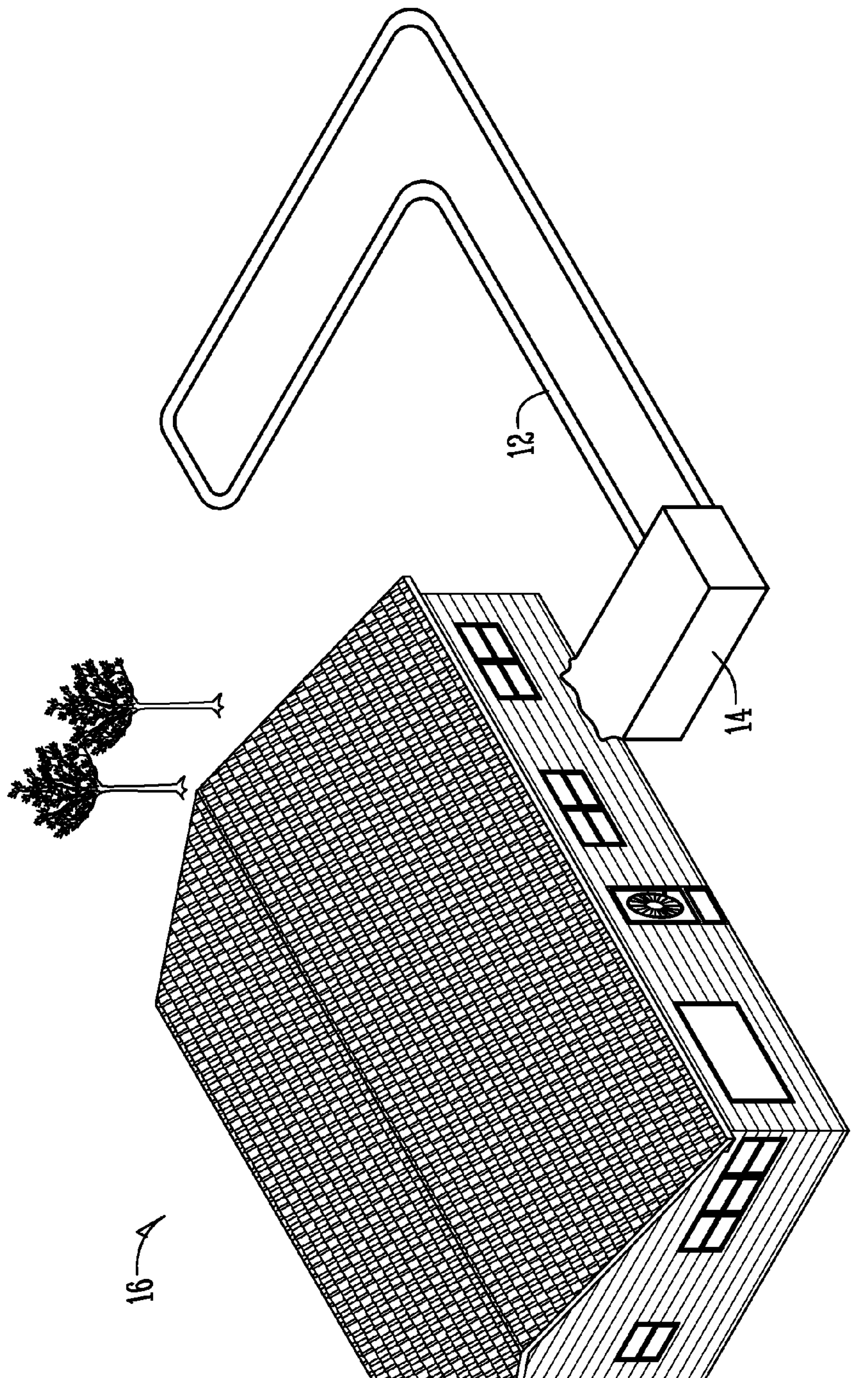


Fig. 3

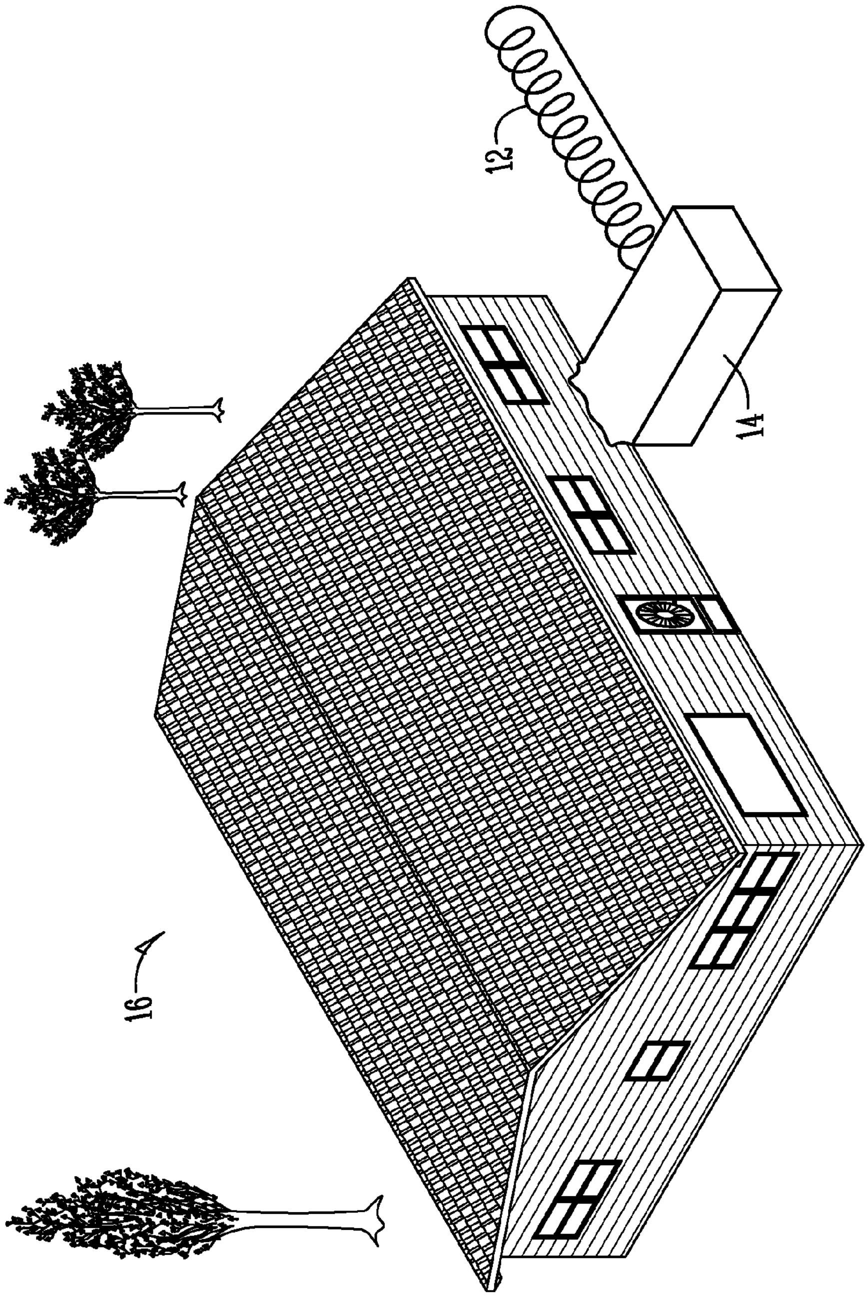


Fig. 4

THERMAL CONDUCTIVITY PIPE FOR GEOTHERMAL APPLICATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119 to provisional application Ser. No. 61/225,815 filed Jul. 15, 2009, herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] Geothermal heating and cooling have been well-known for many years. Geothermal heating and cooling takes advantage of the relatively moderate ground temperatures about 4 to 8 feet below the earth surface. A conventional closed loop geothermal system circulates a water-based solution through pipes buried in the ground.

[0003] The most common closed loop geothermal systems utilize vertical or horizontal closed loops. A vertical loop system is used mainly when land area is limited, with vertical bores drilled into the ground to a depth of 150-300 feet, with the pipe loops residing in the vertical bores. A horizontal loop system is commonly used when there is more open land, wherein trenches are dug 6 to 8 feet deep, and coils of pipe laid in the bottom of the trenches, which are then backfilled. The pipe coils in the horizontal loop system may be concentric or serpentine. Another variation is slinky-type loops which overlap one another, and thereby minimize the trench area. A pond loop geothermal system is an alternative to the vertical or horizontal loop systems. In the pond loop system, the pipes are anchored in a body of water at a depth of 8-10 feet, with approximately 300-500 feet of pipe coils.

[0004] Pipes for a horizontal geothermal system are generally easier and less expensive to install than a vertical system. Drilling of vertical bores is generally more expensive than trenching for horizontal loops. However, the horizontal loops require longer length of pipe due to the seasonal variations in the soil temperature and moisture content. Therefore, a larger area is normally required for horizontal geothermal pipes than for vertical pipes.

[0005] Geothermal systems conserve natural resources and energy by providing climate control very efficiently, thus lowering emissions. Since the heat is extracted from the earth, no fossil fuels are burned to generate heat. Geothermal systems normally are more efficient than propane and natural gas heating systems. Geothermal systems also minimize ozone layer destruction by using sealed refrigeration systems. Because these geothermal systems move heat to and from the earth, rather than burning fossil fuels, geothermal systems reduce the amount of toxic emissions in the atmosphere. The geothermal systems use the earth as both a heat source and a heat sink. Since these systems do not rely on outside air, the inside air of buildings is kept cleaner and free from pollens, outdoor pollutants, mold spores, and other allergens.

[0006] In the heating mode, the water or fluid (typically water mixed with an antifreeze solution, such as propylene glycol or methyl alcohol) circulating in the earth pipe loop is colder than the surrounding ground. This temperature differential causes the liquid to absorb energy from the earth, in the form of heat. The water carries this energy to the heat exchanger of the building heat pump, wherein refrigerant absorbs the heat energy from the liquid, which then leaves the heat exchanger at a colder temperature and circulates through the earth loop to pick up additional energy.

[0007] The refrigerant, which contains energy from the liquid, flows from the heat exchanger to a compressor, wherein the refrigerant temperature is increased to approximately 160° F. From the compressor, the super heated refrigerant travels to the air heat exchanger, wherein the heat pumps blower circulates air across an air coil, increasing the temperature of the air, which is blown through duct work to heat the house or building. After the refrigerant releases its heat energy to the air, the refrigerant flows back to the heat exchanger to start the cycle again.

[0008] The cooling mode operates in reverse from the heating mode. In the cooling mode, the liquid circulating in the earth pipe loop is warmer than the surrounding ground, thereby causing the water to release energy, in the form of heat, into the earth. The cooled liquid then flows to the heat exchanger in the heat pump, wherein hot refrigerant gas from the compressor releases its heat into the liquid, so as to increase the liquid temperature, which is again released to the ground through the earth loop. The refrigerant, which has released its heat energy to the liquid so as to become cooler, flows to the heat exchanger when the heat pump blower circulates warm, humid air from the building across the cold air coil. The air is then blown through the duct work to cool the building. The refrigerant in the air coil picks up the heat from the air, and flows to the compressor. The refrigerant flows from the compressor to the earth loop heat exchanger to start the cycle again.

[0009] While geothermal systems are more energy efficient than conventional fossil fuel heating systems, the initial installation of geothermal systems is more expensive than conventional systems due to the cost of the pipe and the cost of equipment and labor for installing the pipe. Vertical geothermal systems are more expensive than horizontal systems, since drilling is costlier than trenching. However, horizontal geothermal systems require substantial open areas to lay the pipe coils.

[0010] Therefore, a primary objective of the present invention is the provision of an improved geothermal pipe with increased thermal conductivity to minimize the length of pipe used in geothermal systems.

[0011] A further objective of the present invention is the provision of an improved geothermal pipe made of plastic embedded with heat transfer particulates.

[0012] Another objective of the present invention is the provision of an improved thermal conductivity pipe for geothermal applications which has a sufficiently low modulus of elasticity to allow coiling and uncoiling of the pipe.

[0013] Another objective of the present invention is the provision of an improved geothermal pipe made of thermoplastic or thermoset elastomer modified polymer.

[0014] Still another objective of the present invention is the provision of an improved geothermal pipe having metal, metallic oxide, non-ixide, graphite, or other thermally conductive particles embedded in the pipe.

[0015] A further objective of the present invention is the provision of an improved geothermal pipe made of an olefin based polymer (such as HDPE, PP, LLDPE, TPO, XLPE), TPU, COPE, COPA, PVC, or SVC, or a blend or alloy of these polymers.

[0016] Still another objective of the present invention is the provision of an extruded, single wall or multi-layer geothermal pipe having heat transfer particles therein.

[0017] A further objective of the present invention is the provision of an improved geothermal pipe with heat transfer particles and having increased flexibility and ductility.

[0018] Yet another objective of the present invention is the provision of an improved geothermal pipe which minimizes the length of pipe required for efficient heating and cooling of a building.

[0019] Another objective of the present invention is the provision of an improved geothermal pipe which allows for a smaller installation footprint as compared to standard geothermal pipe.

[0020] Another objective of the present invention is the provision of an improved geothermal pipe which allows for shallower vertical bores as compared to standard geothermal pipe.

[0021] A further objective of the present invention is the provision of an improved geothermal pipe which has lower installation costs than conventional geothermal systems.

[0022] A further objective of the present invention is the provision of an improved geothermal pipe which is easy to handle in cold weather conditions.

[0023] Yet another objective of the present invention is the provision of an improved geothermal pipe which has passive gain due to higher thermal mass of thermally conductive compounds.

[0024] Another objective of the present invention is the provision of an improved geothermal elastomeric polymer pipe with thermally conductive additives and a modulus of elasticity less than 200,000 psi.

[0025] Still another objective of the present invention is the provision of an improved geothermal pipe having thermal conductivity greater than 0.5 watts per meter degree K.

[0026] These, and other objectives, will become apparent from the following description of the invention.

SUMMARY OF THE INVENTION

[0027] The present invention is directed towards an improved plastic pipe for geothermal heating and cooling. The pipe is an elastomer modified polymer having thermally conductive particles embedded therein. The particles constitute 30-70% of the pipe, by volume, or 40-90%, by weight. This improved geothermal pipe has a modulus of elasticity less than 200,000 psi. The enhanced thermal conductivity of the pipe allows a shorter length of pipe to be used, with enhanced heat transfer between the fluid in the pipe and ground, as compared to conventional geothermic pipes. The improved heat transfer minimizes the field for the geothermal system. The pipe can be used in both horizontal and vertical systems. The reduced pipe length reduces installation costs and increases installation versatility.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. **1** is a schematic view showing the heating cycle for a geothermal system.

[0029] FIG. **2** is a schematic view showing the cooling cycle for a geothermal system.

[0030] FIG. **3** is a schematic view showing a horizontal loop geothermal system.

[0031] FIG. **4** is a schematic view showing a horizontal slinky loop geothermal system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0032] The present invention is directed towards an improved geothermal pipe having increased thermal conductivity with a low modulus of elasticity. The pipe is made of plastic embedded with heat transfer particles. The particles may be metallic oxide, non-oxides, graphite, or other similar materials which are thermally conductive. The heat transfer particles are preferably 30-70% by volume. Alternatively, the particles may be in the range of 50-90% by weight for metallic oxide, and 40-70% by weight for graphite.

[0033] The pipe may be a thermoplastic or thermoset elastomer modified polymer. The pipe preferably is made of plastic, such as HDPE, PP, LLDPE, XLPE, TPU, COPE, PVC and SBC, or a blend or alloy of these polymers. The pipe may include a preservative layer, so that the pipe is resistant to degradation from light, chemicals, and other adverse materials. The layer may be co-extruded or mono-extruded so as to form a multi-layer pipe extrusion. The pipe of the present invention may be a single walled extrusion or a multi-layer co-extrusion.

[0034] The pipe of the present invention, due to modifications to improve thermal conductivity, will approximate ASTM standard D-3035 (the standard for conventional geothermal pipe). The pipe has sufficient strength to prevent bursting from interior pressure or crushing from exterior pressure. The pipe is suitable for cold weather installation, due to increased flexibility and ductility. The pipe may be used for both vertical and horizontal installations, though is primarily intended for horizontal installations so as to avoid the extra cost of drilling vertical bore holes. The increased thermal conductivity of the pipe minimizes the length of pipe required in horizontal applications, and thereby minimizes the trenching area. The pipe of the present invention can also be utilized in under water installations, while minimizing pipe length.

[0035] Preferably, the modulus of elasticity for the geothermal pipe of the present invention is less than 200,000 psi. The thermally conductive particulates embedded in the pipe are preferably 50%-90% by weight.

[0036] Normally, thermally conductive additives increase the modulus of elasticity. Such stiffness makes the pipe difficult to handle, including coiling and uncoiling. To overcome such stiffness, the present invention utilizes an elastomer polymer modified so as to maintain flexibility of the pipe. The elastomer may be TPV, SBC, TPO, COPE, or other known elastomeric material. This addition of the low modulus elastomer offsets the increase in modulus caused by the addition of the thermally conductive particulates.

[0037] For example, the polymer may be in the range of 1-50% by weight, and the elastomer may also be in the range of 1-50% by weight. Alternatively, both the polymer and elastomer are preferably in the range of 1-70% by volume.

[0038] With the present invention, the geothermal installation will use less than half the length of pipe with twice the heat transfer, as compared to conventional geothermal pipe. With the improved geothermal pipe, one third the conventional length of pipe can be used and still achieve the same heat transfer result. Therefore, the size of the horizontal field can be minimized.

[0039] The pipe of the present invention preferably has thermal conductivity greater than 0.5 watts/meter degree K.

In a tested formulation having a blend of 20% HDPE, 5% TPE and 75% zinc oxide by weight, the resulting thermal conductivity was 0.85 W/M/degree K, compared to 0.36 W/M/degree K than standard HDPE pipe without thermally conductive particles.

EXAMPLES

[0040] Table 1 below is a comparison of standard or conventional HDPE geothermal pipe properties versus two embodiments of pipe according to the present invention (Green Geo Soft and Green Geo Rigid). Thus, the pipe can be tailored or custom manufactured for specific strength and stiffness. The soft and rigid pipe embodiments differ, depending up on the amount of rubber in the pipe. Both the soft (low modulus) and rigid (high modulus) pipe have higher thermal conductivity than the conventional HDPE pipe. The low modulus Green Geo soft pipe has the following composition:

[0041] 3% Polypropylene with Maleic Anhydride as a coupling agent

[0042] 6.5% Thermoplastic Vulcanizate (aka TPV or PP/EPDM Rubber Blend)

[0043] 6.5% Thermoplastic Polyolefin (aka TPO)

[0044] 7.5% SEBS

[0045] 75.5% Zinc Oxide

The high modulus Green Geo rigid pipe has the following composition:

[0046] 22.8% HDPE

[0047] 1.2% maleic anhydride functionalized elastomeric ethylene copolymer

[0048] 76% Zinc Oxide

TABLE 1

Properties of Green Geo Pipe Compounds

Material	Tensile Strength	Modulus	Elongation	Density	Thermal Cond. W/m*K	Burst Strength
HDPE	3000 psi	120 kpsi	80%	0.9555	0.36	650 psi
Green Geo Soft	1100 psi	20 kpsi	400%	2.37	0.6-0.8	220 psi
Green Geo Rigid	3,000 psi	160 kpsi	100%	2.37	0.8-1.0	600 psi

[0049] Product can be tailored for specific strength and stiffness

[0050] Ideally, the geothermal pipe has a thermal conductivity which matches or approaches that of the soil in which it is embedded. Table 2 shows a comparison of the conductivity for standard PP and HDPE pipe, as compared to the Green Geo pipe of the present invention and various types of soil.

TABLE 2

Soil Thermal Conductivities

Material	W/m*K	Btu/hr*ft*F
PP	0.22	0.13
HDPE	0.36	0.21
Green Geo	0.6-1.0	0.34-0.57
Dry Sand	0.77	0.44
Loam	0.91	0.52
Clay	1.11	0.64
Silt	1.67	0.96
Wet Sand	2.50	1.44

Key is having pipe's thermal conductivity match or approach that of the soil

[0051] Tables 3-5 show a comparison of the temperature differentials of 700 feet of standard HDPE pipe with a slinky installation at 6 foot depth versus 320 feet of the Green Geo soft, low modulus pipe of the present invention installed in a slinky pattern at 6 feet depth. These tables show the temperature of the fluid coming into the manifold and out of the manifold over the course of seven months from February-August 2009. During the first month of testing, the soil had not yet compacted, such that intimate contact with the installed pipe was not maximized. The pipe and soil contact improved following the Spring thaw and rain.

TABLE 3

Side by Side - Heating

	DR 3500 - 700 ft. Slinky @ 6' Depth			Green Geo - 320 ft. Slinky @ 6' Depth		
2009	Temp IN	Temp Out	Delta T	Temp IN	Temp Out	Delta T
2-23	40.0 deg	37.7 deg	2.3 deg	43.3 deg	37.7 deg	5.6 deg
3-2	39.9 deg	37.4 deg	2.5 deg	41.0 deg	37.4 deg	3.6 deg
3-9	40.0 deg	37.4 deg	2.6 deg	42.3 deg	37.4 deg	4.9 deg
3-16	40.1 deg	38.3 deg	1.8 deg	42.6 deg	38.3 deg	4.3 deg
3-23	39.5 deg	36.8 deg	2.7 deg	41.4 deg	36.8 deg	4.6 deg
3-30	41.2 deg	37.9 deg	3.3 deg	43.1 deg	37.9 deg	5.2 deg
Avg.			2.5 deg			4.7 deg

New installation - soil yet to be compacted and pipe/soil contact has not yet been maximized

TABLE 4

Side by Side - Heating

	DR 3500 - 700 ft. Slinky @ 6' Depth			Green Geo - 320 ft. Slinky @ 6' Depth		
4-6	42.0 deg	37.3 deg	4.7 deg	44.2 deg	37.3 deg	6.9 deg
4-13	41.8 deg	38.0 deg	3.8 deg	44.0 deg	38.0 deg	6.0 deg
4-20	42.4 deg	38.0 deg	4.4 deg	44.4 deg	38.0 deg	6.4 deg
4-27	42.4 deg	37.8 deg	4.6 deg	44.0 deg	37.8 deg	6.2 deg
5-4	42.4 deg	37.8 deg	4.6 deg	44.1 deg	37.8 deg	6.3 deg
5-11	41.4 deg	36.7 deg	4.7 deg	43.9 deg	36.7 deg	7.2 deg
5-18	41.6 deg	36.9 deg	4.7 deg	44.0 deg	36.9 deg	7.1 deg
5-25	42.0 deg	37.1 deg	4.9 deg	44.4 deg	37.1 deg	7.3 deg
Avg.			4.6 deg			6.7 deg

Same installation after spring thaw and rain; pipe/soil contact has increased

TABLE 5

Side by Side - Cooling						
	DR 3500 - 700 ft. Slinky @ 6' Depth			Green Geo - 320 ft. Slinky @ 6' Depth		
2009	Temp IN	Temp Out	Delta T	Temp IN	Temp Out	Delta T
7-6	65.2 deg	70.9 deg	5.7 deg	61.6 deg	70.9 deg	9.3 deg
7-13	65.4 deg	70.8 deg	5.4 deg	61 deg	70.8 deg	9.8 deg
7-20	65.4 deg	70.8 deg	5.4 deg	60.4 deg	70.8 deg	10.4 deg
7-27	66.0 deg	72.4 deg	6.4 deg	62.9 deg	72.4 deg	9.5 deg
8-3	68.1 deg	74.0 deg	6.1 deg	64.3 deg	74.0 deg	9.7 deg
8-10	67.9 deg	73.6 deg	5.7 deg	65.0 deg	73.6 deg	8.6 deg
8-17	68.7 deg	72.8 deg	4.1 deg	66.1 deg	72.8 deg	6.7 deg
8-24	65.0 deg	70.8 deg	5.80 deg	63.3 deg	70.8 deg	7.5 deg
8-31	64.5 deg	70.6 deg	6.1 deg	60.3 deg	70.6 deg	10.3 deg
Avg.			5.6 deg			9.1 deg F.

[0052] It is further noted that the manufacturer of conventional HDPE produces approximately 2.0 pounds of carbon dioxide per pound of HDPE. Since Applicant's improved geothermal pipe allows for shorter lengths, less CO2 is produced during the manufacture of the pipe.

[0053] Also, in vertical installations using improved geothermal pipe of the present invention, the improved conductivity allows for substantially shorter length of pipe, and thus shallower bores which avoid potential ground water contamination concerns. For example, with Applicant's pipe, vertical bores of only 10 feet may be utilized, as compared to 200 foot deep bores for conventional vertical geothermal installations.

[0054] With respect to the drawings, a geothermal heating and cooling system is generally designated by the reference numeral **10**. The system **10** includes the improved pipe **12** of the present invention. While the drawings show the pipe **12** installed horizontally in the ground, it is understood that the pipe **12** may also be installed in vertical bores in the ground. The opposite ends of the pipe **12** are connected to a heat pump or other fluid heat exchanger **14** for the building **16** so as to form a loop. The pipe **12** may be oriented in any convenient configuration, depending on the available ground space, and obstacles such as trees. The building **16** may be residential or commercial. The geothermal system **10** also includes a compressor **18**, an expansion valve **20**, and an air heat exchanger **22**.

[0055] As seen in FIGS. **1** and **2**, the fluid in the pipe **12** flows in the direction as indicated by the arrows **24**. The fluid in the internal loop **26** connecting the heat pump or water heat exchanger **14**, compressor **18**, air heat exchanger **22** and extension valve **20** flows in a first direction for heating, as shown by arrows **28** in FIG. **1**, and in the opposite direction for cooling, as shown by arrows **30** in FIG. **2**.

[0056] The invention has been shown and described above with the preferred embodiments, and it is understood that many modifications, substitutions, and additions may be made which are within the intended spirit and scope of the invention. From the foregoing, it can be seen that the present invention accomplishes at least all of its stated objectives.

What is claimed is:

1. An improved geothermal pipe for heating and cooling building structures, comprising:
- a plastic pipe embedded with heat transfer particulates; and
- the pipe having a modulus of elasticity less than 200,000 psi.

2. The improved geothermal pipe of claim **1** wherein the plastic pipe is a elastomer modified composite.

3. The improved geothermal pipe of claim **2** wherein elastomer is thermoplastic or thermoset.

4. The improved geothermal pipe of claim **2** wherein the plastic pipe is selected from a group consisting of an olefin based polymer, TPU, COPE, COPA, PVC and SBC.

5. The improved geothermal pipe of claim **1** wherein the particulates are selected from a group consisting of metals, metallic oxide, non-oxides, and graphite.

6. The improved geothermal pipe of claim **1** wherein the plastic pipe includes a preservative layer.

7. The improved geothermal pipe of claim **1** wherein the plastic pipe substantially meets ASTM standard D-3035.

8. A method of geothermally heating and cooling a building, comprising:
- installing in the ground a plastic pipe embedded with heat transfer particles, the pipe having opposite ends;
- connecting the ends of the pipe to a heating and cooling system of the building; and
- flowing a heat transfer fluid through the pipe so as to exchange heat between the building and the ground.

9. The method of claim **8** wherein the particulates are selected from a group consisting of metals, metallic oxide, non-oxides, and graphite.

10. The method of claim **8** wherein the plastic pipe is selected from a group consisting of an olefin based polymer, TPU, COPE, COPA, PVC and SBC.

11. The method of claim **8** wherein the plastic pipe is a thermoplastic or thermoset elastomer.

12. The method of claim **8** wherein the elastomer is selected from a group consisting of TPO. TPV, SBC, TPU, COPA, and COPE.

13. The method of claim **8** wherein the pipe is oriented substantially horizontally or vertically in the ground.

14. An improved geothermal system for heating and cooling a building, comprising:
- a heating and cooling assembly for the building;
- a fluid loop extending in the ground outside the building and having opposite ends connected to the assembly to transfer heat between the interior of the building and the ground;
- the loop including a plastic pipe having embedded heat transfer particles.

15. The system of claim **14** wherein the pipe has a modulus of elasticity less than 200,000 psi.

16. The system of claim **14** wherein the plastic pipe includes a thermoplastic elastomer.

17. The improved geothermal pipe of claim **16** further comprising an elastomer selected from a group consisting of TPO, TPV, SBC, TPU, COPA, and COPE.

18. The improved geothermal pipe of claim **14** wherein the plastic pipe is selected from a group consisting of an olefin based polymer, TPU, COPE, COPA, PVC and SBC.

19. The improved geothermal pipe of claim **14** wherein the particulates are selected from a group consisting of metals, metallic oxide, non-oxides, and graphite.

20. The improved geothermal pipe of claim **14** wherein the plastic pipe includes a preservative layer.

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