12 FePatents
R8

Feng

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Feng Patents

#	Trademark	Title	Co.	App. Number	File Date	Application Status	Case Number
1	FeBTUCell™	Ground Heat Exchange	US	63/139,026	19-Jan-2021	Expired	328-8
	FeBTUCell™	Ground Heat Exchange	CA	3,121,345	07-Jun-2021	Pending	328-8
2	FeH2OLoc™	System and Method for Excavating and constructing a shoring support wall and water management system	CA	3,101,712	04-Dec-2020	Issued	328-6
3	FeHDPlank™	Support structure and method of forming a support structure	CA	3,112,125	17-Mar-2021	Issued	328-10
	FeHDPlank™	Support structure and method of forming a support structure	US	17/697,445	17-Mar-2022	Pending	328-10
4	FeSpiral™	Method and apparatus for repairing culverts and pipes	US	63/139,085	19-Jan-2021	Expired	328-9
	FeSpiral™	Method and apparatus for repairing culverts and pipes	CA	3,125,165	20-Jul-2021	Pending	328-9
	FeSpiral™	Method and apparatus for repairing culverts and pipes	US	17/579,540	19-Jan-2022	Pending	328-9
5	FeHeligent™	Pile wall system	CA	3,115,957	21-Apr-2021	Pending	328-11
	FeHeligent™	Pile wall system	US	17/237,544	22-Apr-2021	Allowed	328-11
6	FeSolarCurb™	Frame with plenum for supporting a photovoltaic array	CA	3,116,049	23-Apr-2021	Pending	328-13
	FeSolarCurb™	Frame with plenum for supporting a	US	17/697,445	19-Apr-2022	Pending	328-13

		photovoltaic array					
7	FeTremie™	Method and System for forming a permeable reactive barrier in the ground	CA	3,117,017	04-May-2021	Granted	328-14
8	Feng Solar Frame	Solar panel frame with plenum	US	29/780,101	23-Apr-2021	Pending	328-12
	Feng Solar Frame	Solar panel frame with plenum	CA	202,960	21-Apr-2021	Granted	328-12
9	Feng Waterproof Concrete™	Concrete composition	CA	3,128,332	16-Aug-2021	Abandoned	328-17
	Feng Waterproof Concrete™	Concrete composition	US	63/233,345	16-Aug-2021	Expired	328-17
10	Feng Waterproof Shotcrete™	Shotcrete composition	CA	3,129,300	30-Aug-2021	Abandoned	328-18
		Shotcrete composition	US	63/238,641	30-Aug-2021	Expired	328-18
11	FeWindmill						
12	FeHDGP	High Deck Gravel Pile 5 Ton					
	FeHCGP	High Capacity Gravel Pile 30 Ton					
		Ground Heat Exchanger	US	17/533,894	23-Nov-2021	Allowed	328-20 Relates to 328-8
		Ground Heat Exchanger And Wind Turbine	US	17/833,214	6-Jun-2022	Pending	328-20 Relates to 328-8
		Ground Heat Exchanger And Wind Turbine	CA	3,161,613	6-Jun-2022	Pending	328-20 Relates to 328-8
		FENG 200 Year Concrete	US	17/561,785	24-Dec-2021	Pending	328-21

An Alternative to Ground Geothermal
FeBTUCellTM: Innovation in Ground Geothermal
Part 1 of 2

The current industry mainly uses two systems that offer a low return on energy applied:

Geothermal System Option 1 or some use of the term Geo exchange, is a system involving glycol and an excavated trench with plastic tubing. The return on input energy /output energy or Coefficient of Performance (COP) is 2-3. It is typical to place a horizontal trench below frost level where it is approximately 50°F. This may be 7-10 ft deep and involves excavation, backfill and may involve importing free draining materials to the site. This work often precedes landscaping, and roads and services like hydro and water which do need careful pre-planning. It is rarely possible, in cities or existing homes with limited square footage left, to fit this in after a home parkina lot or landscaping area is installed. The schedule usually requires 2 weeks of good weather days, being similar in duration to a house basement foundation.

Geothermal System Option 2 is a system involving vertical ground loops via a well drilling machine / geothermal unit, often driven with road tires. Water is typically used to drill to avoid ground loss, or a mud slurry like polymer or bentonite. Plastic tubing and Glycol is placed and the mud is stabilized with cement. A license is required to handle Glycol. The return on input energy / output energy or Coefficient of Performance (COP) is 2.5-3.5. This schedule is usually 3 days to complete 200 ft of vertical drilling and loop placement. For Clay or Rock, this is a very messy operation to control.

An Alternative to Ground Geothermal
FeBTUCellTM: Innovation in Ground Geothermal
Part 2 of 2

THE SOLUTION

FeBTUCell™ is patented in the US and Canada on a unique overflow system that allows for Evaporative Cooling which will enhance the high return on inputted energy. COP=10. The use of clean water is easier and a clear benefit over Glycol.

One of the key advantages of **FeBTUCell™** is that it uses readily available steel liners. Typically these are supplied at .375 - .500 wall thickness. The diameter of the liner sizes used are 48, 72 and 120 inches. 30 ton Heat-Cool Geo exchange is possible with a caisson drill rig floated to the site.

Examples of foundation drill types to use: Bauer 28 (if near a lake or near an ocean). Drill depths vary from 25-50 feet enabling a high number of units by one caisson drill in a day. The closed water system has a heat pump. Make up water supplies 5-10 gallons overflow in a day. Ultimately this water is available to supply annulus water. The annulus water can then supply all overflow water to the outer casing perimeter. See drawing **FeBTUCell™.**

The unique high COP of **FeBTUCell™** can be explained by the fact that the water is in contact with steel which has a high rate of heat transfer. The overflow is truly unique given the evaporative cooling effect in dry soil.

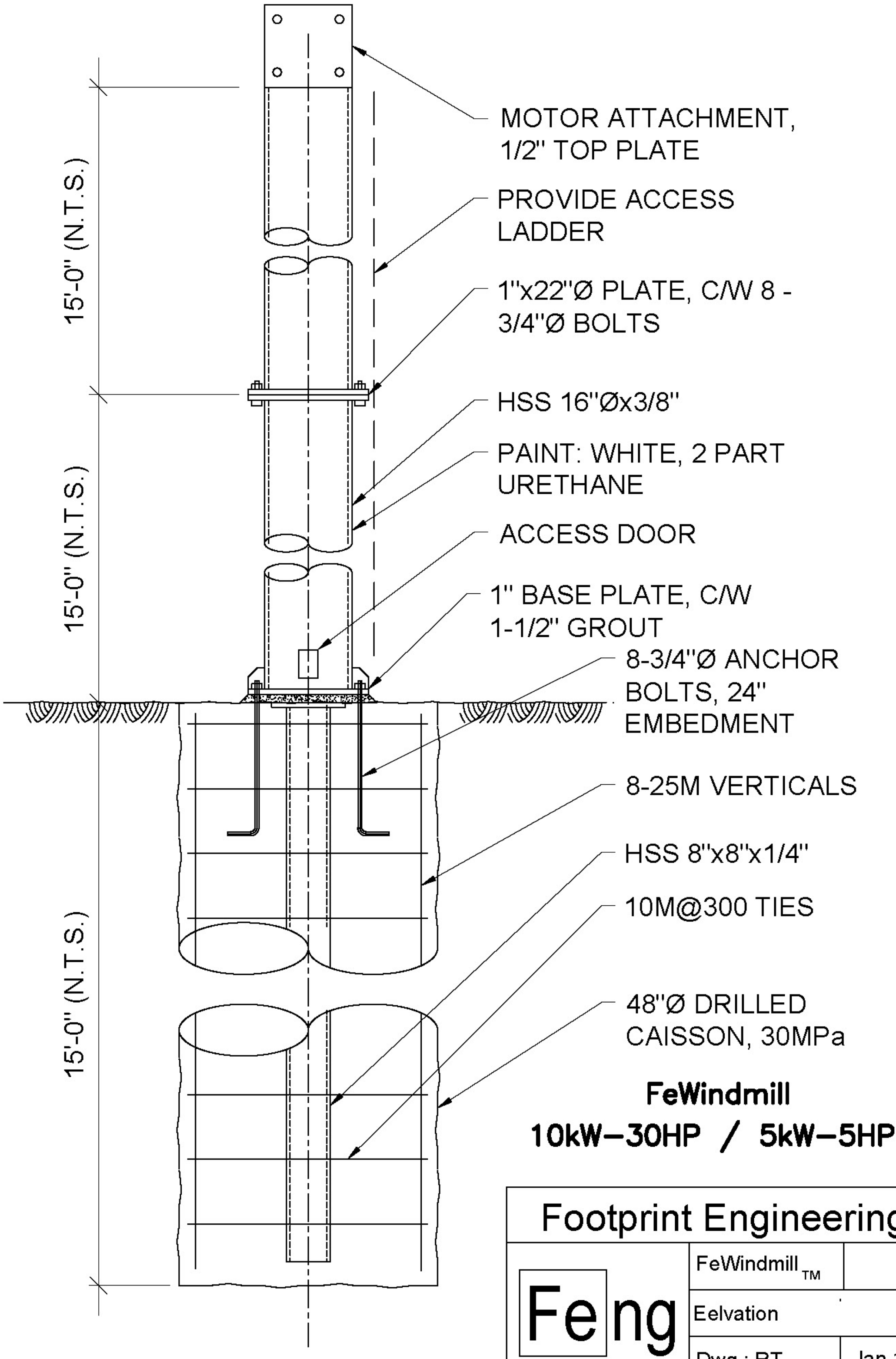
Fe

geowind

FeGeoWind™

Footprint Engineering has developed an off-the-grid windmill capable of generating 10 kW of power using a 30-foot tall structure. Power is generated via the use of 600 lbs. of high pull magnets and 10mph winds.

Typical installations are 25 ft to 50 ft deep, and circumference varies from 48-120 diameter. FeGeoWind utilizes the FeBtuCell as a base foundation helping improve efficiency and output. Using evaporative cooling, FeBTUcell is COP=10 (energy out / energy in).



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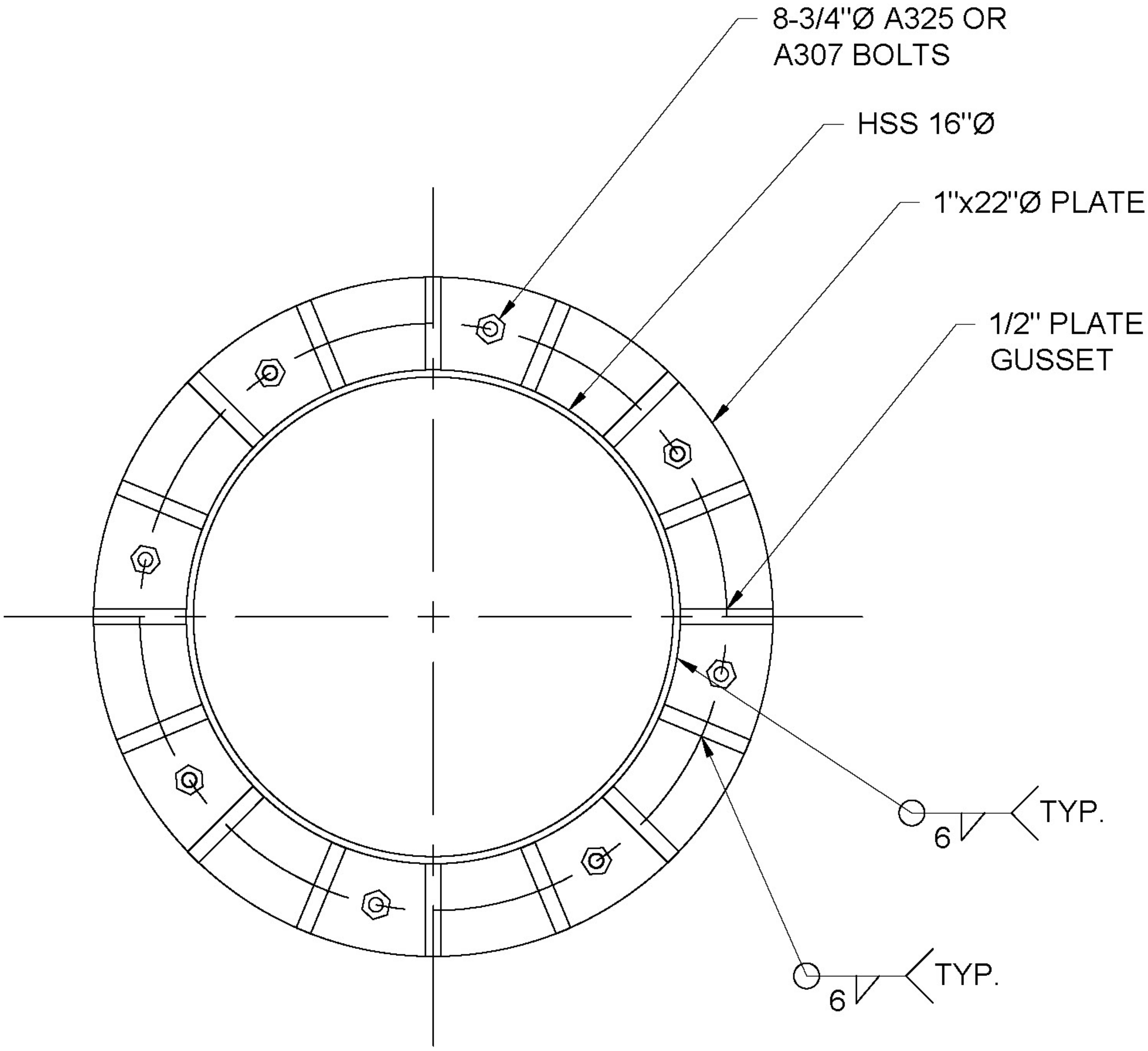


SECTION AT SPLICE OR BASEPLATE

Footprint Engineering Inc.		
Feng	FeWindmill TM	13
	Detail	
	Dwg : RT	Jan 18, 2022

Fe|ng

MEMO

To: Martin Halliwell

Cc: Fe Team

From: Andriy Kumanovskyy, P.Eng

Date: May 29, 2023

Subject: FeBTUCell **Report 1** - COP Calculations

DEFINITIONS

Coefficient of Performance (COP): Defined as the ratio of useful energy out over the amount of energy used (electrical input). This is a more intuitive ratio as opposed to 'EER' since both the top and bottom units are the same (Watts/Watts), so COP will be used exclusively in this report. *You can convert from EER to COP by diving by **3.41214**. Higher* than unity COPs with heat pumps are possible since heat is not created but rather *moved* via a heat pump.

Thermal Reservoir: A thermodynamic system with a heat capacity so large that the temperature of the reservoir changes relatively little when a much more significant amount of heat is added or extracted. Normally this is assumed in Ground Source Heat Pump (GSHP) systems, though incorrectly since the ground heats up over time. FeBTUCell reduces the temperature increase of the ground due to excess heat removal via overflow + evaporation, making the 'thermal reservoir' assumption more accurate, for higher COPs that are consistent over the long term.

Ground Source Heat Pump (GSHP): An HVAC approach that uses the ground/geothermal thermal reservoir as an evaporator during heating mode (extracting heat from ground to home), and as a condenser during cooling mode (dumping heat into ground from home) by electrically running a Carnot heat pump. ***Cooling mode*** is the focus of this report, using the ground as a condenser.

Entering Water Temperature (EWT): Entering water temperature of the closed water loop.

FeBTUCell: A Higher COP approach with a more effective thermal reservoir performance geothermal system for GSHP systems. This patent also presents significantly improved drilling and implementation options (even up to 25-50ft deep) due to it being in dry ground.

SUMMARY

FeBTUCell is a geothermal patent held by Martin Halliwell. FeBTUcell serves the function of improving the condenser side heat transfer during cooling operation. FeBTU cell layers typical heat pump efficiencies (often between 3-6 COP) by offering cool ground temperatures with an added benefit of evaporative cooling. This effectively translates into ***colder Entering Water Temperatures (EWT)*** of the closed water loop back to the heat pump (ref. Figure 1). Colder EWP results in higher Coefficients of Performance (COP) for all heat pump systems (ref. Table 1).

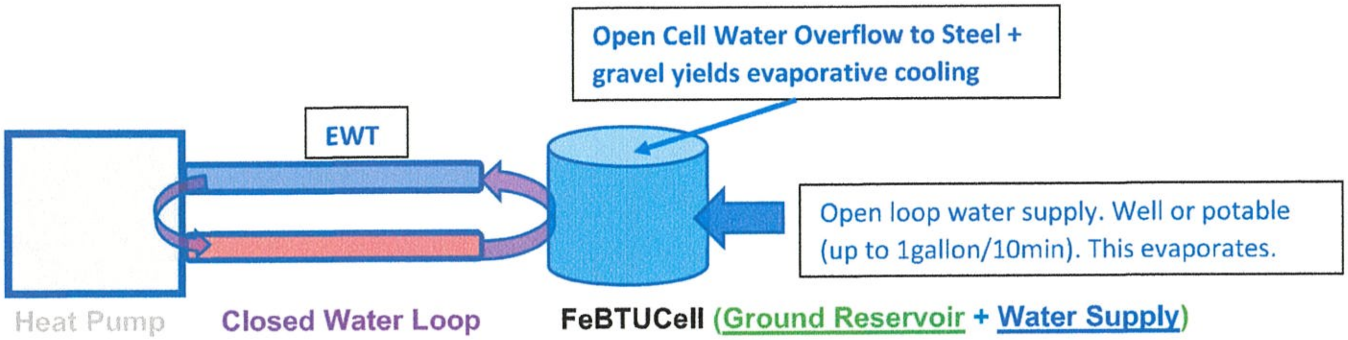


Figure 1: GSHP System Deploying FeBTUCell

Note: *The open water addition is separate water from the closed loop.*

This is the ***first of three*** COP studies to be done, this first one serving as a preliminary step defining the problem, showing the max possible COP gains with the addition of evaporative cooling, as well as steps and mechanical modifications required to achieve them. The second report will assure these values given more conclusive info on materials, pipe thickness (namely the closed water loop pipe), which will be assessed using some measured temperatures. The third will be an empirical and site test report.

UB070 - Performance Data

Single Speed with PSC (2200 cfm)

EWT °F	Flow GPM	WPD		HEATING - EAT 70°F					COOLING - EAT 80/67°F					
		psi	ft	HC MBtu/h	Power kW	HE MBtu/h	LAT °F	COP	TC MBtu/h	SC MBtu/h	S/T Ratio	Power kW	HR MBtu/h	EER
20	12.0	5.8	13.4	Operation not recommended					Operation not recommended					
	15.0	9.1	20.9											
	18.0	12.3	28.4	42.5	3.90	29.2	86.7	3.20						
30	12.0	5.7	13.2	Operation not recommended					Operation not recommended					
	15.0	8.9	20.4	50.2	4.15	36.0	90.1	3.54	66.2	41.5	0.63	2.90	76.1	22.8
	18.0	12.0	27.7	48.6	4.15	34.5	89.4	3.43	67.1	42.4	0.63	2.73	76.4	24.6
40	12.0	5.7	13.2	Operation not recommended					Operation not recommended					
	15.0	8.9	20.4	56.9	4.37	42.0	93.1	3.81	71.3	46.6	0.65	3.16	82.0	22.6
	18.0	12.0	27.7	57.0	4.39	42.0	93.1	3.81	71.4	46.5	0.65	3.03	81.8	23.6
50	12.0	5.6	13.0	63.3	4.57	47.7	95.9	4.06	76.8	52.6	0.68	3.50	88.8	21.9
	15.0	8.6	19.8	64.3	4.60	48.7	96.4	4.10	76.3	51.6	0.68	3.41	87.9	22.4
	18.0	11.5	26.6	65.4	4.63	49.6	96.8	4.14	75.7	50.6	0.67	3.33	87.1	22.8
60	12.0	5.5	12.7	72.1	4.81	55.7	99.8	4.40	74.2	52.2	0.70	3.88	87.4	19.1
	15.0	8.4	19.3	73.6	4.85	57.0	100.4	4.45	74.2	51.7	0.70	3.79	87.1	19.6
	18.0	11.2	25.9	75.0	4.88	58.3	101.1	4.50	74.2	51.3	0.69	3.70	86.8	20.0
70	12.0	5.4	12.5	80.9	5.05	63.7	103.7	4.70	71.5	51.8	0.72	4.26	86.1	16.8
	15.0	8.2	18.9	82.8	5.09	65.4	104.5	4.76	72.1	51.9	0.72	4.17	86.3	17.3
	18.0	11.0	25.5	84.6	5.14	67.1	105.3	4.83	72.6	51.9	0.72	4.08	86.5	17.8
80	12.0	5.3	12.2	88.9	5.23	71.1	107.2	4.99	66.5	50.2	0.76	4.86	83.0	13.7
	15.0	7.9	18.2	90.6	5.28	72.5	107.9	5.02	67.2	50.3	0.75	4.63	83.0	14.5
	18.0	10.5	24.3	92.2	5.34	74.0	108.7	5.06	68.1	50.5	0.74	4.48	83.4	15.2
90	12.0	5.2	12.0	96.9	5.40	78.4	110.7	5.26	61.4	48.6	0.79	5.30	79.5	11.6
	15.0	7.7	17.7	98.4	5.47	79.7	111.4	5.27	62.3	48.8	0.78	5.05	79.6	12.3
	18.0	10.1	23.4	99.9	5.54	81.0	112.0	5.28	63.6	49.1	0.77	4.89	80.3	13.0

Table 1: Cooling EER/COP increases as EWT decreases (versatecbase-spec.pdf)

OBJECTIVE

The objective of this first report is to present how much the EWT can decrease thanks to the addition of the evaporative cooling effect of the FeBTUCell, vs. no FeBTUCell and typical GSHP systems.

What's important here is the ***relative increase***, since choosing a more efficient heat pump will result in higher absolute COP values. For example, if the best possible COP value of the best heat pump is a COP of 8 given 40F EWT and 15GPM closed loop flow… deploying FeBTUCell (and required surface area / convection + conduction modifications) will yield a COP of 9-9.5+. For perspective, the COP of Martin's current *WaterFurnace* UBV070TR000PBNAN0A30 heat pump given these conditions may only reach a COP of 5 or 6. An improvement of COP from 6 to 7 via FeBTUCell would translate similarly when using a better heat pump (from 8 to 9+), getting closer to the difficult (but not impossible) COP values of 10+.

ASSUMPTIONS, CALCULATIONS and ASSESSMENT

1. Closed loop water flows at a rate of 18.0 GPM from the heat pump to the FeBTUcell and back to the heat pump's heat exchanger (with a Carnot Cycle heat pump system + refrigerant).

2. Open loop well or potable water is supplied at a rate of up 1gallon/10 minutes. This rate must be adjusted to ensure full evaporation. This is at a temperature of 50-55F, combining with a heat pump exit temperature of 100F+ yields a water overflow temperature of around 70F (21C).

3. The water overflows and takes advantage of the gravel near steel to add more surface area for evaporation.

4. More evaporation/more flow can be supplied with increased surface area on the FeBTUcell steel overflow, perhaps permitting a thinner steel liner (and other steel), as well as a shorter path between the reduced evaporated Surface Temperature (TS), and the EWT.

5. Air blows between 15-30km/hr, or near this range.

6. RH is assumed to be 45%, 50%, and 55%.

Evaporative Temperature Reduction

Air is blown naturally over a steel liner with a fair amount of water absorption to cool the steel liner by simultaneous heat and mass transfer.

Note 1: Low mass flux conditions exist so that the Chilton-Colburn analogy between heat and mass transfer is applicable since the mass fraction of vapor in the air is low (about 2 percent for saturated air at 20-25 deg C).

Note 2: Both air and water vapor at specified conditions are ideal gases (the error involved in the assumption is less than 1 percent).

Note 3: Radiation effects are negligible.

$$T_s = T_\infty - \frac{h_{fg}}{c_p\, Le^{2/3}} \frac{M_v}{M} \frac{P_{v,s} - P_{v,\infty}}{P}$$ (Chilton-Colburn analogy for evaporative cooling)

$$T_s = 21C - \frac{2466}{1.007*0.858^{2/3}} \frac{18}{29} \frac{1.705 \quad .05}{101.3}$$ = **10.1C** at 45% RH

Note: 21C = Overflow water temperature, and close to ambient tempature in cooling season

$$T_s = 21C - \frac{2466}{1.007*0.858^{2/3}} \frac{18}{29} \frac{1.705-1.17}{101.3}$$ = **12.1C** at 50% RH

$$T_s = 21C - \frac{2466}{1.007*0.858^{2/3}} \frac{18}{29} \frac{1.705-1.29}{101.3}$$ = **14.0C** at 55% RH

Note: at an RH of 40% Ts was found to be **8.2C**, at 35% Ts was **6.3C**, and 30% = **4.3C**

At a reasonable RH of 45% we can expect the Ts to reduce to 10.1C (50 F) from 21C (70 F), assuming the open loop water supply = evaporation flow rate. This is about 11C of reduction (**20F**). If the path from Ts to EWT is reduced, more of this temperature reduction in Ts can be translated to reduced EWT and increased COP. With more conduction info (closed loop pipe dimensions and materials), this can be calculated (ideally simulated with software), but for now, we can assume that ***a quarter to half*** of this reduction can be translated to reduced entering water temperature EWF back to the heat pump (**5-10F**).

A max EWT reduction of **10F** via table 2 takes the EER from 20.0 to 22.8, which is a COP boost from 5.86 to 6.68 (COP boost of 0.8). ***We can round off to a max COP boost of 1,*** *when deploying FeBTUCell vs no FeBTUCell.* This is still significant. Assuming this same conductive heat transfer through piping will result in even further COP gains when running with an RH of 40% or lower, since Ts would be lower than 10.1C, and the reduction would exceed 20F.

RECOMMENDATIONS

These are recommendations to help reach the maximum possible gains, which can be deployed by the us, installer, or future owner of the patent. Maximum possible gains are caused by lowest possible **Ts** temperatures, and shortest conductive path to the closed water loop **EWT** returning to the heat pump.

1. Closed loop heat pump water line should touch the 48" (or whatever the size) steel rim on the inside. Perhaps inside the steel rim we can have multiple loops of the closed loop water pipe instead of what appears to be just one loop (Figure 2).
2. Consider a wet cloth near the top several feet of the steel liner outside to absorb and evaporate more water.
3. Consider testing with light fans to increase the evaporative cooling portion of the cooling.

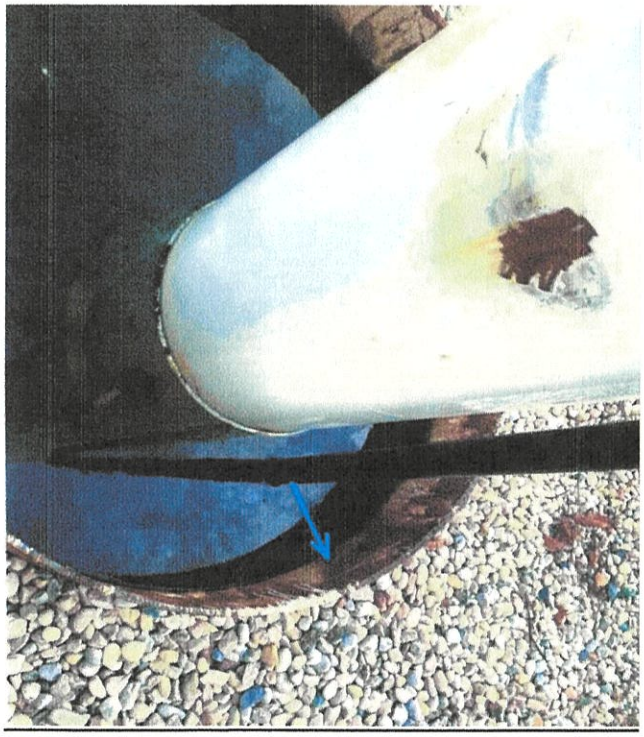


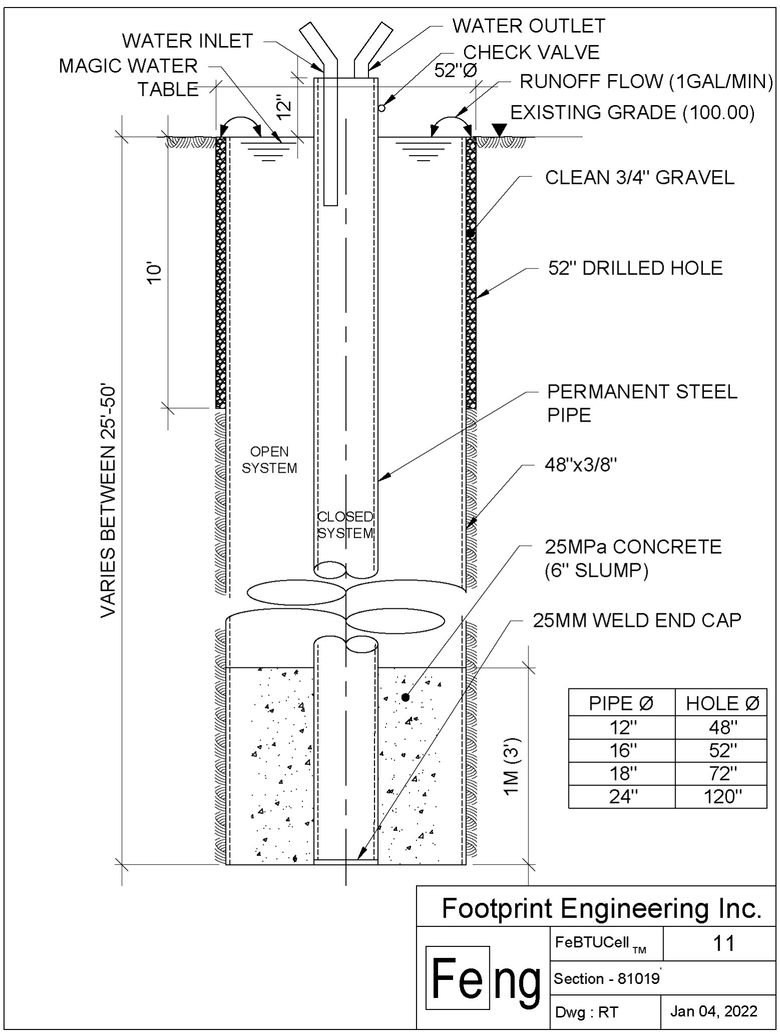
Figure 2: Moving closed loop water line to touch the steel liner on the inside*

* Moving this pip to the inside of the steel liner may benefit from the cool water on the inside, plus maximum conductive heat transfer to the outside where the bulk of evaporative cooling is taking place.

Note: Moving the closed loop water line to touch the outside ofthe steel liner at gravel may also be beneficial if the evaporative cooling effect is greater than the direct sensible benefit of cooler water (than gravel) inside the FeBTUCell steel liner. This can be simulated in future reports or tested at site.

FeBTUCell™

This invention relates to a geothermal system of heat exchange and more particularly to a geothermal pile that is disposed in the ground inside a contained source of water. Through this method we can harness the heat energy present that is underneath the surface of the earth. It is said to be one of the most abundant sources of heat on earth and through proper utilization of this heat energy we aim to reduce energy consumption through conventional means. The FeBTUCellTM has an expected co-efficient of efficiency (COE) of 10, which is the highest COE observed in dry-ground. Furthermore, the FeBTUCellTM will be useful in any dry soil, even with well water at 200 feet as we can, with this Feng System water furnace, create high elevation local water tables.



2022 Footprint Engineering Inc.

FeBTUCell RSS QA and Details

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Section 1.0: FeBTUCell™ (M.H. Rating: 9/10 - Winner)

This invention relates to a geothermal system of heat exchange and more particularly to a geothermal pile that is disposed in the ground inside a contained source of water. Through this method we can harness the heat energy present between rocks and metallic alloys that lie underneath the surface of the earth. It is said to be one of the most abundant sources of heat on earth and through proper utilization of this heat energy we aim to reduce energy consumption through conventional means. The FeBTUCell™ is currently being tested at Martin's farm, with an expected co-efficient of efficiency (COE) of 10, which when demonstrated in testing, will be the highest COE observed in dry-ground. Furthermore, the FeBTUCell™ will be incredibly useful in any desert with well water at 200 feet as we can, with this Feng System water furnace, create local water tables.

Section 1.1: FeBTUCell™ RSS

This RSS System provides a geothermal system with a high COP and conductivity.

1-SURVEY SITE CONDITIONS

Prior to any work being initiated, the owner must survey the site conditions, looking for any abnormalities or additional problems that may exist on site.

2-DRILL DIRT/ROCK AND INSTALL LINER

Drill holes open to water table. Drill liners into water table to seal into bottom at 30-100 ft. No rock or glacial till. Sizing combinations are to be 8 in a 36 inch diameter tube, 12 in a 48 inch diameter tube, and 18 in a 72 inch diameter tube. Add end cap.

3-PILE

Drive pile into the ground.

4-INSERT FEBTUCELL

Insert ID Pipe (Plated) into pile.

5-CONCRETE FILL

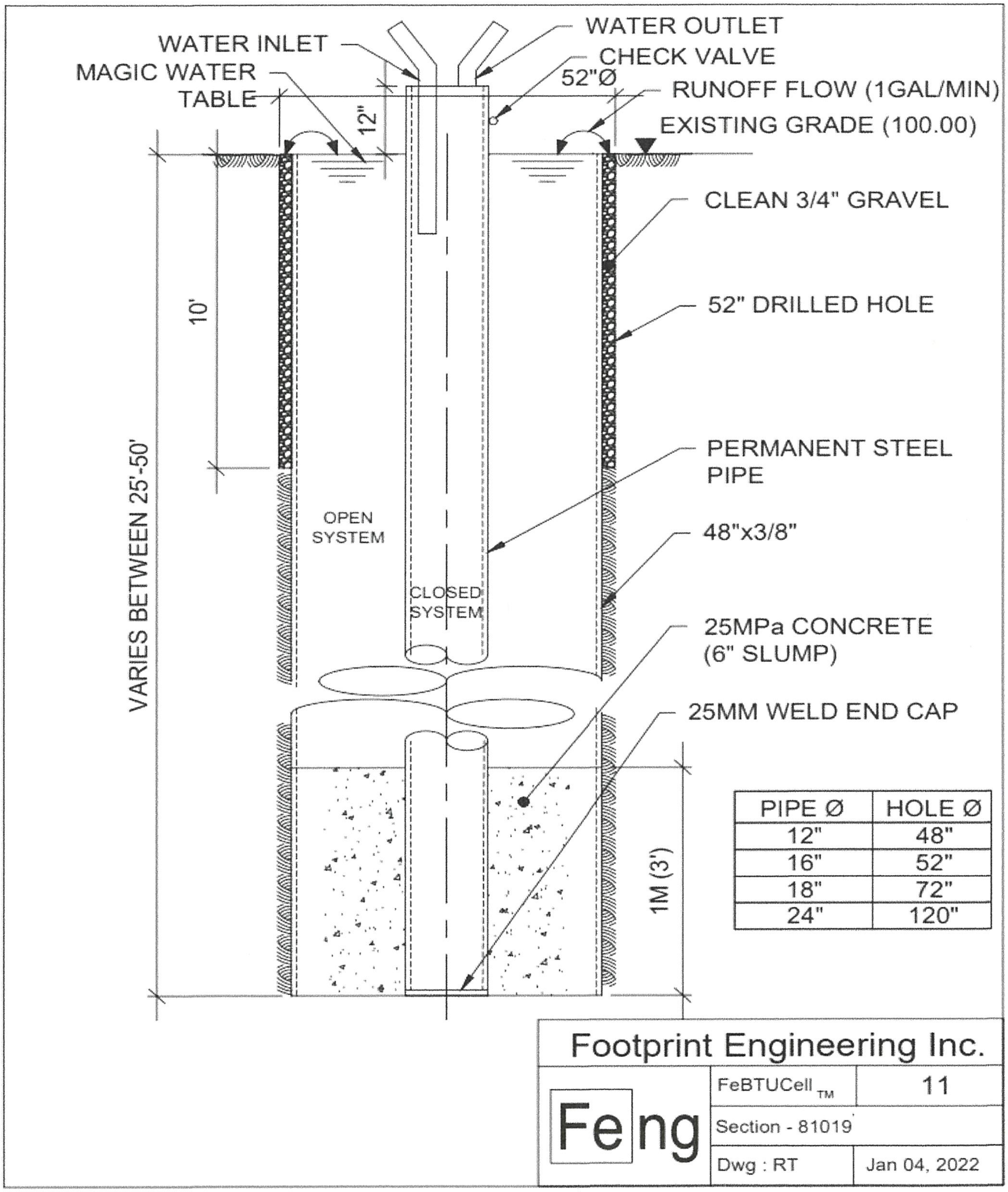
Fill the area surrounding the pile with 5 MPa concrete.

6-GRAVEL AND WATER FILL

Brace the remaining annular space around the ID pile with clean gravel. Finally, fill the gravel pit with water.

Section 1.2: FeBTUCell™ CAD Illustration

A sketch depicting a typical FeBTUCell™ unit can be seen below.



PIPE Ø	HOLE Ø
12"	48"
16"	52"
18"	72"
24"	120"

US011614259B2

(12) **United States Patent**
Halliwell

(10) **Patent No.: US 11,614,259 B2**
(45) **Date of Patent: Mar. 28, 2023**

(54) **GROUND HEAT EXCHANGER**

(71) Applicant: **HC Properties Inc**, Clinton (CA)

(72) Inventor: **John Martin Halliwell**, Clinton (CA)

(73) Assignee: **HC Properties Inc.**, Goderich (CA)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **17/533,894**

(22) Filed: **Nov. 23, 2021**

(65) **Prior Publication Data**

US 2022/0228778 A1 Jul. 21, 2022

Related U.S. Application Data

(60) Provisional application No. 63/139,026, filed on Jan. 19, 2021.

(51) **Int. Cl.**
F24T 10/10 (2018.01)
F03G 4/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F24T 10/10*** (2018.05); ***F03G 4/00*** (2021.08)

(58) **Field of Classification Search**
CPC F24T 10/10; F03G 4/00; Y02E 10/10
USPC 60/641.2–641.4
See application file for complete search history.

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2013/0232973	A1 *	9/2013	McBay	F28D 15/00	165/45

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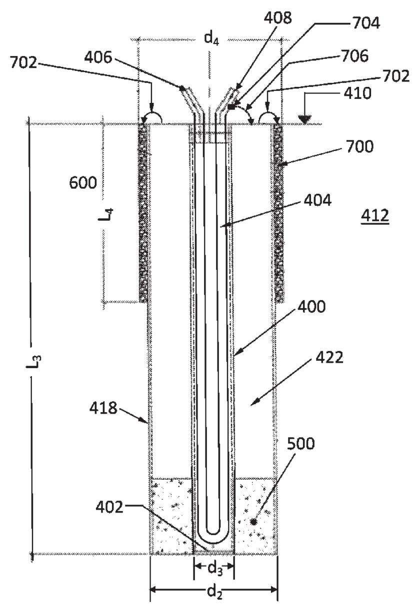
Primary Examiner — Hoang M Nguyen
(74) *Attorney, Agent, or Firm* — Teitelbaum & Bouevitch; Neil Teitelbaum

(57) **ABSTRACT**

A geothermal system includes an outer vessel having a sidewall that is in contact with surrounding ground material. A geothermal pile is disposed within an interior volume of the outer vessel, wherein a first heat conducting liquid at least partially fills a space between an inner surface of the sidewall of the outer vessel and an outer surface of the geothermal pile when in an installed condition. A conduit disposed within an interior space of the geothermal pile conducts a second heat conducting liquid along a flow path within the geothermal pile toward a bottom end thereof and then back to an outlet at a top end thereof. During operation, heat is transferred from the surrounding ground to the second heat conducting liquid via the first heat conducting liquid within the space between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile.

12 Claims, 10 Drawing Sheets



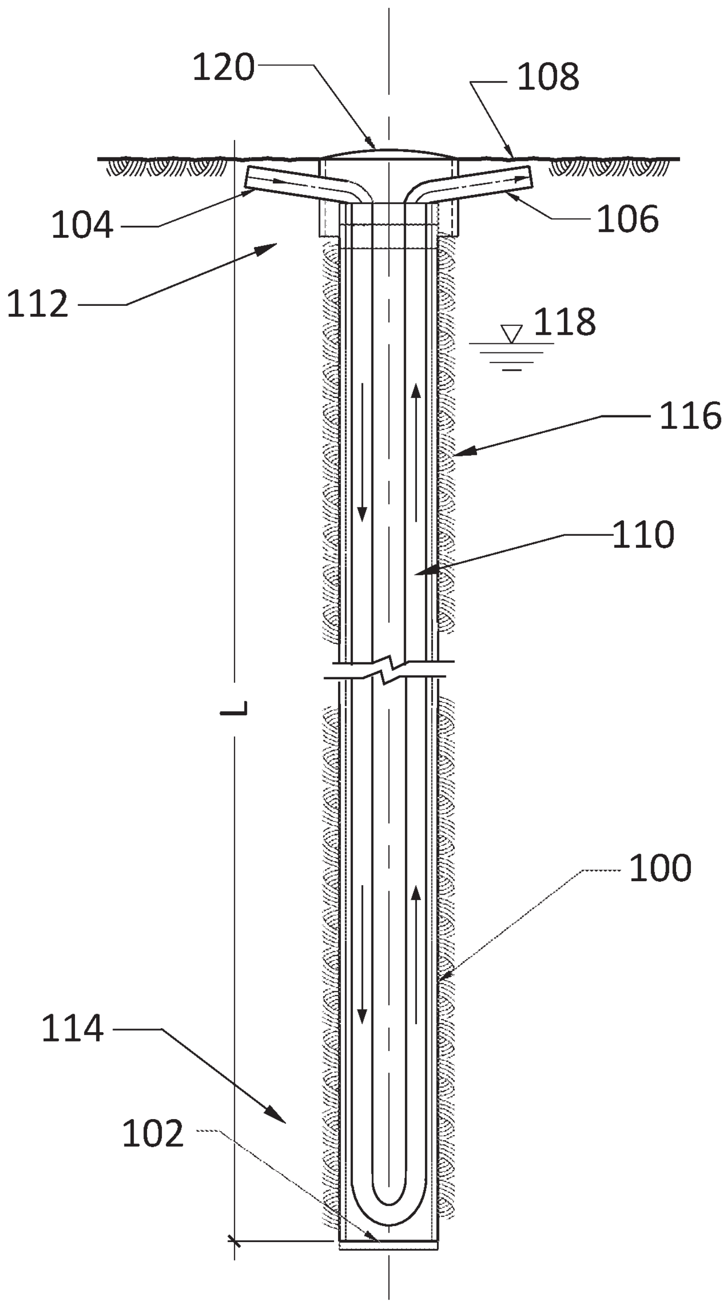


FIG. 1

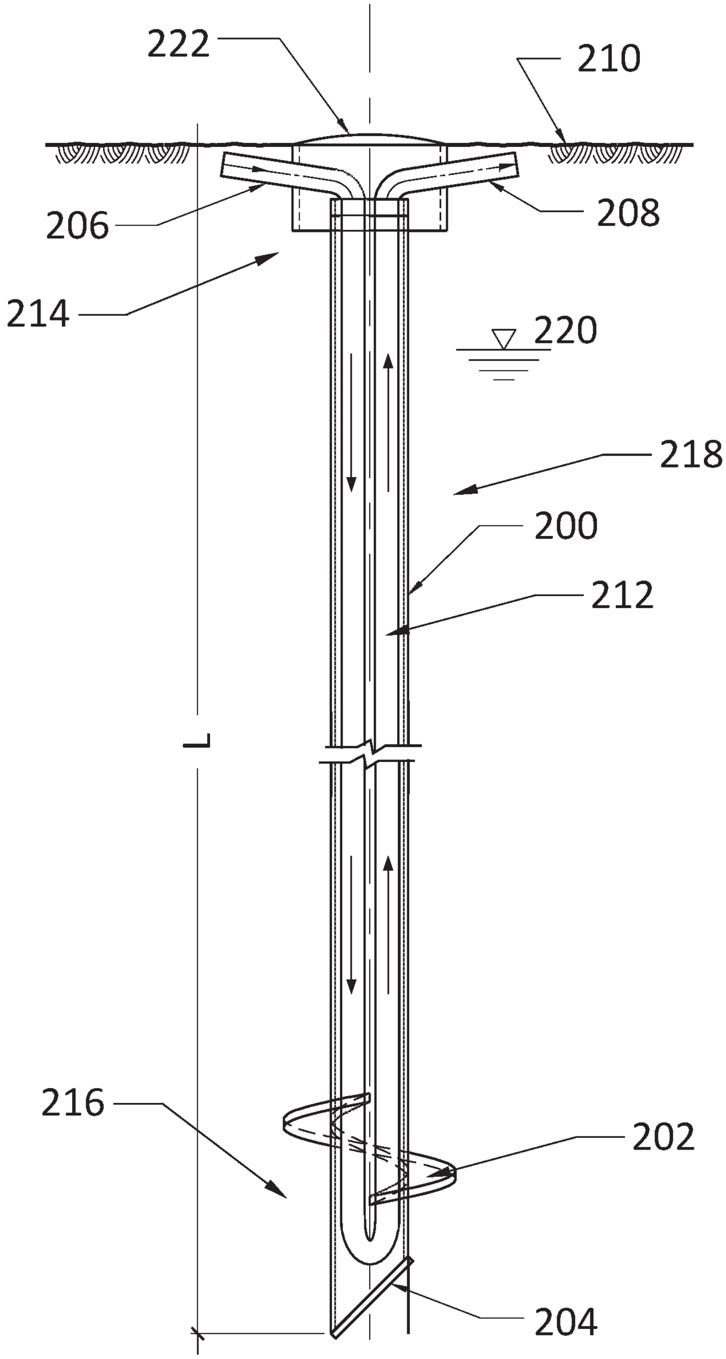


FIG. 2

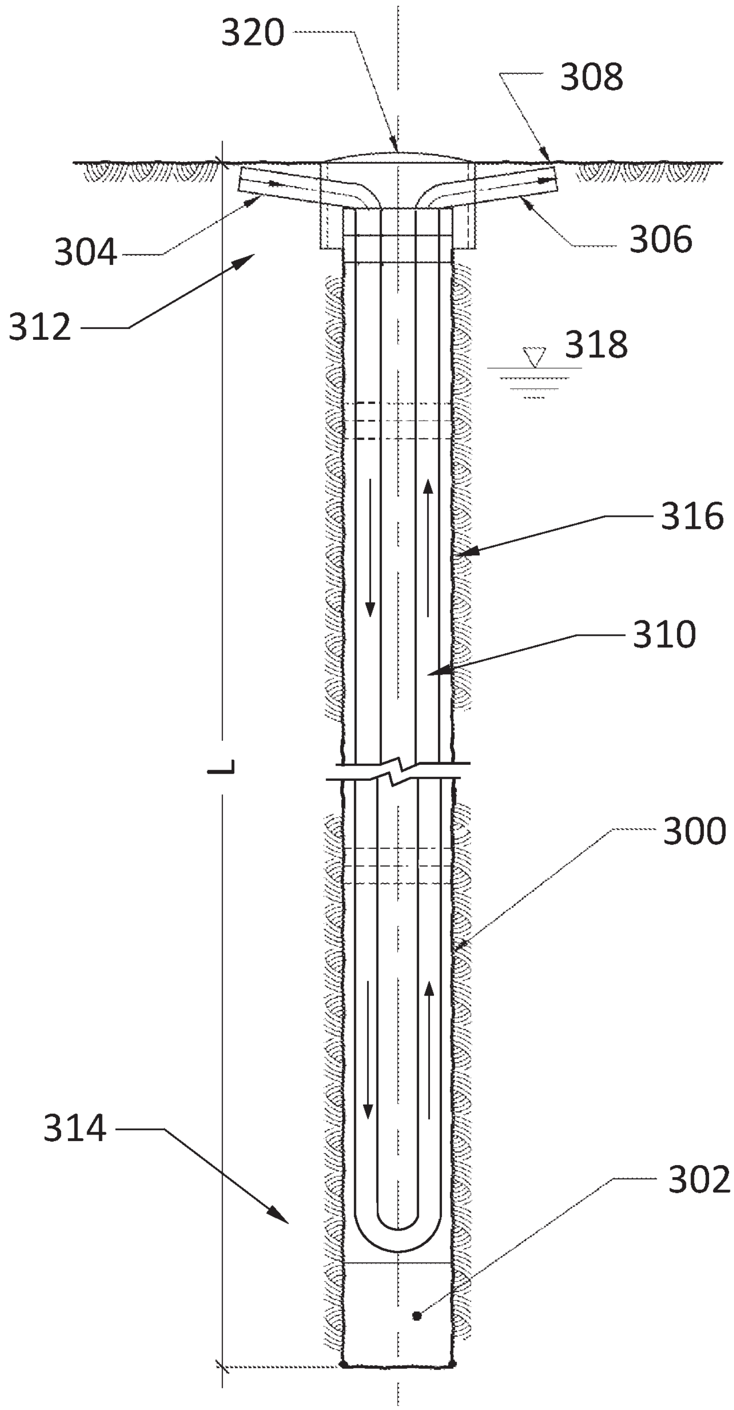


FIG. 3

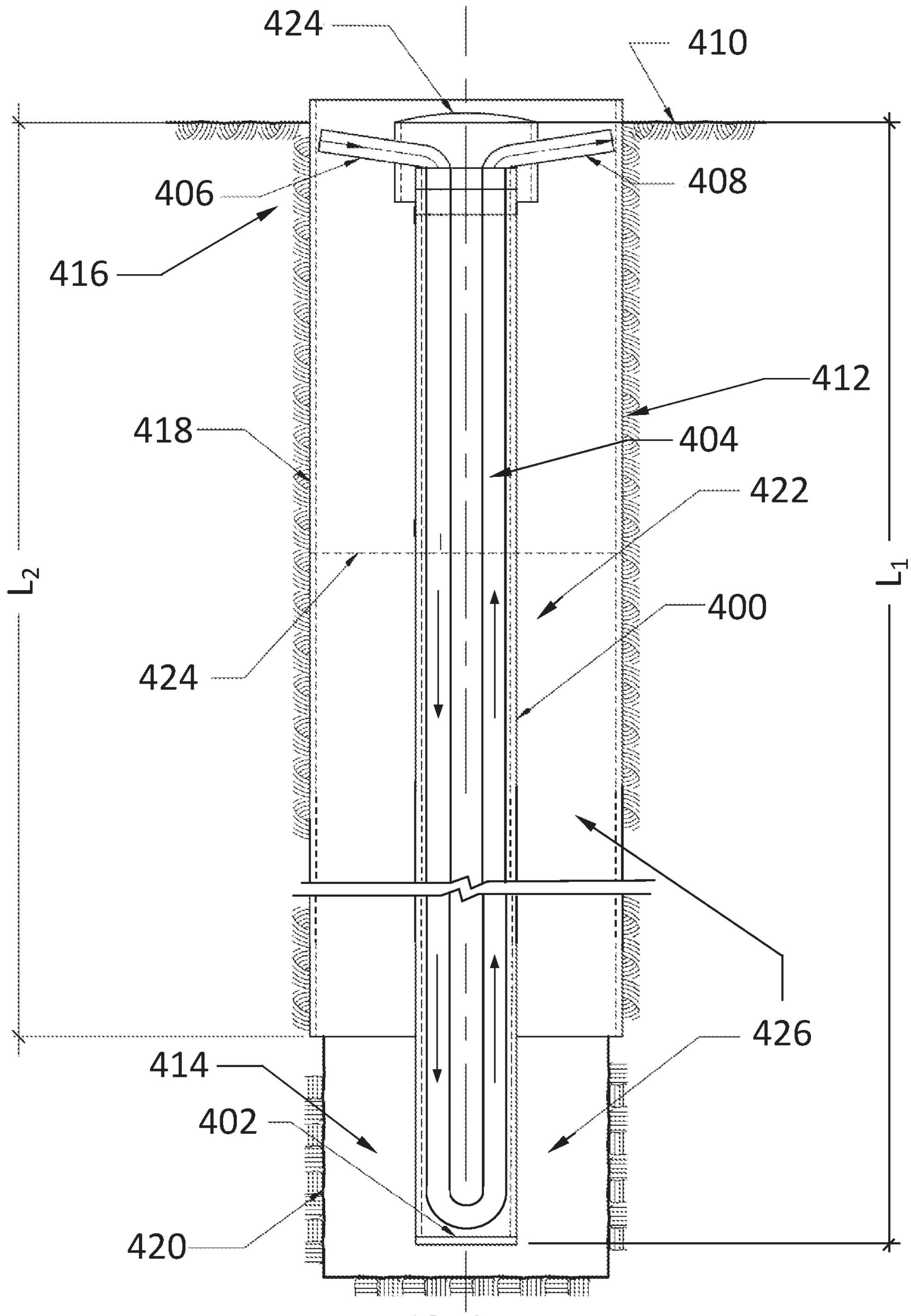


FIG. 4

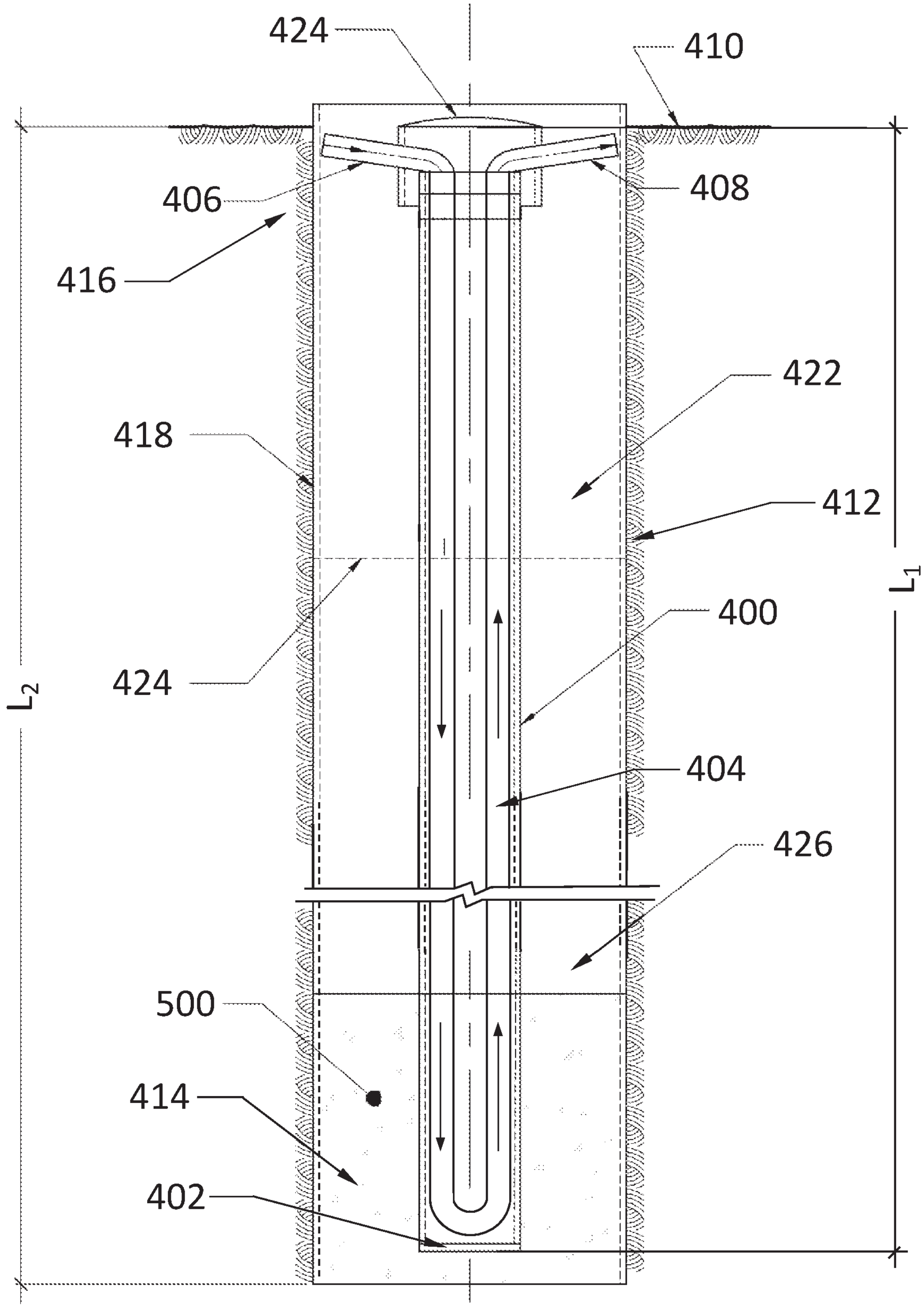


FIG. 5

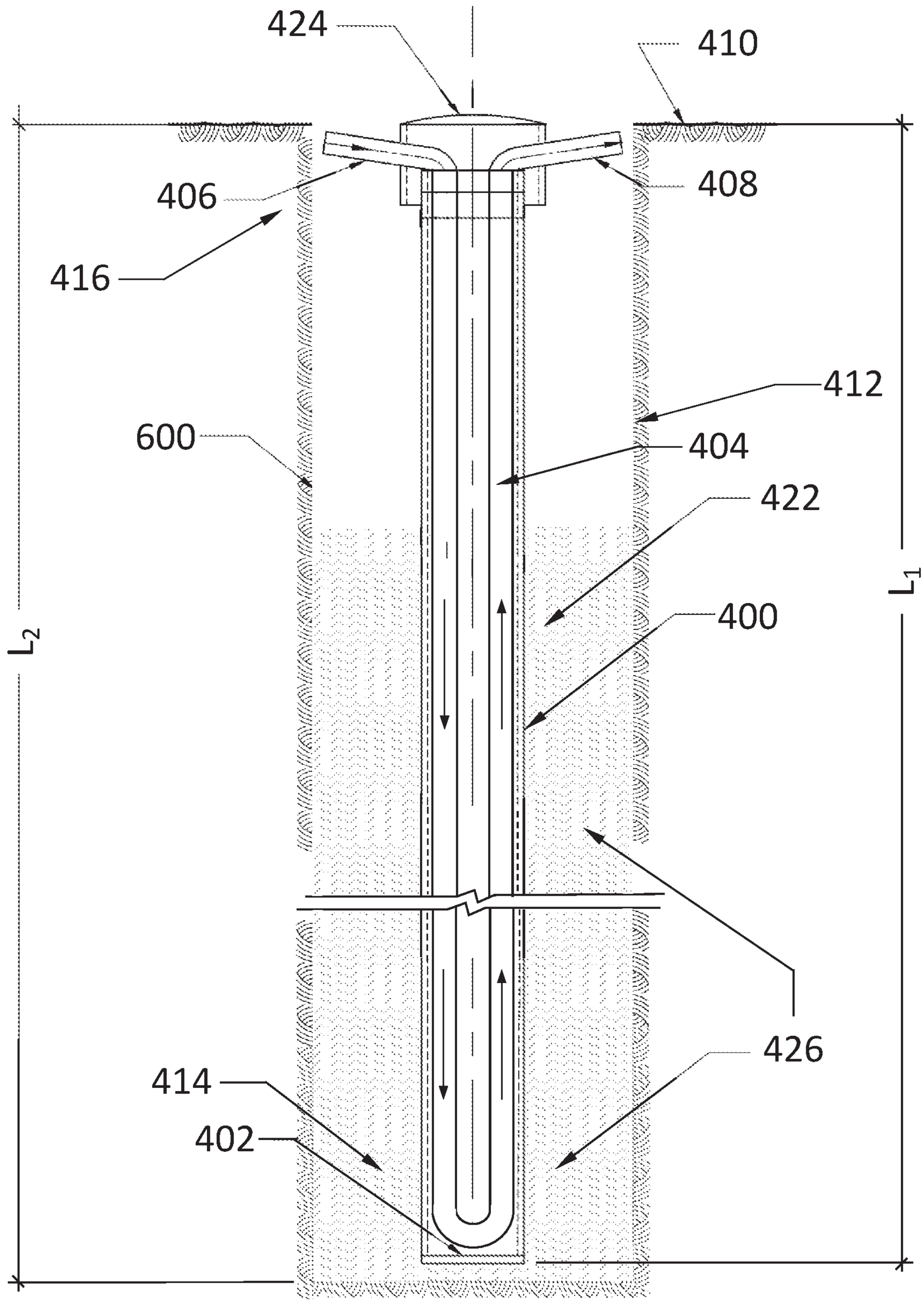


FIG. 6

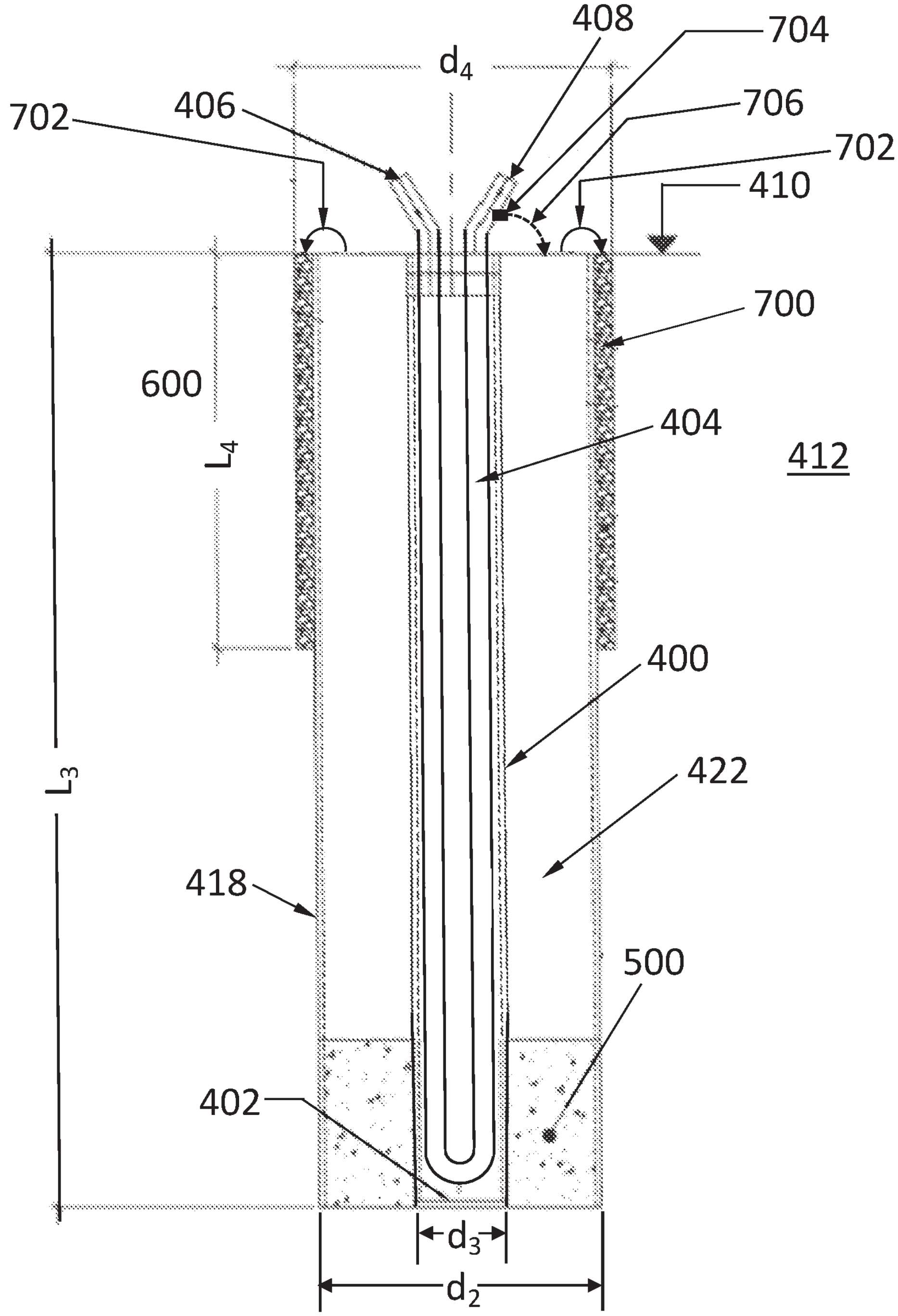

408
704
d4
706
702
406
702
410
700
600
404
L4
412
400
L3
422
418
500
402
d3
d2

FIG. 7

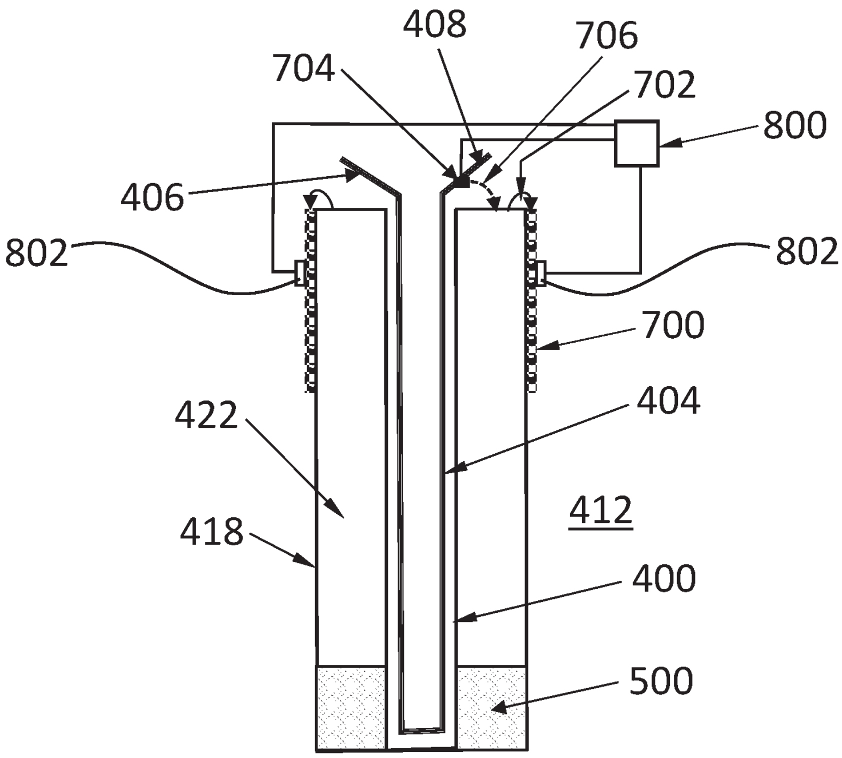


FIG. 8

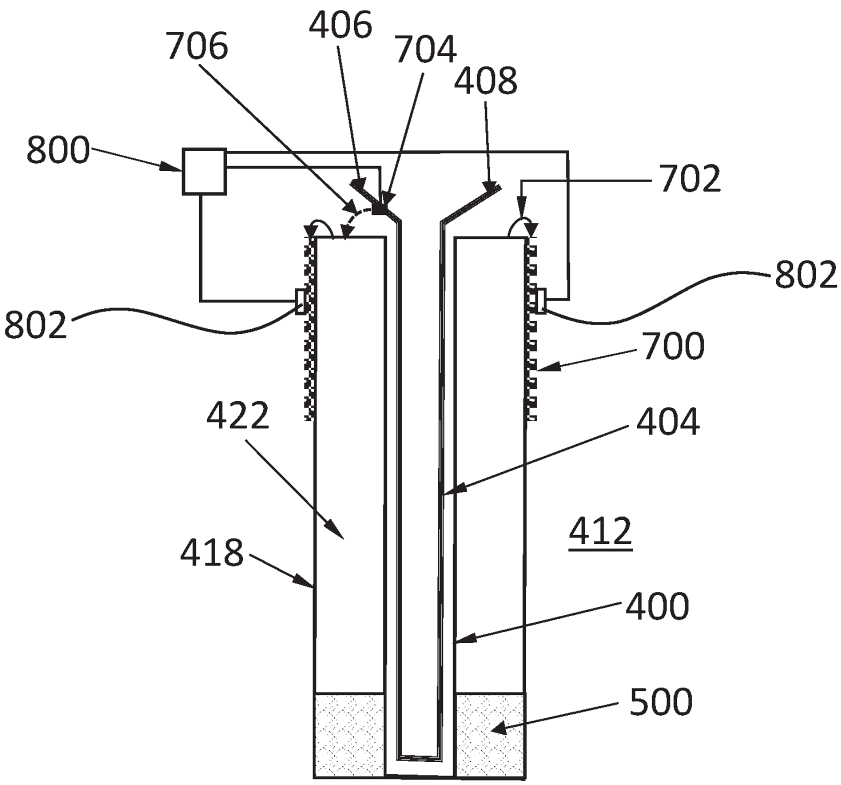


FIG. 9

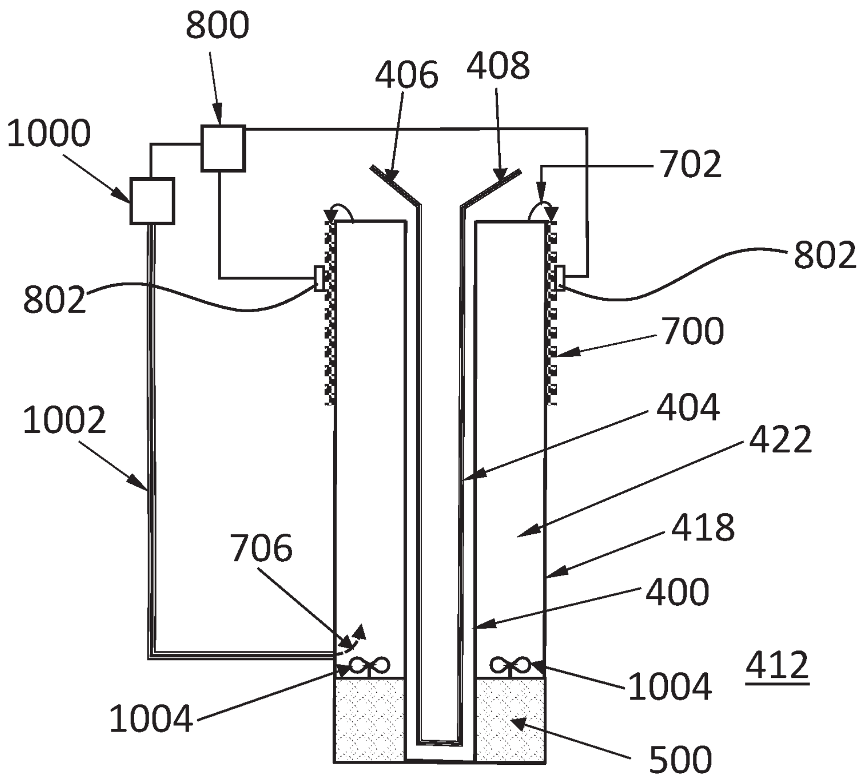

800
406
408
1000
702
802
802
700
404
1002
422
418
706
400
412
1004
1004
500

FIG. 10

GROUND HEAT EXCHANGER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application No. 63/139,026, filed on Jan. 19, 2021 and from Canadian Patent Application No. 3,121,345 filed Jun. 7, 2021 and incorporated herein by reference in their entirety.

FIELD

This disclosure relates to a geothermal system of heat exchange and more particularly to a geothermal pile that is disposed in the ground inside a contained volume of water or another liquid.

BACKGROUND

Geothermal energy is said to be the second most abundant source of heat on Earth. It is the heat energy that is stored in the Earth and contained in rocks and metallic alloys, just below the outer surface of the Earth. The temperature of these rocks and metal alloys is at or near their melting points. Geothermal piles are often used to capture and bring above ground this heat stored below the ground. U.S. Pat. No. 10,655,892 to Kong et al. describes a geothermal heat transfer pipe embedded in a prefabricated pipe pile, sealed by closing the bottom thereof. U.S. Pat. No. 9,611,611 to Klekotka et al. describes the process of driving piles and the installation of piles into the ground for geothermal applications. U.S. Pat. No. 9,708,885 to Loveday et al., entitled System and Method for Extracting Energy, describes ways in which to better couple a pile with the walls of a surrounding borehole by injecting water into an annulus between the pile and the soil, to have the soil form a better thermal coupling with the pile after mixing with the injected water.

Geothermal piles are typically made of concrete or steel, having a wellhead at an upper end and having a U-shaped conduit within the center thereof for carrying a liquid such as water, alcohol, refrigerant, or a combination thereof. Although piles of this type perform a function, their ability to capture heat from the surrounding soil is somewhat limited and depends to some degree on the type of soil in which the pile is installed.

The presence of a groundwater table can facilitate heat transfer to and from the ground because thermal conductivities of water and soil are orders of magnitude higher than that of air. Thus, water-saturated soil is a more efficient medium for heat transfer than dry soil. Furthermore, having a greater surface area in which to collect the heat energy, and a medium to augment the transfer is advantageous.

It would be beneficial to provide an improved geothermal system for extracting heat energy from the ground.

SUMMARY OF EMBODIMENTS

It is well known that energy transfer in a medium such as water has a convective and a conductive component. Although other liquids may be used, in at least some embodiments described hereinafter water is selected as a suitable medium to transfer heat from the ground to a geothermal pile rather than directly coupling the geothermal pile to the surrounding ground. Water has the significant advantage of being present in the environment under natural conditions and does not cause any environmental concerns.

As such, using water as an intermediary coupling medium offers numerous advantages—it is abundant, safe in the instance of a leak in the vessel, and it has adequate conductive properties.

An embodiment includes an in-ground vessel containing a liquid such as water, which forms an artificial water table, for collecting heat from the surrounding ground. A geothermal pipe or pile is disposed generally coaxially within the vessel for collecting heat from the ground-heated water contained within the vessel. The vessel containing the geothermal pipe or pile may have crushed gravel or another solid medium disposed therein to assist in securing the geothermal pipe or pile. In some embodiments the in-ground vessel is a steel pipe or tube having a closed bottom end. Alternatively, the steel pipe or tube of the in-ground vessel has an open bottom end that butts up against an impermeable ground layer, such as a rock layer, or is set in a concrete plug that serves to seal and anchor the bottom end of the pipe or tube. Further alternatively, the in-ground vessel is fabricated from another suitable material such as for instance concrete or plastic, etc.

In some embodiments, a geothermal system includes a pipe or pile disposed substantially coaxially within a vessel located at a depth within the ground, the pipe or pile containing a conduit for transporting a liquid from an inlet port to an outlet port through at least a portion of the pipe or pile in two directions (i.e., initially downward and then back upward). The vessel contains a liquid such as water in a region around the outside of the pipe or pile so that the liquid surrounds and contacts the pipe or pile. The outer surface area of the vessel is significantly greater than the outer surface area of the pipe or pile at same height, by virtue of having a larger diameter, and therefore contacts a larger area of the surrounding ground for extracting energy therefrom than would be the case if the pipe or pile was in direct contact with the surrounding ground.

In areas with dry or otherwise poor soil conditions a fill material may be added around the vessel and the water contained within the vessel may be controlled to overflow into the surrounding material to thereby create a region of improved thermal conductivity between the surrounding ground material and the sidewall of the vessel. The overflow of water may be a continuous flow, or the overflow of water may be actively controlled to maintain a desired moisture condition within the fill material.

A method for installing a geothermal system according to an embodiment may include boring a hole in the ground having depth of at least 25 feet (i.e., up to at least 50 feet or more) and having a first diameter d_1 of at least 40 inches (i.e., generally at least in the range 36-60 inches in diameter or more). An outer vessel is positioned of formed in the bored hole and having a second diameter d_2 conforming to the first diameter d_1 of the bore hole (i.e., a steel pipe or tube is inserted into the bore hole or concrete is poured to form a tube-shaped concrete vessel within the bore hole). A bottom end of the vessel is either sealed prior to being inserted into the bore hole or is arranged adjacent to a naturally or artificially occurring impermeable layer at the bottom end of the bore hole (i.e., abuts an impermeable rock layer or is set into a poured concrete plug). The vessel forms a container suitable for containing a heat conducting first liquid, such as for instance water. A geothermal pile is then arranged within the vessel, having third diameter d_3 smaller than the second diameter d_2. A region between the geothermal pile and inner wall of the vessel is filled with the heat conducting first liquid to a height so that at least a bottom portion of the geothermal pile is surrounded with the heat conducting first liquid. The geothermal pile has a conduit disposed therein for circulating a heat conducting second liquid into and out of the geothermal pile, the heat conducting first liquid being isolated from the heat conducting second liquid. In operation, heat is transferred between the ground surrounding the vessel and the heat conducting first liquid, and then subsequently between the heat conducting first liquid and the heat conducting second liquid through conduction.

In some embodiments, an upper portion of the borehole is formed with a diameter that is larger than the diameter d_1, and a layer of a fill material such as for instance sand and/or gravel is packed between the sidewall of the vessel and the surrounding ground material.

In accordance with an aspect of at least one embodiment, there is provided a geothermal system for extracting heat energy from the ground, comprising: an outer vessel having a diameter d_2, the outer vessel disposed within the ground and having a sidewall with an outer surface that is in contact with surrounding ground material when the geothermal system is in an installed condition, and the outer vessel having an inner surface defining an interior volume of the outer vessel; a geothermal pile having a diameter d_3 that is less than d_2 and being disposed within the interior volume when the geothermal system is in the installed condition; and a first heat conducting liquid at least partially filling a space that is defined between the inner surface of the sidewall of the outer vessel and an outer surface of the geothermal pile when the geothermal system is in the installed condition, wherein the geothermal pile comprises a conduit contained within an interior space thereof for conducting a second heat conducting liquid into the geothermal pile at a top end thereof and along a flow path within the geothermal pile toward a bottom end of the geothermal pile and then back to an outlet at the top end thereof, and wherein during operation heat is transferred from the surrounding ground to the second heat conducting liquid via the first heat conducting liquid within the that is defined space between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile.

In accordance with an aspect of at least one embodiment, there is provided a method of constructing a heat exchange system in the ground, comprising: providing a borehole in the ground having a first diameter d_1; providing an outer vessel, having a diameter d_2 less or equal to d_1, within the borehole; arranging a geothermal pile having an internal conduit extending along a length thereof within the outer vessel; at least partially filling a space between an inner sidewall surface of the outer vessel and an outer surface of the geothermal pile with a first heat conducting liquid; and coupling an inlet port and an outlet port of the conduit to a liquid circuit for a second heat conducting liquid.

In accordance with an aspect of at least one embodiment, there is provided a geothermal system for extracting heat energy from the ground, comprising: an outer vessel having a diameter d_2, the outer vessel disposed within the ground when in an installed condition and having a sidewall with an outer surface and with an inner surface, the inner surface defining an interior volume of the outer vessel; a geothermal pile having a diameter d_3 that is less than d_2 and being disposed within the interior volume when the geothermal system is in the installed condition; a volume of water filling a space between the inner surface of the sidewall of the outer vessel and an outer surface of the geothermal pile when the geothermal system is in the installed condition; a fill material packed around the outer surface of the outer vessel and extending to a depth L_4 below an open upper top of the outer

vessel; and means for adding water to the volume of water such that, during use, a flow of water overflows the open upper top of the outer vessel and enters into the fill material; wherein the volume of water is a first heat conducting liquid and the geothermal pile comprises a conduit contained within an interior space thereof for conducting a second heat conducting liquid into the geothermal pile at a top end thereof and along a flow path within the geothermal pile toward a bottom end of the geothermal pile and then back to an outlet at the top end thereof, and wherein during operation heat is transferred from the surrounding ground to the sidewall of the outer vessel via the fill material.

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments will be described in accordance with the drawings, which are not drawn to scale, and in which:

FIG. **1** is a simplified diagram of a prior art closed end geothermal heat exchange pile.

FIG. **2** is a simplified diagram of a prior art closed end geothermal heat exchange pile with helical flights.

FIG. **3** is a simplified diagram of a prior art geothermal heat exchange pile having a grout sealed closed end.

FIG. **4** is a simplified diagram of a co-axial geothermal heat exchanger in accordance with an embodiment.

FIG. **5** is a simplified diagram of another co-axial geothermal heat exchanger in accordance with an embodiment.

FIG. **6** is a simplified diagram of a geothermal heat exchanger in accordance with an embodiment.

FIG. **7** is a simplified diagram of a geothermal heat exchanger in accordance with an embodiment.

FIG. **8** is a simplified diagram of a geothermal heat exchanger system including a controller and sensors in accordance with an embodiment.

FIG. **9** is a simplified diagram of a geothermal heat exchanger system including a controller and sensors in accordance with an embodiment.

FIG. **10** is a simplified diagram of a geothermal heat exchanger system including a controller and sensors in accordance with an embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

While the present teachings are described in conjunction with various embodiments and examples, it is not intended that the present teachings be limited to such embodiments. On the contrary, the present teachings encompass various alternatives and equivalents, as will be appreciated by those of skill in the art. All statements herein reciting principles, aspects, and embodiments of this disclosure, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

FIG. **1** is a simplified diagram showing a construction pile **100** adapted for use as a geothermal pile. The pile **100** has a closed end, e.g., a 25 mm base plate **102** is welded to the cylindrical sidewall of the pile **100**. The pile **100** has a length L and is driven into the ground in known fashion. For instance, the length of the pile **100** is a standard 50 ft. length. Alternatively, the pile **100** may be any suitable length required for a specific application.

Pile **100** is adapted to have an inlet port **104** and an outlet port **106** approximately at or above grade **108**. A continuous conduit **110** is disposed within the pile **100**, which extends longitudinally from a top end **112** to near the bottom end **114** along a substantial portion of the length L of the geothermal energy pile **100**. The conduit **110** may be coiled or U-shaped (as shown in FIG. **1**) and provides a path (indicated by the arrows within the conduit **110**) for liquid to flow from the top end **112** to the bottom end **114** of the pile **100** and then back up to the top end **114** and out through the outlet port **106**. As the liquid moves along the path through the conduit **110** in the pile **100**, heat is transferred into or out of the liquid from outside the conduit **110**. In heating applications, this heat is collected from the surrounding ground **116**, which has a high water table **118** as shown in FIG. **1**. An access cover **120** optionally is provided to allow access for servicing, etc.

FIG. **2** is a simplified diagram showing a helical construction pile **200** adapted for use as a geothermal pile. The pile **200** has a set of helical flights **202**, which are used to advance the pile **200** into the ground when the pile **200** is rotated about its longitudinal axis. The pile **200** has an angled, closed bottom-end, e.g., a 25 mm base plate **204** is welded to the cylindrical sidewalls of the pile **200**. The pile **200** has a length L and is screwed into the ground in known fashion. For instance, the length of the pile **200** is a standard 50 ft. length. Alternatively, the pile **200** may be any suitable length required for a specific application.

Pile **200** is adapted to have an inlet port **206** and an outlet port **208** approximately at or above grade **210**. A continuous conduit **212** is disposed within the pile **200**, which extends longitudinally from a top end **214** to near the bottom end **216** along a substantial portion of the length L of the geothermal energy pile **200**. The conduit **212** may be coiled or U-shaped (as shown in FIG. **2**) and provides a path (indicated by the arrows within the conduit **212**) for liquid to flow from the top end **214** to the bottom end **216** of the pile **200** and then back up to the top end **214** and out through the outlet port **208**. As the liquid moves along the path through the conduit **212** in the pile **200**, heat is transferred into or out of the liquid from outside the conduit **212**. In heating applications, this heat is collected from the surrounding ground **218**, which has a high water table **220** as shown in FIG. **2**. An access cover **222** optionally is provided to allow access for servicing, etc.

FIG. **3** is a simplified diagram showing a construction pile **300** adapted for use as a geothermal pile. The pile **300** has a non-shrink grout seal **302** closing a bottom end thereof. The pile **300** has a length L, for instance a standard 50 ft. length. Alternatively, the pile **300** may be any suitable length required for a specific application.

Pile **300** is adapted to have an inlet port **304** and an outlet port **306** approximately at or above grade **308**. A continuous conduit **310** is disposed within the pile **300**, which extends longitudinally from a top end **312** to near the bottom end **314** along a substantial portion of the length L of the geothermal energy pile **300**. The conduit **310** may be coiled or U-shaped (as shown in FIG. **2**) and provides a path (indicated by the arrows within the conduit **310**) for liquid to flow from the top end **312** to the bottom end **314** of the pile **300** and then back up to the top end **312** and out through the outlet port **306**. As the liquid moves along the path through the conduit **310** in the pile **300**, heat is transferred into or out of the liquid from outside the conduit **300**. In heating applications, this heat is collected from the surrounding ground **316**, which has a high water table **318** as shown in FIG. **3**. An access cover **320** optionally is provided to allow access for servicing, etc.

Referring now to FIG. **4**, a geothermal pile **400** has a closed end, e.g., a 19 mm end cap **402** is welded to the

cylindrical sidewalls of the pile **400**. Other means for closing the end of the geothermal pile **400** may be used. The geothermal pile **400** has a circular cross-section of e.g., diameter d_3 about 8 inches, but optionally the diameter d_3 may be greater than or less than 8 inches depending upon specific requirements. A conduit **404**, having an inlet port **406** and an outlet port **408** both disposed approximately at or above grade **410**, is arranged within the geothermal pile **400**. The conduit **404** extends along a substantial portion of a length L_1 of the geothermal pile. The length L_1 may be any suitable length depending on specific requirements, for instance between about 25 feet and 50 feet. Alternatively, the length L_1 is less than 25 feet or greater than 50 feet, depending on specific requirements. The conduit **404** is preferably fabricated from a heat conducting material such as for instance copper, although plastic tubing or other suitable materials may be used with less effectiveness in transferring heat to or from a liquid within the conduit **404**.

The description which follows refers to the capturing of heat from the ground **412** to the liquid within the conduit **404**, however it should be understood that the reverse may occur if the ground **412** is cooler than the liquid flowing into the conduit **404** via the inlet port **406**. Depending on the temperature difference, the geothermal system shown in FIG. **4** may be used for heating or cooling.

Geothermal energy pile **400** is shown disposed within and being substantially co-axial with a larger energy transfer pile **418**, which is also referred to herein as an outer vessel, having circular cross-section with a diameter d_2 of e.g., 24 inches and a length L_2. The energy transfer pile **418** may have a closed bottom end (not shown in FIG. **4**), or alternatively the energy transfer pile **418** may butt up against an impermeable subsurface layer, such as for instance a rock layer **420**. The energy transfer pile **418** is shown to have a diameter d_2 approximately three times greater than the diameter d_3 of the energy pile **400**, and the length L_2 in this example is less than the length L_1. Of course, other pile sizes may be used, such as for instance a pile **400** having a 16-inch diameter d_3 and a pile **418** having a 48-inch diameter d_2, etc. In addition, the lengths L_1 and L_2 may be substantially equal, or L_2 may be greater than L_1 etc. In general, both L_1 and L_2 are typically in the range of 25 feet to 50 feet, but lengths less than 25 feet or greater than 50 feet may be used depending on specific requirements.

A liquid, such as for instance water, is contained within an annular space **422** that is formed between an outer wall surface of the pile **400** and an inner wall surface of the energy transfer pile **418**. The liquid preferably fills the annular space **422** to a height H that is sufficient to cover less than 75% of the length L_1 of the pile **400**, however the liquid may fill the annular space **422** above this level and may even overflow the top of the energy transfer pile **418** into the surrounding ground **412**. Thus, pile **418** acts as an outer vessel containing water and also contains the geothermal pile **400** in a generally central region thereof. The pile **418** is made of any suitable material, such as for instance sections of steel pipe or tube that are joined together along joints **424** (such as for instance by welding) and having a predetermined thickness selected to provide a required strength and longevity to withstand forces upon it. As will be apparent, the larger diameter pile **418** has a much greater outer surface area than the outer surface area of the centrally disposed geothermal pile **400**. Since the surface area of a pile having a circular cross section is given by $\pi r^2 h$, the larger surface area of pile **418** is capable of collecting a significantly greater amount of energy from the soil **412** that is directly adjacent to it, compared to the amount of energy that could be collected by the smaller diameter pile **400** in the absence of the larger pile **418**, due to the squared term r^2. For instance, a geothermal pile having a height of 10 feet and a radius of 1 foot has a surface area of 10 π contacting the surrounding ground but a geothermal pile having the same height of 10 feet and a radius of 4 feet has a surface area of 160 π contacting the surrounding ground. The water contained within the annular region **422** between the pile **418** and the geothermal pile **400**, which may be referred to as an artificial water table, is in contact with the large surface area (steel) wall of the pile **418**, and absorbs the ground heat from the soil **412** adjacent to the outer wall of the pile **418**. The heat that is absorbed by the contained water is transferred, though conduction and convection, to the inner geothermal pile **400**. The speed at which heat transfers by conduction and convection is considerably greater than the speed of heat transfer by conduction alone, and accordingly the efficiency of heat transfer between the surrounding ground and the inner geothermal pile **400** is improved in the system that is shown in FIG. **4**.

As shown in FIG. **4**, a material such as for instance one or more of sand, gravel or another solid medium may be placed within the annular space **422** between the geothermal pile **400** and the pile **418**, to assist in securing the geothermal pile **400**. In this embodiment, the liquid and the sand, gravel or other solid medium transfer the heat from the surrounding ground **412** to the conduit **404** within the geothermal pile **400**. An access cover **424** optionally is provided to allow access for servicing, etc.

Referring now to FIG. **5**, shown is an alternative embodiment similar to the embodiment of FIG. **4**, except a concrete plug **500** is formed at the bottom end of the outer vessel **418** and the bottom end of the geothermal pile **400** is embedded in the concrete plug **500**. The concrete plug **500** effectively seals the bottom of the outer vessel **418** to facilitate containing the first heat conducting liquid therein.

Various alternative and/or optional embodiments in addition to those described with reference to FIGS. **4** and **5** may be envisaged. Some important variations are discussed in the following paragraphs, which apply equally to the embodiments shown in FIGS. **4** and **5**.

In a not illustrated embodiment, an upper portion of the conduit **404** is insulated or double jacketed so that ground-heat that is collected at the lower portion of the pile **400** is not lost when the liquid in the conduit **404** travel upward toward the outlet port **408**.

In a further not illustrated embodiment, the conduit **404** is made of a first length of a highly conductive material at its bottom end, which is the end closest to where the bottom end **414** of the pile **400** is located within the borehole, and is made of a second length of an insulating material at its top end, which is the end closest to where the top end **416** of the pile **400** is located within the borehole. In this way, the heat that is collected by the liquid at the bottom end of the conduit **404** is not lost along the return path toward the outlet port **408**.

In another not illustrated embodiment, a circulating pump is provided to increase the turbulence and hence enhance the convective effect and speed of energy transfer through the water that is contained within the annular space **422** between the pile **418** and the pile **400**.

In yet another not illustrated embodiment, a small rotating hub with radiating blades (i.e., an impeller) is disposed within the water near the bottom of the pile **418** to provide additional circulation and increase turbulence, so as to increase the rate of heat transfer.

In yet another not illustrated embodiment, the larger diameter energy transfer pile **418** may be significantly shorter in length that the geothermal cell or pile **400** placed therewithin. What is important is that the larger pile **418** or outer vessel be located at a depth in the ground where the most energy transfer will take place.

One or more of the various embodiments described above may further include a means to ensure that the outer vessel **418** contains a suitable amount of water. A simple sump pump (not shown) can be provided, which fills the outer vessel **418** if the amount of water therewithin is less than a predetermined amount.

In a not illustrated embodiment the water fills the space **422** between the inner surface of the sidewall of the outer vessel **418** and the outer surface of the geothermal pile **400** only to a height that is sufficient to cover less than ¾ of the length L_1 of the geothermal pile **400**. What is important is that the water covers the geothermal pile at a depth in the ground where the most energy transfer will take place. In other embodiments the water may fill the space **422** between the inner surface of the sidewall of the outer vessel **418** and the outer surface of the geothermal pile **400** to a height that is sufficient to cover more than ¾ of the length L_1 of the geothermal pile **400**. In some embodiments, the water may cover the entire length L_1 of the geothermal pile **400** and may even overflow the space **422** into the surrounding ground material **412**.

In another embodiment, a flow control valve can be added to the bottom of the larger outer vessel **418** to allow pumped in water to flow into the outer vessel **418** slowly and/or in a controlled manner and/or to overflow over the annulus **422** to the surrounding soil **412** so as to have a better thermal contact between the surrounding soil **412** and the outer vessel **418**. This flow preferably adds turbulence to the water within the outer vessel **418** in the anulus **422** which is advantages for convective heat transfer between the surrounding soil and the geothermal pile. This, and other related embodiments, is described in more detail below, with reference to FIGS. **7** to **10**.

Referring now to FIG. **7**, a geothermal pile **400** has a closed end, e.g., a 19 mm end cap **402** is welded to the cylindrical sidewalls of the pile **400**. Other means for closing the end of the geothermal pile **400** may be used. The geothermal pile **400** may have a circular cross-section of e.g., diameter d_3 about 16 inches, but optionally the diameter d_3 may be greater than or less than 16 inches depending upon specific requirements. A conduit **404**, having an inlet port **406** and an outlet port **408**, both disposed approximately at or above grade **410**, is arranged within the geothermal pile **400**. The conduit **404** extends along a substantial portion of a length L_3 of the geothermal pile. The length L_3 may be any suitable length depending on specific requirements, for instance between about 25 feet and about 50 feet. Alternatively, the length L_3 is less than 25 feet or greater than 50 feet, depending on specific requirements. The conduit **404** is preferably fabricated from a heat conducting material such as for instance copper, although plastic tubing or other suitable materials may be used with less effectiveness in transferring heat to or from a liquid within the conduit **404**.

The description which follows refers to the capturing of heat from the ground **412** to the liquid within the conduit **404**, however the reverse may occur if the ground **412** is cooler than the liquid flowing into the conduit **404** via the inlet port **406**. Depending on the temperature difference, the geothermal system shown in FIG. **7** may be used for heating or cooling.

Geothermal energy pile **400** is shown disposed within and being substantially co-axial with a larger energy transfer pile **418**, also referred to herein as an outer vessel, having a circular cross-section with a diameter d_2 of e.g., 48 inches. A concrete plug **500** is formed at the bottom end of the outer vessel **418** and the bottom end of the geothermal pile **400** is embedded in the concrete plug **500**. The concrete plug **500** effectively seals the bottom of the outer vessel **418** to facilitate containing a first heat conducting liquid therein. Alternatively, the energy transfer pile **418** may have a closed bottom end (not shown in FIG. **7**), or the energy transfer pile **418** may butt up against an impermeable subsurface layer, such as for instance a rock layer (not shown in FIG. **7**).

A liquid, also referred to as the first heat conducting liquid, is contained within an annular space **422** that is formed between an outer wall surface of the pile **400** and an inner wall surface of the energy transfer pile **418**. In the instant embodiment, the liquid is water. The liquid preferably completely fills the annular space **422** and overflows the top of the energy transfer pile **418** into a fill material **700** that surrounds the outer vessel **418**. As shown in FIG. **7**, the fill material **700** is disposed between an outer wall of the outer vessel **418** and the surrounding ground **412**. In the example that is shown in FIG. **7**, the fill material forms a ring around the outer wall of the outer vessel **418**. The ring of fill material **700** may have an outer diameter d_4 of approximately 52 inches, thereby providing a layer of the fill material **700** having an approximately uniform thickness of about 2 inches. Of course, the thickness of the ring of fill material **700** may be greater than or less than 2 inches depending on specific requirements. The fill material **700** extends approximately from the existing grade **410** to a depth L_4, such as for instance about 10 feet. Of course, the fill material **700** may extend to a greater or lesser depth below the existing grade **410** depending on specific requirements. The fill material is for instance an aggregate material that includes sand, gravel, or a combination thereof, such that water entering the top of the fill material percolates downward therethrough under the influence of gravity.

The energy transfer pile **418** acts as an outer vessel containing the water, and also contains the geothermal pile **400** in a generally central region thereof. The energy transfer pile **418** is made of any suitable material, such as for instance sections of steel pipe or tube that are joined together along joints (such as for instance by welding) and having a predetermined thickness selected to provide a required strength and longevity to withstand forces acting upon it. The top end of the energy transfer pile **418** is open. In this context, the term "open" is intended to mean that water can escape from the annular space **422** into the fill material **700**. An open-top energy transfer pile **418** may be uncovered, in which case water simply flows over the rim at the top end of the pile **418** (as shown e.g., in FIG. **7**), or the top end may be covered, and slots or perforations may be formed in the sidewall of the pile **418** proximate the covered top end to allow water to flow out. In either case, what is important is that the water level within the annular space **422** is close to or level with the top of the pile **418** and there is a route for the contained water to escape into the surrounding fill material **700** substantially continuously around the circumference of the pile **418**.

As will be apparent, the larger diameter pile **418** has a much greater outer surface area than the outer surface area of the centrally disposed geothermal pile **400**. Since the surface area of a pile having a circular cross section is given by $\pi r^2 h$, the larger surface area of pile **418** can collect a significantly greater amount of energy from the surrounding ground **412**, compared to the amount of energy that could be collected by the smaller diameter pile **400** in the absence of the larger pile **418**, due to the squared term r^2. For instance, a geothermal pile having a height of 10 feet and a radius of 1 foot has a surface area of 10 π contacting the surrounding ground but a geothermal pile having the same height of 10 feet and a radius of 4 feet has a surface area of 160 π contacting the surrounding ground. The water contained within the annular region **422** between the pile **418** and the geothermal pile **400**, which may be referred to as an artificial water table, is in contact with the large surface area (steel) wall of the pile **418**, and absorbs the ground heat from the soil **412**. The heat that is absorbed by the contained water is transferred, though conduction and convection, to the inner geothermal pile **400**. The speed at which heat transfers by conduction and convection is considerably greater than the speed of heat transfer by conduction alone, and accordingly the efficiency of heat transfer between the surrounding ground **412** and the inner geothermal pile **400** is improved in the system that is shown in FIG. **7**.

To enhance the efficiency of heat transfer between the surrounding ground **412** and the inner geothermal pile **400**, the system as shown in FIG. **7** includes means for overflowing a volume of liquid **702** from the annular space **422** into the fill material **700**. This embodiment is particularly advantageous in areas in which the soil is very dry or is otherwise poorly suited for transferring heat to the geothermal pile **400** within the outer vessel **418**. For instance, the overflowed liquid, typically water, percolates downward through the fill material, which may include sand and/or gravel, and thereby increases the thermal conductivity adjacent to the sidewall of the outer vessel **418** and increases the efficiency of heat transfer.

In the example that is shown in FIG. **7**, a valve **704** is provided in the outlet line **408**. When water is used as the fluid that is pumped through the conduit **404**, a small amount may be bled out through the valve **704** (shown using a dashed line) into the annular space **422**. Using the overflowed liquid **702** (i.e., water) to keep the fill material **700** damp increases the thermal transfer capacity of the fill material **700** compared to the dry fill material. Preferably, the valve **704** is adjustable to allow the amount of water **706** that is added from the outlet line **408** into the annular space **422** to be controllably varied. In this way, the amount of overflowed water **702** can be controlled to suit different soil types, etc. The valve **704** may be adjustable in a manual and/or automatic fashion. In one aspect, the valve **704** may be adjusted manually based on visual and/or other observations of the condition of the fill material **700**. For instance, if the fill material **700** appears to be dry then the valve **704** may be opened wider to increase the flow of water **706** into the annular space and thereby cause more water to overflow **702** into the fill material **700**. Alternatively, if the fill material **700** appears to be submerged in water, then the valve **704** may be partially or fully closed. In another aspect, the valve **704** may be adjusted automatically using a suitably configured electronic controller, as discussed in more detail below, either based on a timer or based on feedback from sensors that are arranged around and or within the outer vessel **418**.

Referring now to FIG. **8**, shown is a more simplified illustration of the system of FIG. **7** and further including a control arrangement for varying the flow of water **706** into the annular space **422** via valve **704** in the outlet line **408**. An electronic controller **800** is provided in operative communication with at least one sensor **802**, but in this specific example a plurality of sensors **802** is arranged around the outer vessel **418**. The sensors **802** sense e.g., moisture content of the fill material **700** and provide a signal relating to the sensed moisture content to the controller **800**. The controller **800** actuates the valve **704** in dependence upon the received signals. For instance, when the received signals are indicative of a fill material moisture content that is below a predetermined range the controller **800** opens the valve **704** to increase the flow of water **706** into the annular space **422**, and thereby increase the overflow of fluid **702** into the fill material **700**. After a time, the controller **800** closes either partially or fully the valve **704** in response to received signals that are indicative of a fill material moisture content within the predetermined range.

The system that is shown in FIG. **9** is substantially the same as the system shown in FIG. **8**, except the valve **704** is provided in the inlet line **406**. In this case, the flow of water **706** is bled out through valve **704** into the annular space **422** prior to being heated within the conduit **404**. The system of FIG. **9** is suitable for warmer climate in which ice formation near the grade level is not a major concern, and advantageously does not result in the loss of warmed water. Optionally, a valve **704** is provided in both the inlet line **406** and the outlet line **408** and the controller controls operation of one or both valves **704** depending on other factors including ambient temperature, sensed formation of ice within fill material **700** etc.

Referring now to FIG. **10**, shown is a simplified illustration of another system and a control arrangement for varying the flow of water **706** into the annular space **422** via a source of water **1000** that is external to the conduit **404**. In FIG. **10**, the flow of water **706** is introduced near the bottom of the annular space **422** via a separate conduit **1002**. Optionally, the flow of water **706** is introduced at a different height along the outer vessel **418**. Further optionally, the flow of water **706** is introduced at a plurality of different heights along the outer vessel **418** and/or at different circumferentially spaced locations around the outer vessel **418**. FIG. **10** also shows a small rotating hub with radiating blades (i.e., an impeller **1004**) disposed within the water near the bottom of the outer vessel **418**, which provides additional circulation and increase turbulence, so as to increase the rate of heat transfer. The impeller **1004** or another suitable device may be used in any of the other embodiments that have been described above.

The system that is shown in FIG. **10** functions similar to the systems that have already been described with reference to FIGS. **8** and **9**. The controller **800** is provided in operative communication with at least one sensor, in this specific example a plurality of sensors **802** is arranged around the outer vessel **418**. The sensors **802** sense e.g., moisture content of the fill material **700** and provide a signal relating to the sensed moisture content to the controller **800**. The controller actuates the external source of water **1000**, e.g., opens or closes a valve of the source **1000**, in dependence upon the received signals. For instance, when the received signals are indicative of a fill material moisture content that is below a predetermined range the controller **800** controls the source **1000** to increase the flow of water **706** into the annular space **422**, and thereby increase the overflow of water **702** into the fill material **700**. After a time, the controller **800** controls the source **1000** to provide a reduced flow of water **706**, or now flow, in response to received signals that are indicative of a fill material moisture content within the predetermined range.

Although the embodiments described heretofore have shown the liquid disposed between the inner geothermal cell and the outer pile to be water, other liquids can be used. In addition, although the embodiments described heretofore describe and illustrate providing a borehole, disposing a large diameter pile having a closed end (or an open end butted up against an impermeable layer) in the borehole, placing a geothermal pile within the large diameter pile, and filling the annulus between the two piles with an energy conducting liquid such as water, other embodiments may be envisaged. For example, a geothermal cell, which is not in the form of a pile, but is a conduit which directs a liquid into and out of the geothermal cell, may be disposed in the center of the large diameter pile.

The geothermal heat exchange systems described with reference to FIGS. **4** and **5** may be constructed according to the following method. A bore borehole is formed in the ground having a first diameter d_1. Known techniques, appropriate for the ground type within which the installation is occurring may be used to form the borehole. An outer vessel, having a diameter d_2 that is less than or substantially equal to d_1, is inserted into the borehole. The outer vessel may be formed using a single length of pipe or tubing formed of a suitable metal or metal alloy, or by arranging a series of shorter lengths of pipe or tubing in a stacked arrangement with joints (sealed or unsealed) between adjacent lengths, or by pouring a concrete liner having a generally circular cross section with an internal diameter d_2. A geothermal pile having an internal conduit extending along a length thereof is arranged generally centrally and coaxially within the outer vessel. The diameter d_3 of the geothermal pile is less than d_2, preferably d_3 is about ⅓ d_2. The generally annular space between an inner sidewall surface of the outer vessel and an outer surface of the geothermal pile is at least partially filled with a first heat conducting liquid, such as for instance water. An inlet port and an outlet port of the conduit within the geothermal pile is connected to a liquid circuit for a second heat conducting liquid. The liquid circuit e.g., collects the heated second heat conducting liquid from a plurality of geothermal piles, and provides the heated liquid to one or more points of use, such as for instance a building heating system.

In the case of the geothermal heat exchange systems described with reference to FIGS. **7** to **10**, the construction method is substantially similar however the borehole is formed with the enlarged diameter d_4 to the depth L_4, and the fill material **700** is added after the outer vessel **418** is in place. The additional control/sensor arrangements and/or conduit for the external water supply are installed at appropriate and convenient points of the construction, with final connections and fittings preferably being made after placement of the fill material **700** and not-illustrated external infrastructure, if any, has been completed. Although not shown explicitly in FIGS. **7** to **10**, the space between the inner wall of the outer vessel **418** and the outer surface of the geothermal pile **400** may be partially filled with sand and/or gravel, as discussed below e.g., with reference to FIG. **6**.

Referring now to FIG. **6**, shown is a geothermal heat exchanger similar to the ones that are shown in FIGS. **4** and **5**, but without a separate outer vessel for containing a volume of water. The configuration that is shown in FIG. **6** may be employed e.g., when the ground material **412** is stable and substantially impermeable to water, such that the inner wall **600** of the bore hole in the ground performs the roll of containing the volume of water. For instance, the bore hole may be formed into ground material **412** such as clay or rock, etc. to a depth L_2, and geothermal pile **400** having length $L_1<L_2$ may be arranged substantially centrally within the borehole. A material **426** such as for instance sand and/or gravel or another suitable material may be added into the

annular space **422** between the inner wall **600** and the outer surface of the geothermal pile **400**, to a height that is sufficient to cover at least the lower portion of the geothermal pile **400** so as to secure the geothermal pile **400** in its desired position within the borehole. The generally annular space **422** is also at least partially filled with a first heat conducting liquid, such as for instance water. An inlet port and an outlet port of the conduit within the geothermal pile **400** is connected to a liquid circuit for a second heat conducting liquid. The liquid circuit e.g., collects the heated second heat conducting liquid from a plurality of geothermal piles **400**, and provides the heated liquid to one or more points of use, such as for instance a building heating system.

In the specific embodiments that are described above with reference to FIGS. **4-10**, the diameter d_2 of the outer vessel **418** is approximately 3 times the diameter d_3 of the geothermal pile **400**. In this way, the annular space **422** between the inner surface of the sidewall of the outer vessel **418** and the outer surface of the geothermal pile **400** has a width that is approximately equal to d_3, which extends circumferentially around between the concentrically arranged piles. In general, the annular space is dimensioned to contain a volume of water that is suitable for transferring heat extracted from the surrounding ground **412** to the geothermal pile, and the width of the annular space **422** may be selected to suit the requirements for different sites. Preferably, d_2 is at least 1.5 times d_3, or d_2 is at least 2 times d_3, or d_2 is at least 3 times d_3 as shown in the embodiments disclosed herein. Of course, optionally d_2 may be more than 3 times d_3 is the requirements of a particular site necessitate the use of a larger volume of water within the annular space **422**.

Throughout the description and claims of this specification, the words “comprise”, “including”, “having” and “contain” and variations of the words, for example “comprising” and “comprises” etc., mean “including but not limited to”, and are not intended to, and do not exclude other components.

It will be appreciated that variations to the foregoing embodiments of the disclosure can be made while still falling within the scope of the disclosure. Each feature disclosed in this specification, unless stated otherwise, may be replaced by alternative features serving the same, equivalent or similar purpose. Thus, unless stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

All of the features disclosed in this specification may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. In particular, the preferred features of the disclosure are applicable to all aspects of the disclosure and may be used in any combination. Likewise, features described in non-essential combinations may be used separately (not in combination).

What is claimed is:

1. A geothermal system for extracting heat energy from the ground, comprising:

an outer vessel having a diameter d_2, the outer vessel disposed within the ground when in an installed condition and having a sidewall with an outer surface and with an inner surface, the inner surface defining an interior volume of the outer vessel;

a geothermal pile having a diameter d_3 that is less than d_2 and being disposed within the interior volume when the geothermal system is in the installed condition;

a volume of water filling a space between the inner surface of the sidewall of the outer vessel and an outer surface of the geothermal pile when the geothermal system is in the installed condition;

a fill material packed around the outer surface of the outer vessel and extending to a depth L_4 below an open upper top of the outer vessel; and

means for adding water to the volume of water such that, during use, a flow of water overflows the open upper top of the outer vessel and enters into the fill material;

wherein the volume of water is a first heat conducting liquid and the geothermal pile comprises a conduit contained within an interior space thereof for conducting a second heat conducting liquid into the geothermal pile at a top end thereof and along a flow path within the geothermal pile toward a bottom end of the geothermal pile and then back to an outlet at the top end thereof, and wherein during operation heat is transferred from the surrounding ground to the sidewall of the outer vessel via the fill material.

2. The geothermal system of claim **1**, wherein the fill material is an aggregate material comprising at least one of gravel and sand.

3. The geothermal system of claim **2**, wherein the second heat conducting liquid is water and the means for adding water comprises a valve disposed within the conduit.

4. The geothermal system of claim **2**, wherein the second heat conducting liquid is water and the means for adding water comprises a valve disposed within an inlet of the conduit or the outlet of the conduit.

5. The geothermal system of claim **2**, wherein the means for adding water comprises an external source of water that is separate from the second heat conducting liquid within the conduit, and further comprising a valve disposed between the external source of water and the space that is defined between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile.

6. The geothermal system of claim **2**, wherein the means for adding water comprises:

an adjustable valve for controllably varying a rate of addition of the added water into the space that is defined between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile; and

an electronic controller in communication with the adjustable valve, the electronic controller for automatically adjusting the adjustable valve for controllably varying a rate of addition of the added water.

7. The geothermal system of claim **6**, further comprising at least one sensor for sensing a moisture content of the fill material and for providing a signal to the electronic controller relating to the sensed moisture content, wherein the controller is responsive to the provided signal for controllably adjusting the adjustable valve.

8. The geothermal system of claim **2**, wherein the outer vessel extends to a depth L_3 that is between about 25 and about 50 feet below surface grade level, wherein L_4 is at least 10 feet, and wherein the fill material forms an annular layer that is at least 2 inches thick around the outer vessel.

9. The geothermal system of claim **2**, wherein the means for adding water comprises a flow control valve for controlling a pumped flow of water into the space that is defined between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile.

10. The geothermal system of claim **1**, further comprising a circulating pump or an impeller arranged to increase turbulence of the water within the space that is defined between the inner surface of the sidewall of the outer vessel and the outer surface of the geothermal pile.

11. The geothermal system of claim **1**, wherein d_2 is between 1.5 and 3 times d_3.

12. The geothermal system of claim **1**, wherein d_2 is at least 3 times d_3.

* * * * *

An Alternative to Concrete Bathtubs for Developers

THE GTA BATHTUB

Large-scale excavation sites in the GTA region for developments typically use a combination of shoring walls and concrete raft slab solutions to hold soil in place, to prevent the walls from caving in on themselves and to keep groundwater out of the site.

However, this approach does not always work as well as expected, often resulting in significant amounts of groundwater still leaking in between the ties and joints of the shoring walls. This is an important issue since understanding exactly how much groundwater will ultimately enter the site is a very imprecise estimating process that can end up costing owners millions in extra materials, labour, and additional permits if not done correctly.

Adding to the challenge, the City of Toronto has insisted that *"no groundwater should pass through the sanitary tax mechanism"*. Now, when you consider that 90% of Toronto soils are comprised of clay over rock. Allow upper fills to drain is a much better idea.

Many current P4/P5 level buildings are large, costly storing bathtubs. Ultimately, even when done correctly without complications, the bathtub method is extremely financially and environmentally costly.

THE SOLUTION

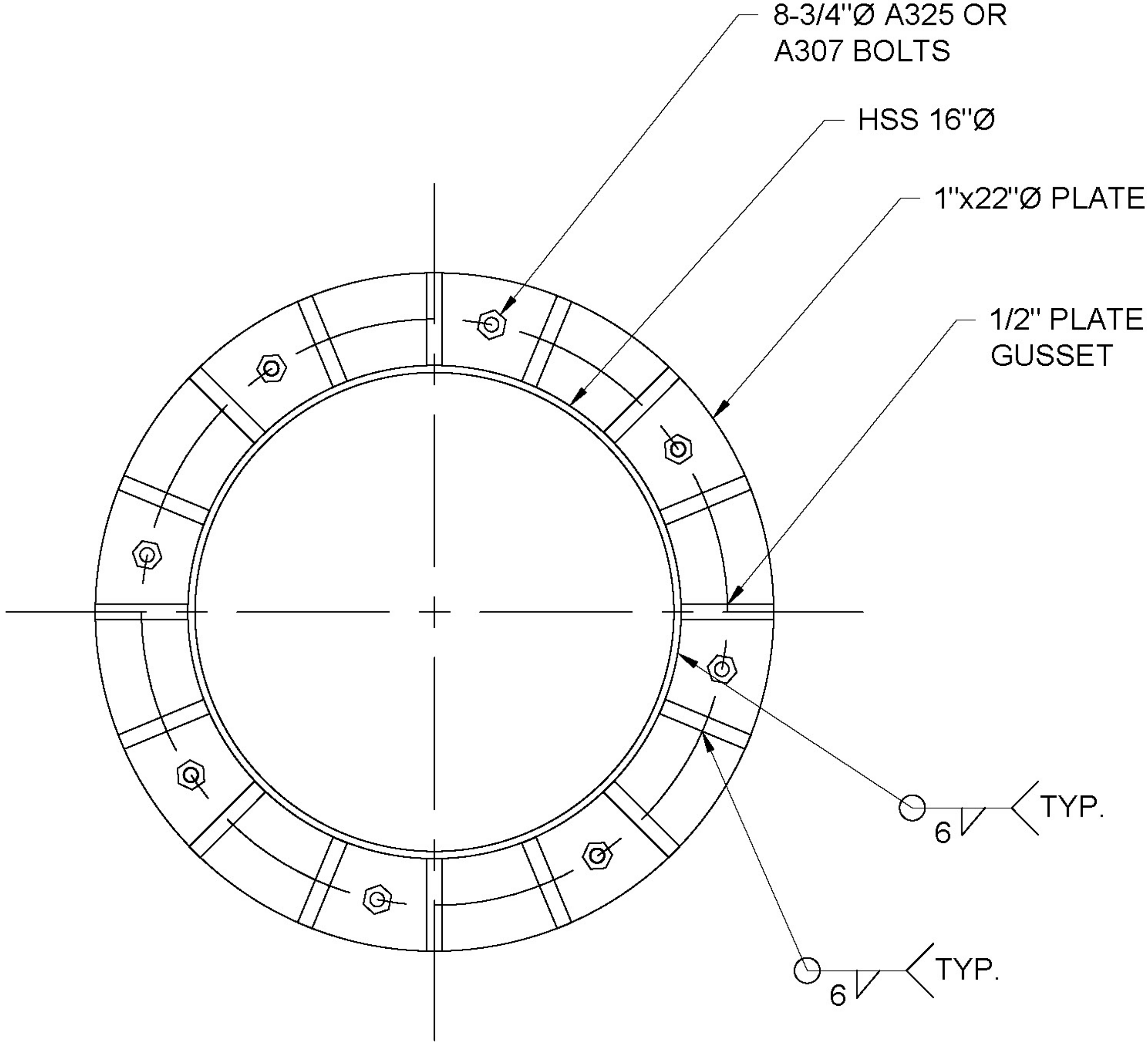
A more cost-effective and environmentally sound solution is the FeH20Loc® system.

The FeH20Loc® system is a top-down shoring solution constructed with one-of-a-kind shotcrete feather joints, ensuring that water does not penetrate the shoring walls and rather drains down till the bottom of the excavation where it can be dealt with as per the rate of seepage. In the extremely rare case where groundwater presence is overbearing and the seepage rate exceeds acceptable ranges, it can be easily corrected utilizing a specialized detailed curtain grouting step.

The FeH20Loc® system features a series of quilt-like patches of shotcrete panels. These sit neatly between equally spaced steel beams. The construction behind the system, oversimplified, is that soil is dug out in lifts that are 3 to 6 feet in depth, ensuring that groundwater does not enter the site ahead of the FeH20Loc® being constructed. The unique shotcrete design also prevents any shrinkage from occurring, resulting in a crack-free, water-proof wall. No water-proofing required. Reduce schedule. Reduce cost & CO2. Reduce Anchor Loads.

FeH20Loc® SYSTEM

6-8 million in savings can be realized, and a 50% cut in below-grade project schedule can be achieved utilizing the FeH20Loc® system. 30 MPA concrete resulting in water-proof shotcrete, ensuring that P1-P2-P3-P4 levels will never leak. Standard final structural walls & floors can apply in any design, as before. FE QA Steps (RSS) will ensure successful implementation of the system. The two-acre condo with $80,000 of caisson wall, reverts to an $8 million 'Developer' savings is now possible by 'no waterproofing' now being needed. The water is drained behind the 2@5-inch Shotcrete Layers of Feng Waterproof Shotcrete by engineered drain board between two 5 MPA @1 m diameter piles drilled from street level.



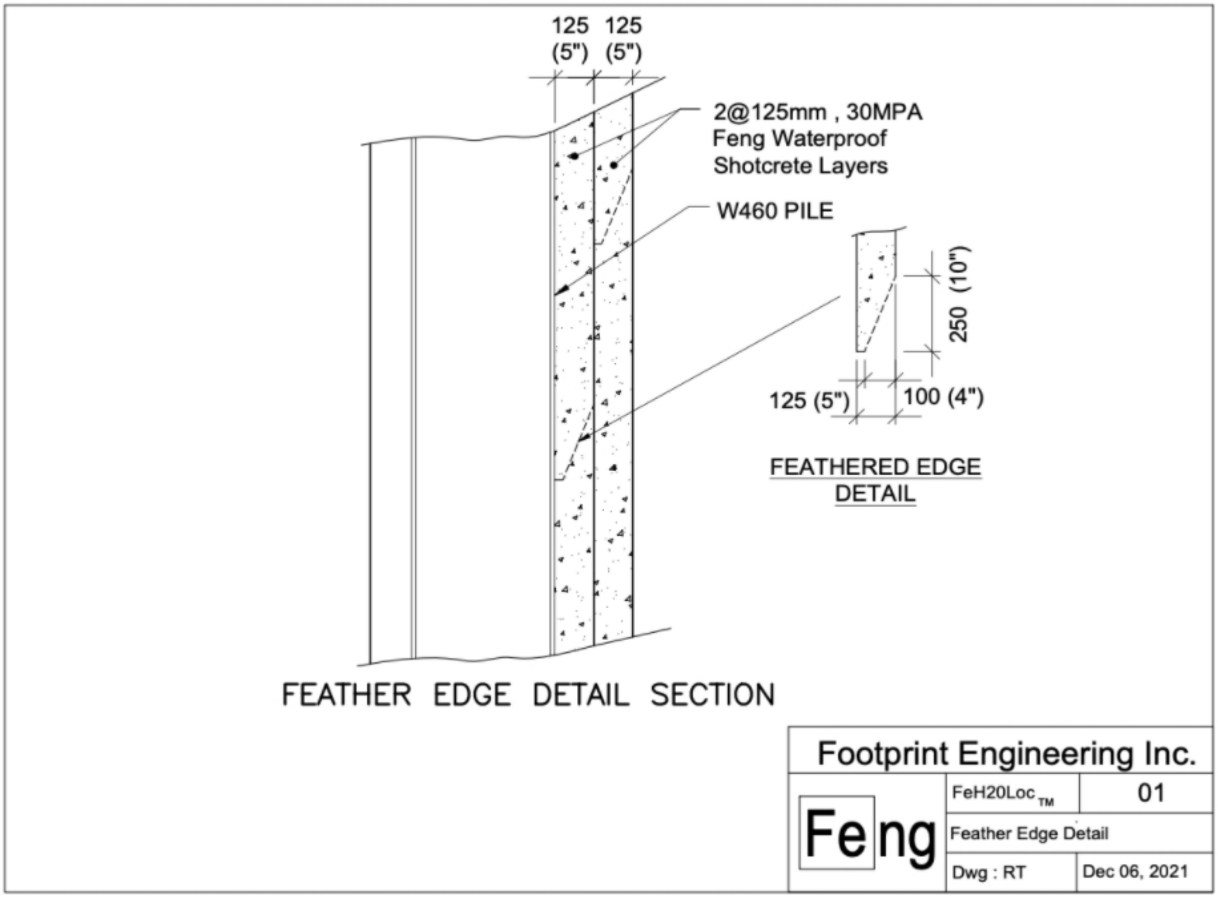
SECTION AT SPLICE OR BASEPLATE

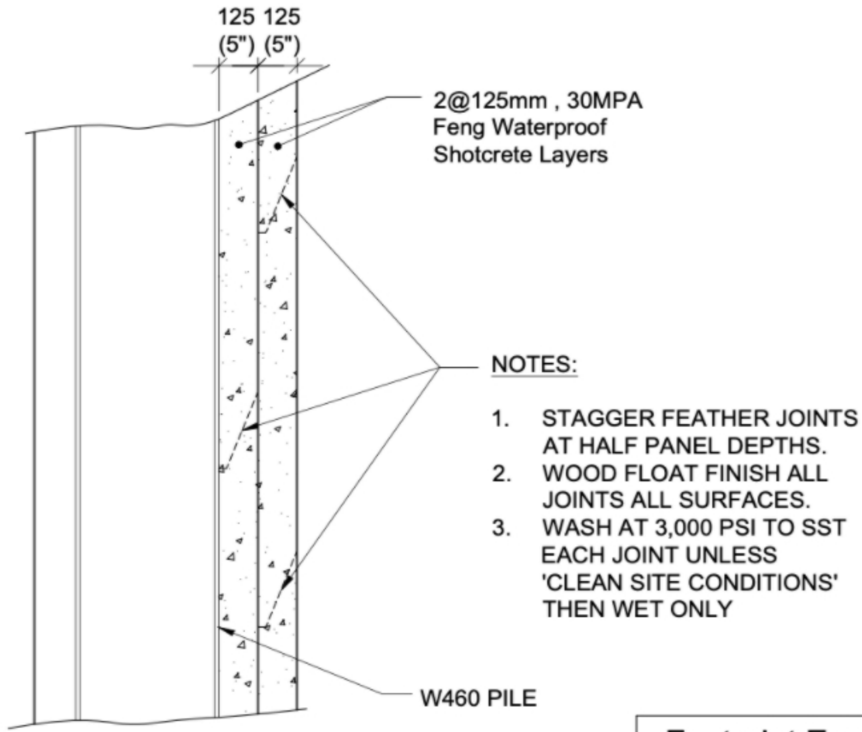
Footprint Engineering Inc.		
Feng	FeWindmill TM	13
	Detail	
	Dwg : RT	Jan 18, 2022

FeH2OLoc™

It is clear that what is required is a less expensive, more environmentally friendly solution to shoring walls and managing an unknown or imprecise expected quantity of ground water in an environmentally sensitive manner. To solve this, Footprint Engineering has created the FeH2OLoc.

This system is a top-down shoring solution constructed with one-of-a-kind shotcrete feather joints ensuring no water will penetrate the wall. The drain board lowers loading, and enhances performance. In the rare case where there is excess flow behind the wall, this can be adjusted accordingly with a detailed curtain grouting feature. The system features 2 quilt-like shotcrete layers. These 5” layers sit between equally spaced steel piles in 5 MPa backfill. To construct, soil is excavated 4 to 6 feet in depth at a time so as to ensure no ground loss before the FeH2OLocTM is constructed. The unique shotcrete design ensures no cracking of the wall.

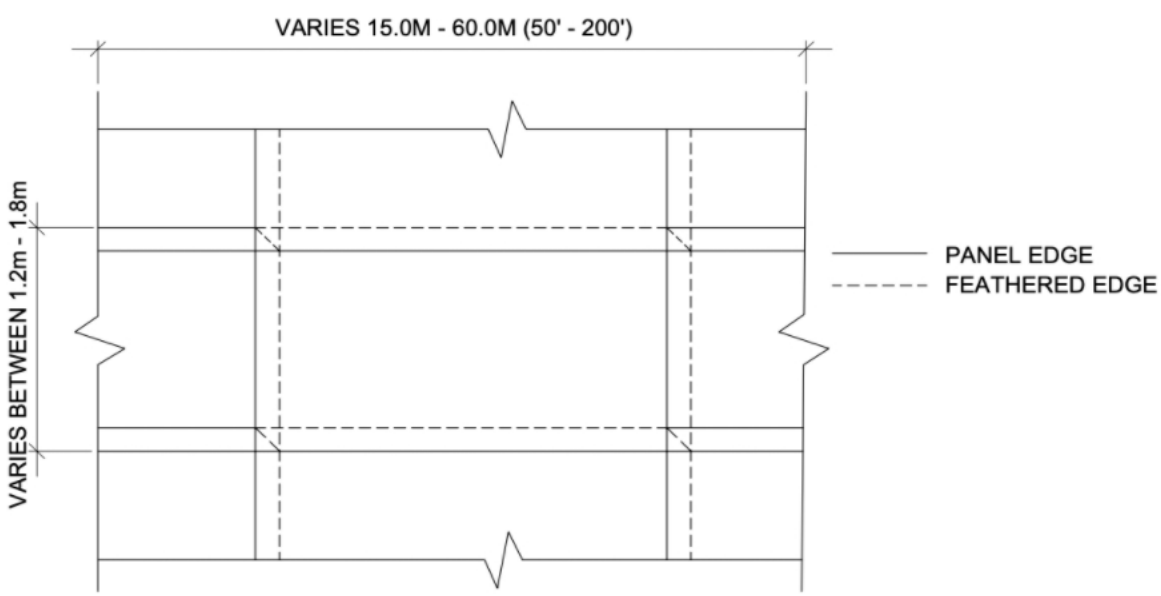




SECTION:TYPICAL STAGGERED FEATHER JOINTS

Footprint Engineering Inc.

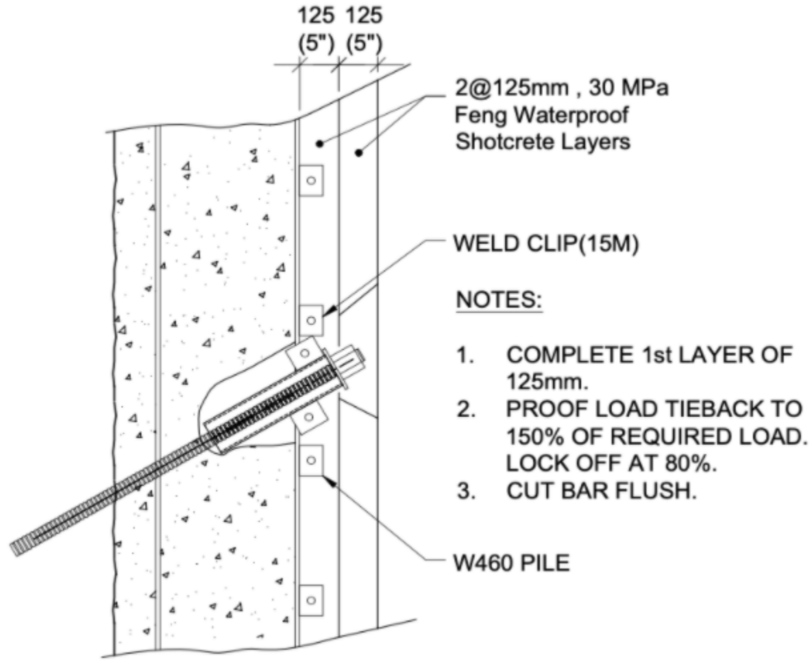
Feng	FeH20Loc™	02
	Staggered Feather Joint	
	Dwg : RT	Dec 06, 2021



ELEVATION: TYPICAL SHOTCRETE PANEL

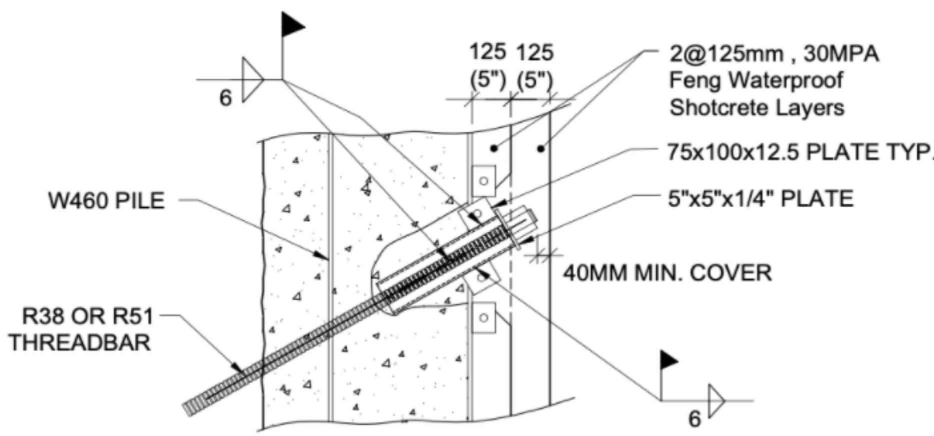
Footprint Engineering Inc.

Feng	FeH20Loc™	03
	Typical Shotcrete Panel	
	Dwg : RT	Dec 06, 2021



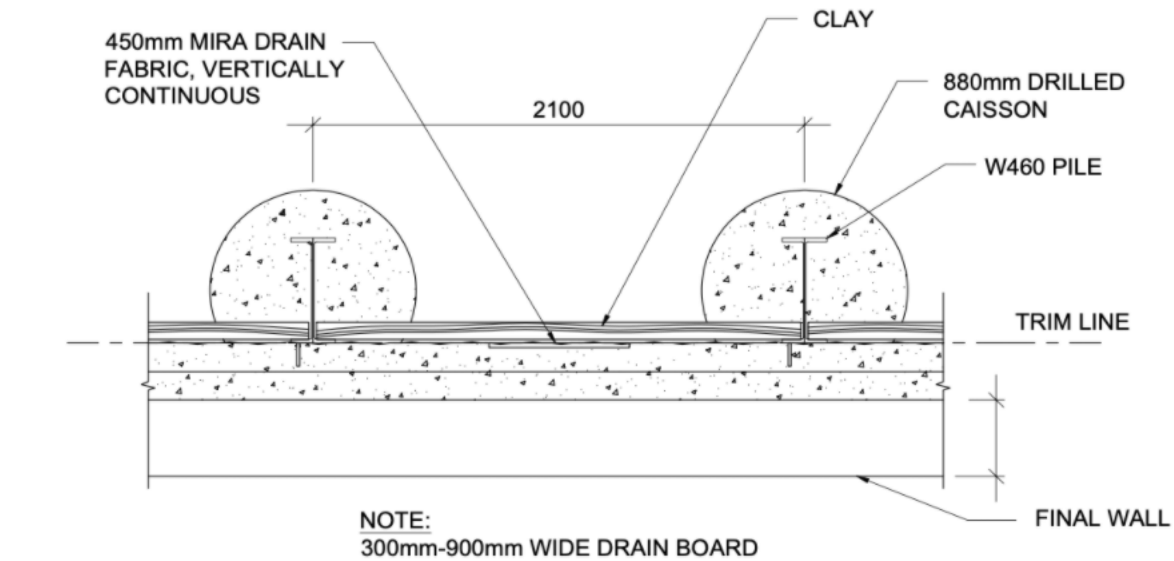
ANCHOR "SPIGOT A" SECTION

Footprint Engineering Inc.
Feng
FeH20Loc™ 04
Section: Spigot "A" Detail
Dwg : RT Dec 06, 2021



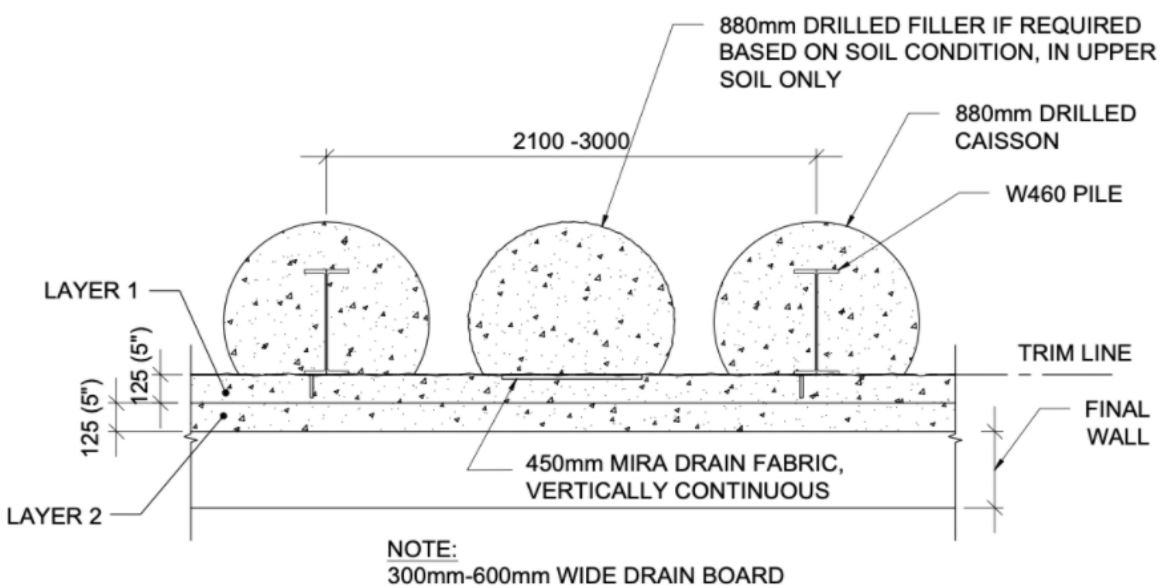
ANCHOR "SPIGOT A" DETAIL

Footprint Engineering Inc.
Feng
FeH20Loc™ 05
Spigot "A" Section
Dwg : RT Dec 06, 2021



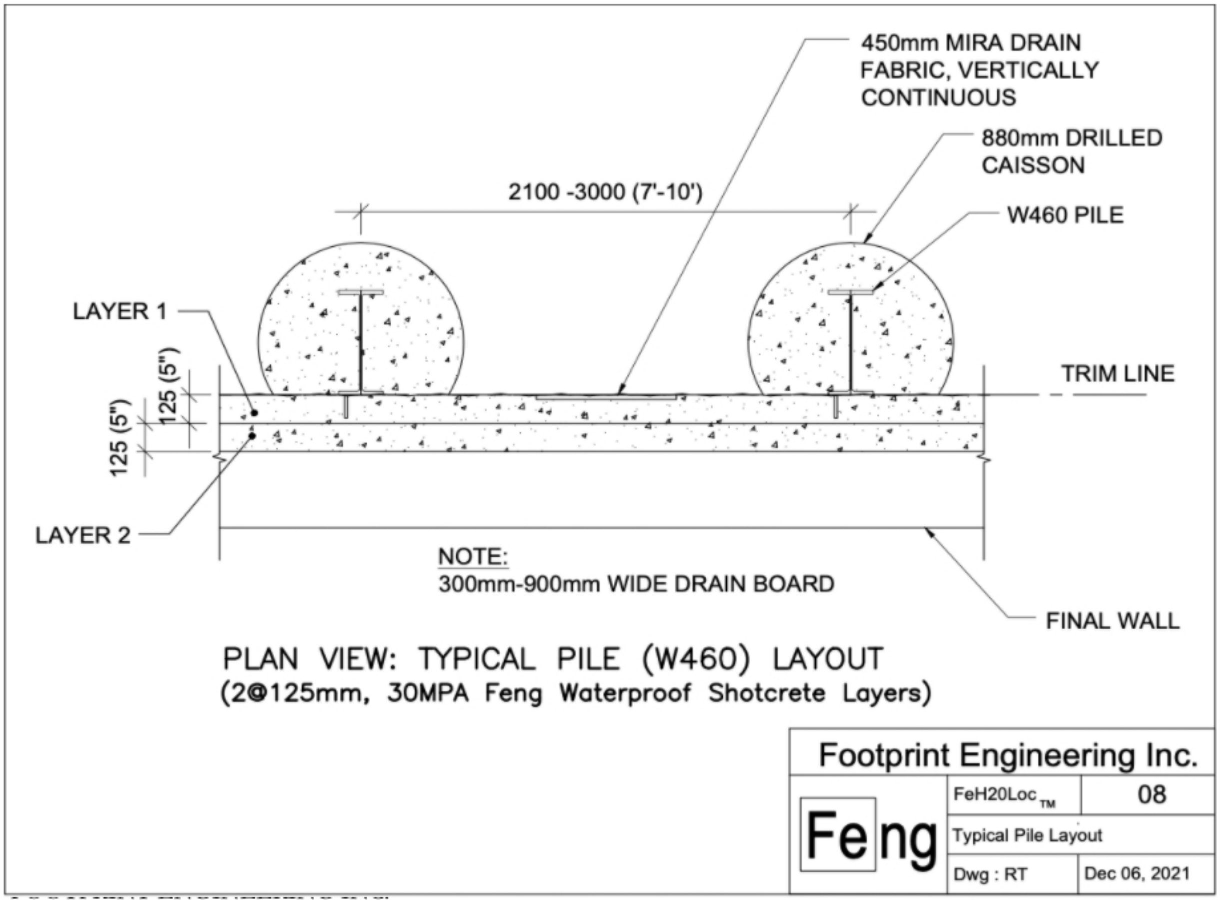
PLAN VIEW. TYPICAL PILE (W460) LAYOUT
(2@125mm, 30MPA Feng Waterproof Shotcrete Layers)

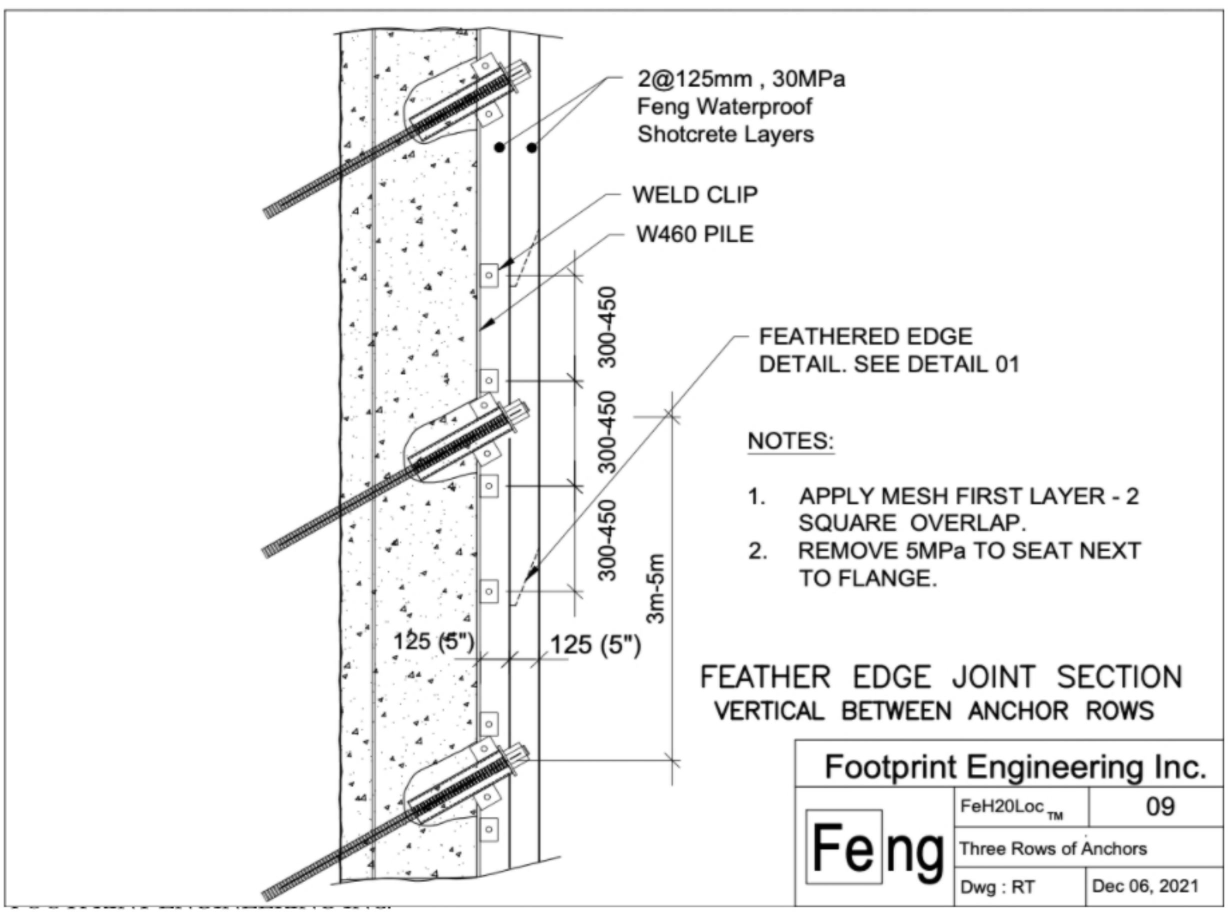
Footprint Engineering Inc.		
Feng	FeH20Loc TM	06
	Typical Pile with Drain Board	
	Dwg : RT	Dec 06, 2021

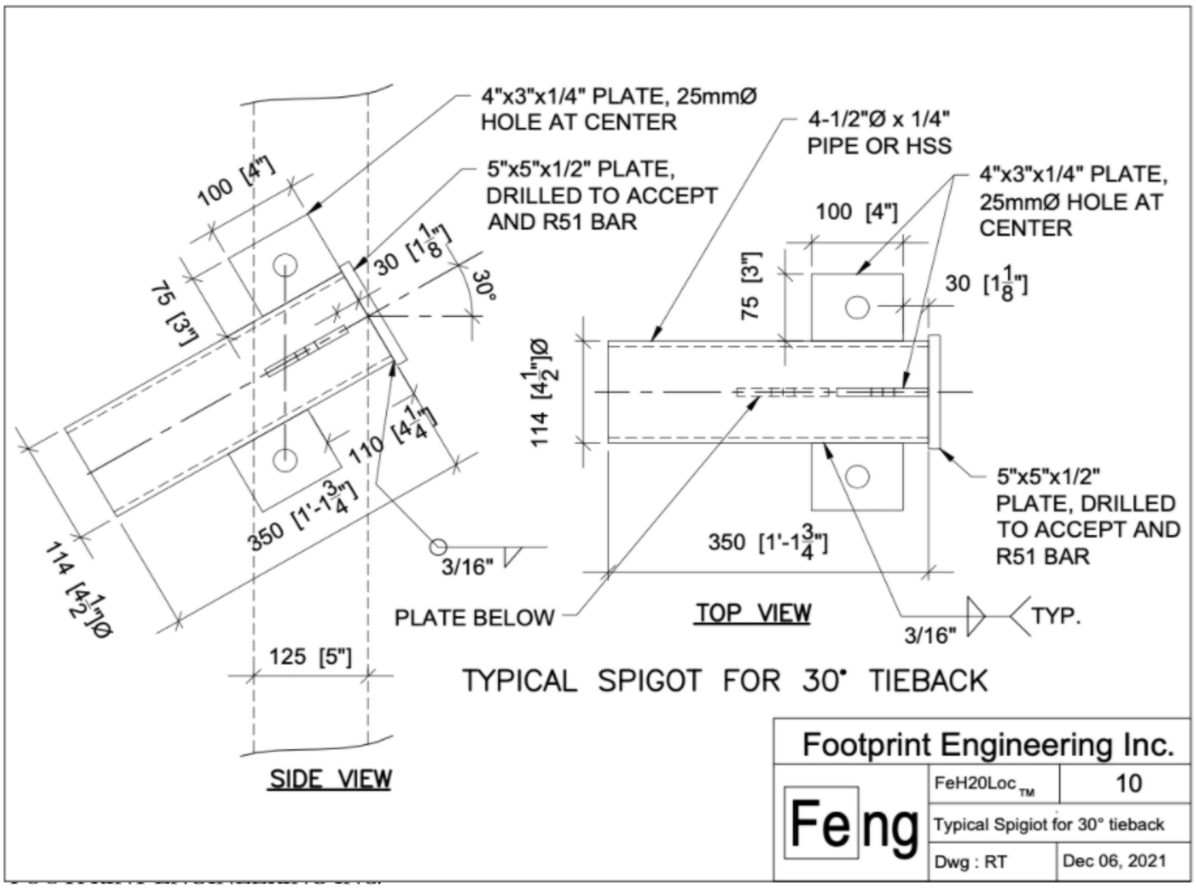


PLAN VIEW. TYPICAL PILE (W460) LAYOUT
CAISSON WALL (2@125mm, 30MPA Feng Waterproof Shotcrete Layers)

Footprint Engineering Inc.		
Feng	FeH20Loc TM	07
	Typical Pile with a Filler	
	Dwg : RT	Dec 06, 2021


450mm MIRA DRAIN FABRIC, VERTICALLY CONTINUOUS
880mm DRILLED CAISSON
W460 PILE
2100 -3000 (7'-10')
LAYER 1
TRIM LINE
125 (5")
125 (5")
LAYER 2
NOTE:
300mm-900mm WIDE DRAIN BOARD
FINAL WALL
PLAN VIEW: TYPICAL PILE (W460) LAYOUT
(2@125mm, 30MPA Feng Waterproof Shotcrete Layers)
Footprint Engineering Inc.
Feng
FeH20Loc TM
08
Typical Pile Layout
Dwg : RT
Dec 06, 2021


2@125mm , 30MPa Feng Waterproof Shotcrete Layers
WELD CLIP
W460 PILE
FEATHERED EDGE DETAIL. SEE DETAIL 01
300-450
300-450
300-450
3m-5m
125 (5")
125 (5")
NOTES:
1. APPLY MESH FIRST LAYER - 2 SQUARE OVERLAP.
2. REMOVE 5MPa TO SEAT NEXT TO FLANGE.
FEATHER EDGE JOINT SECTION
VERTICAL BETWEEN ANCHOR ROWS
Footprint Engineering Inc.
Feng
FeH20Loc TM
09
Three Rows of Anchors
Dwg : RT
Dec 06, 2021


4"x3"x1/4" PLATE, 25mmØ HOLE AT CENTER
5"x5"x1/2" PLATE, DRILLED TO ACCEPT AND R51 BAR
100 [4"]
75 [3"]
30 [1 1/8"]
30°
110 [4 1/4"]
350 [1'-1 3/4"]
114 [4 1/2"]Ø
3/16"
125 [5"]
SIDE VIEW
4-1/2"Ø x 1/4" PIPE OR HSS
4"x3"x1/4" PLATE, 25mmØ HOLE AT CENTER
100 [4"]
75 [3"]
30 [1 1/8"]
114 [4 1/2"]Ø
5"x5"x1/2" PLATE, DRILLED TO ACCEPT AND R51 BAR
350 [1'-1 3/4"]
PLATE BELOW
TOP VIEW
3/16"
TYP.
TYPICAL SPIGOT FOR 30° TIEBACK
Footprint Engineering Inc.
Feng
FeH20Loc TM
10
Typical Spigiot for 30° tieback
Dwg : RT
Dec 06, 2021

Feng

FeH2OLoc System

System Compare Summary

Key Savings Summary		
Cost	$9,599,185	-32%
Schedule (work days)	384	-37%
Concrete (m3)	27,168.0	-77%
Steel (kg)	769,508.1	-49%
Fuel (L)	124,388.3	-76%
CO2 (tons)	70,599.3	-74%

Description	Original (Before FeH2OLoc)	With FeH2OLoc	Delta	%
Steel (Bar and Beams) - Supply	$ 2,610,621	$ 1,803,303	$ (807,318)	-31%
Excavation	$ 15,205,267	$ 13,618,108	$ (1,587,159)	-10%
Waterproofing - Supply and	$ 1,563,000	$ 71,210	$ (1,491,790)	-95%
Concrete - Supply	$ 7,541,870	$ 1,849,538	$ (5,692,332)	-75%
Drilling	$ 739,924	$ 309,792	$ (430,132)	-58%
Shotcrete - Install	$ -	$ 1,110,310	$ 1,110,310	100%
Anchors - Supply and Install	$ 1,772,700	$ 1,262,250	$ (510,450)	-29%
Fuel - Drilling Rigs	$ 251,609	$ 61,295	$ (190,314)	-76%
Totals:	**$ 29,684,991**	**$ 20,085,806**	**-$9,599,185.02**	**-32%**
Schedule (work days)	**1026**	**643**	**-384**	**-37%**
Concrete Volume (m3)	35,215	8,047	- 27,168	-77%
Steel Weight (kg)	1,582,595	813,086	- 769,508	-49%
Fuel (L)	164,450	40,062	- 124,388	-76%

CO2 Produced (kg)				
Concrete	84,248,902	19,170,561	- 65,078,341	-77%
Steel (Bar and Beams)	11,078,162	5,691,605	- 5,386,557	-49%
Fuel Drilling	7,155	2,556	- 4,600	-64%
Fuel Disposal	410,617	366,627	- 43,990	-11%
Grout	183,593	97,788	- 85,805	-47%
Totals:	**95,928,428**	**25,329,136**	**-70,599,292**	**-74%**

Seda Score = CO2 Original Design / CO2 FeH2OLoc

Seda Score	**3.79**
Tons CO2 Saved	**70,599**

Feng

FeH2OLoc System

Project Summary

Project Name	Sample 2 - two acres
Project Address	
City	

Parcel Excavated Area

N/S Length (avg)	600	ft	182.9	m
E/W Width (avg)	300	ft	91.5	m

Original depth of final excavation (if raft slab used)

Depth (avg)	44	ft	13.4	m

Original Supported Earth Area

79,200	sq.ft	7,362	sq.m

Other Key Project Variables

Is raft slab being replaced by SOG?:	Yes	
Original Shoring Pile Diameter:	1	m
Shoring Pile Spacing:	0.61	m
Original Shoring Pile QTY:		
Original Thickness of Raft Slab (if appl):	1.2	m
Thickness of shotcrete wall:	0.25	m
Excavation production:	400	m3/day
Original Waterproofing production:	100	sq.m/day

KEY SAVINGS SUMMARY

Cost	$9,599,185	-32%
Schedule (work days)	384	-37%
Concrete (m3)	27,168	-77%
Steel (kg)	769,508.1	-49%
Fuel (L)	124,388.3	-76%
CO2 (tons)	70,599.3	-74%

RSS FeH2OLoc Interrupt Water System RS 192-113SA

Rehabilicrete™ System Steps & Layers 'Summary Steps'

Please refer to Manufacturer Technical Data Sheets before application process and refer to the Guide RSG 192-113SA for details of key QA inspection step and tips. See (RSG) for correct Tools also for recommendations and guidance.

RSS FeH2OLoc Interrupt Water System RS 192-113SA

This System is dual purpose. It has use as a 'Drained Excavation Support System (Raker or Struts option and tiebacks option). In addition, with High Strength Low Shrinkage Shotcrete (HSLS) it has use as a permanent full perimeter Waterproofing System with a TPH Curtain Seal 'Stop Water' option which can be utilized as permanent final 'below grade Structure floor slabs' are built.

1-1 INSTALL TEMPORARY SUPPORT PILES

Install vertical excavation W12 to W24 support piles in .75m to 1.2 m diameter vertical drill holes with 5 to 10 MPA backfill concrete. Pile Spacing to be 2.1 meters for Two Secants (mid bay hole) to 2.7 meters for Three Secants. Ground loss prevention will be ensured by using casing and the correct drilling tools. These are further explained in an installation guide (RSG) which will be available at every installation.

Figure A-1 and A-2 are schematic illustrations which show a typical layout of the support piles with the locations of the proposed final walls and caisson line.

2-2 INSTALL DRAIN BOARD

The drain board is to be installed mid bay in 300mm-900mm vertical excavation lifts with a 150mm vertical drain board overlapping a typical splice.

Schematic illustrations, figures A-1 and A-2, show the position of the drain board in relation to the support piles.

3-3 INSTALL 100mm Steel Mesh c/w 15m horizontal Rebar weld tabs

Weld the Tabs so as to stagger them at an R38 or T51 bar. The associated tieback sleeves should be pre welded. Figure A-8 is a schematic illustration showing the assembly of the tieback sleeves.

4-4 APPLY FIRST STAGE LAYER HDLS (HDLS-1) AT 100mm

Some of the steel mesh will be spliced to one another. Therefore, one to two steel mesh squares will be left open and not be filled with shotcrete. The mesh splice around the area of the 'Integral Tieback pipe (4.5 inches)' should be removed so as to allow for the 'Anchor Head 3.5 Spigot' to be inserted before HDLS stage one is applied.

Install first layer stage one 25-35MPA HDLS in each excavation step. This will occur on all vertical excavation lifts with 'Feng Feather Joint'. Schematic illustration, Figure A-6, details a Feng Feather Joint with the placement of HDLS layers 1 and 2 as well as the position of the W460 pile.

The most preferable embodiment of the concrete mix will comprise of 300 to 400kg of Portland Cement per m3 as well as additional elements.

The mix may contain Fly Ash with a preferred range of between 30kg and a maximum of 112.5kg.

Alternatively, the mix may contain Slag with a preferred range of between 60kg and a maximum of 225kg.

The most preferable embodiment of the mix will contain between 6kg and a maximum of 40.5kg two-part powder containing micro-silica (powder). The preferred embodiment of the admixture shall also contain between 5kg to a maximum of 36kg of light-burn calcine magnesia (powder). The micro-silica in our preferred admix should have a particle Specific Surface Area (SSA) between 20m2/gr and 200m2/gr. The particle sizes shall average between 15nm and 40nm in order to meet the preferred admix.

The preferred iteration of this mix shall contain from 0.09kg to 0.45 kg of natural rheology modifier and mix stabilizer (Acti-Gel).

The first layer, HDLS-1, shall be reinforced with Spigot B. Schematic illustrations Figures A-9A through A-10B detail Spigot B at different viewpoints.

The first layer, HDLS-1, shall be reinforced with rebar. Schematic illustration, Figure A-8 shows the layout and positioning of the rebar.
Layer 1 HDLS shotcrete shall be float finished.

The foundation wall will be installed in multiple horizontal sections. Sections will be installed from top to bottom.

Part B Curing

Post apply colloidal silica spray (SCP327). This will fill the bleed Channels after a Wood Float Finish. This application should take place at each 100mm layer and is required with where any Feng Feather Joint is present.

5-5 DRILL TIEBACK & INSTALL ANCHOR

Use the R38 or T51 anchor per Tieback drawings and install under Feng QA Direction. Schematic illustration Figure A-7A shows the pile tieback with the drilled caisson and Spigot Sleeve assembly. Figure A-8 depicts the positioning of the anchor in relation to the rebar.

For Spigot Type B, Install R38 or T51 anchors through web welded connection 4.5 inch pipe. All the anchors should be proof tested until 150% complete with final the hardware left in place. Figure A-9A shows a schematic illustration of the the positioning of the pile to accept the pipe. Figure A-10A also shows the pipe and plate positioning.

Insert at each 115mm ID, which was pre welded to pile, a 115mm steel pipe placed next to a W460 pile web. This will be used to guide the correct placement of 'Anchor Head 89mm pipe Spigot Internal Chair 'C'' to its correct placement in the pile face. For Spigot Type A this should take place after the anchor is installed and during the application of layer 1 HDLS at 100 mm.

Cut anchor bar to be within 5 to 15 mm of anchor head prior to Velosit WP 101 application and after all tensioning/stressing requirements are completed.

Note: Industry Standard Shoring Excavation Monitoring of +/- 2mm on W460 will apply. Until the final structure replaces temporary works all conditions must be monitored.

6-6 FINISH SHOTCRETE FACE. APPLY SECOND LAYER of HDLS (HDLS-2)

The final application of HDLS shotcrete shall be float finished. Repeat Step 4-4.

Note; The second HDLS layer shall be applied only after the successful proof testing of each anchor. Cover each anchor Head and use 'RSS Feng Seal Spigot' after proof test and Feng QA to determine lock load on anchor respecting free zone sleeve 3m min. Maintain shotcrete surface heat above 5 degrees for initial set 12-24 hours per Feng QA.

The preferred concrete mix will comprise of 300 to 400kg of Portland Cement.

The preferred embodiment of the mix may contain between 30kg and a maximum of 112.5kg of Fly Ash.

Alternatively, the mix may contain a preferred range of between 60kg and a maximum of 225kg Slag.

The preferred iteration of the mix will contain between 1kg and a maximum of 6kg two-part powder containing micro-silica (powder). This admixture shall also preferably contain between 5kg to a maximum of 36kg of light-burn calcine magnesia (powder). The micro-silica should have a preferred particle Specific Surface Area (SSA) between 20m2/gr and 200m2/gr. The particle sizes shall average between 15nm and 40nm. The mix shall contain between 3kg to a maximum of 30kg of micro-silica with an average Specific Surface Area (SSA) of 20m2/gr.

Our preferred embodiment of the mix shall contain from 0.09kg to 0.45 kg of natural rheology modifier and mix stabilizer (Acti-Gel).

The mix will contain a preferred range from 6kg to 12.5kg of liquid crystalline admixture (Velosit CA 115) which will contain a choice of Melamine, Naphthalene and/or Polycarboxylate as water reducers.

The layer of HDLS-2 shall be reinforced with Microfibres applied from a preferred range 3kg to 4.5kg per cubic meter of concrete.

Figures A-11 through A-14 depict the Typical Elevations and Profiles of single, double and triple anchor rows.

Part B Curing

Post Applied colloidal silica spray (SCP327) (to fill bleed Channels after a Wood Float Finish).

Post apply colloidal silica spray (SCP327). This will fill the bleed Channels after a Wood Float Finish. This application should take place at each 100mm layer and is required with where any Feng Feather Joint is present.

7-7 REPAIR MORTAR 50 MPA OPTIONAL

Apply repair mortar which cures to 20 MPA in 3 hours to nicely cover final anchor head hardware. Tarping is required with suitable means to hold in the mix Heat. Supplement Heat as required or accelerate actual mix cure.

8-8 CEMENTITIOUS TOPPING OPTIONAL

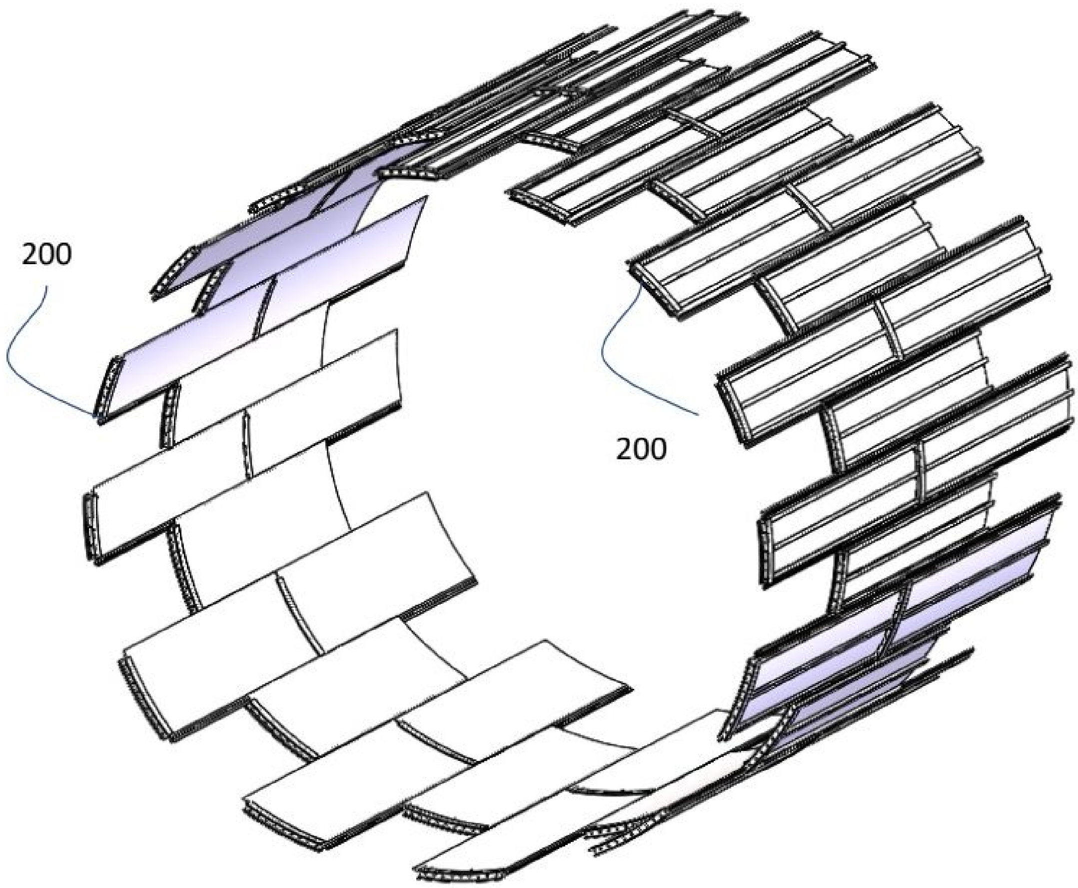
A polymer modified flexible cementitious crack bridging waterproofing slurry shall be applied where required. The topping shall be applied by trowel coat to a thickness of 5mm. The final optional topping may be spray-applied for 2 coats of 2mm each.

9-9 GROUNDWATER FLOW ANALYSIS / TPH CURTAIN GROUTING CHOICE – PRESCRIPTIVE-OPTIONAL

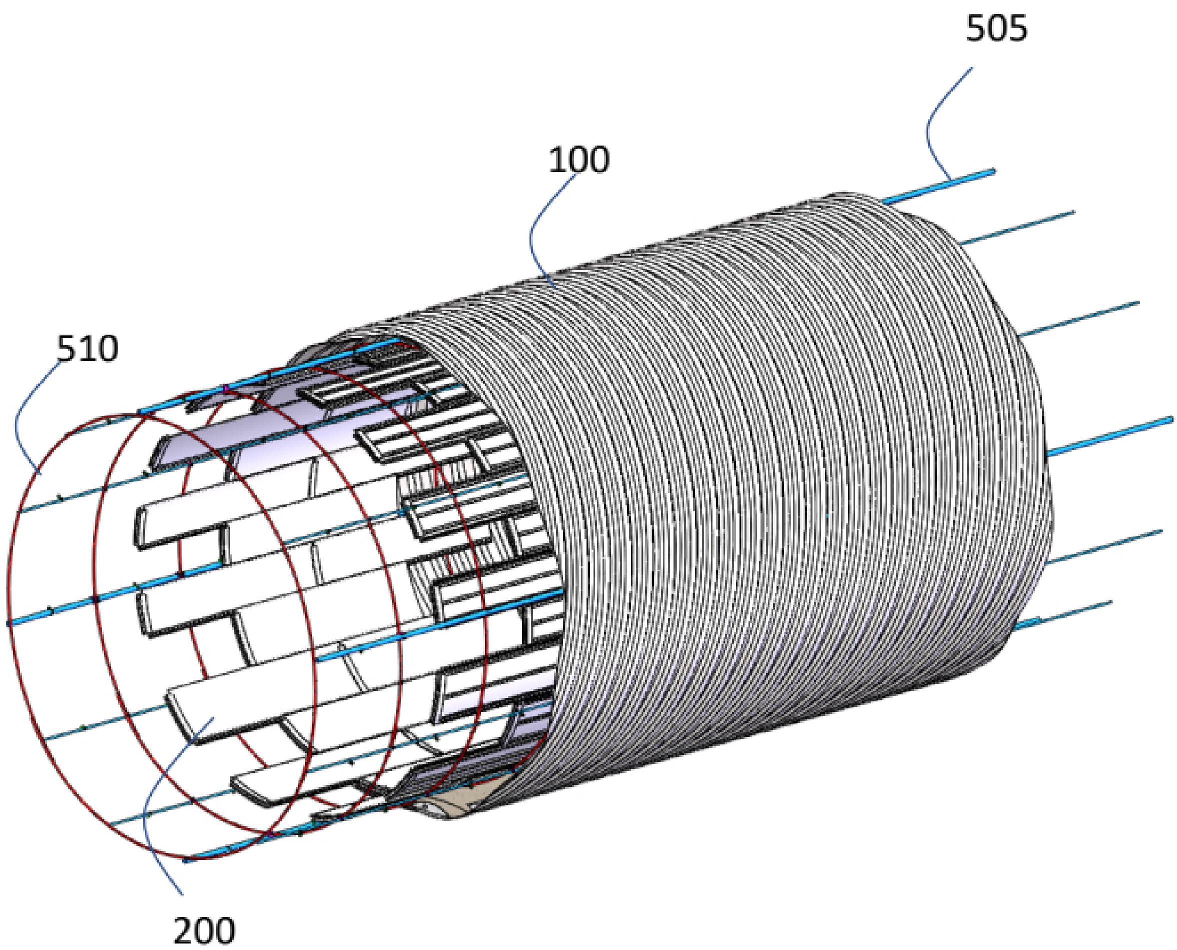
As the final structure proceeds to be constructed, determine TPH curtain grouting choice – prescriptive – based on a baseline of 1.0 liter per excavation Bay per minute leakage into site containment area. Flows greater than the baseline shall warrant curtain grouting via TPH solutions technology. After the floor slabs are installed, seal drainage behind the shotcrete. This will provide added water pressure and temperature bracing Equivalent.

FeHDPlank™

A method and apparatus for repairing a damaged host pipe, such as a corrugated steel pipe or other conduit. A plurality of interlocking plastic planks are positioned within the invert of the host pipe forming a liner. Rebar is first installed and attached to the host pipe for supporting the planks. A cementitious grout non-shrink grout for concrete such as VELOSIT NG 511 is installed in the spaces between the liner formed by the interlocking planks and the host pipe so that the 5 mm basaltic coil is encapsulated with the concrete and so that the planks are immovably secured.

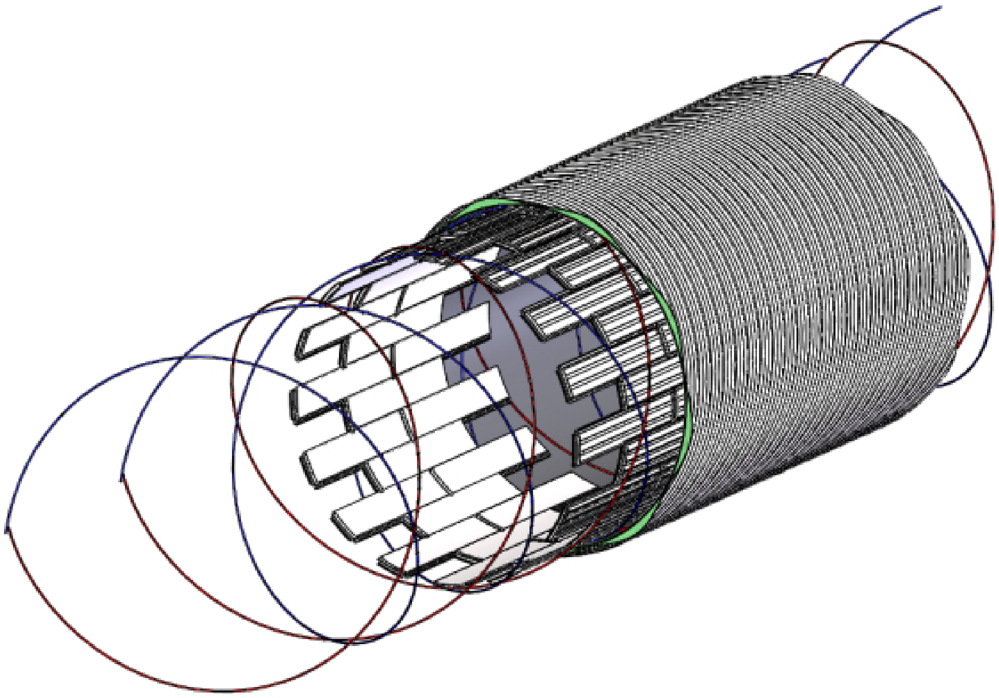


Footprint Engineering Inc.		
Fe ng	FeHDPlank	SK1
	CSP Culvert Rehab 75-Year	
	Dwg : RT	Jan 23, 2022

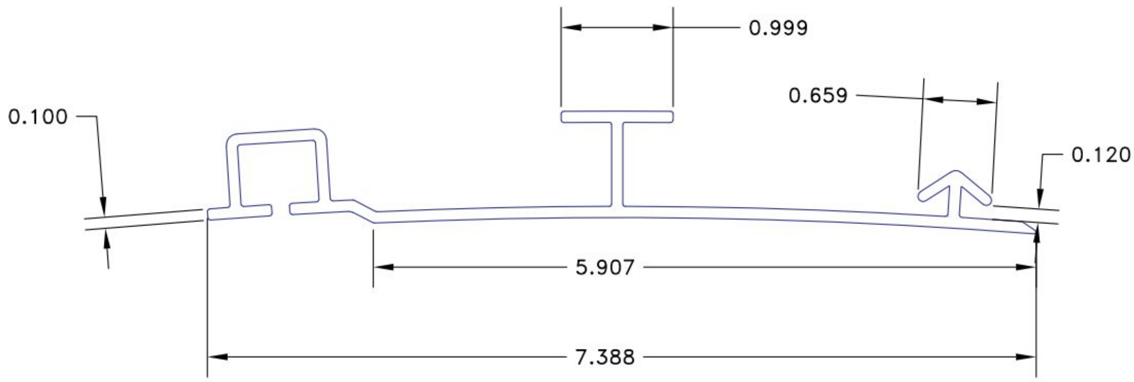


Footprint Engineering Inc.		
Feng	FeHDPlank	SK2
	CSP Culvert Rehab 75-Year	
	Dwg : RT	Jan 23, 2022

EXPLODED VIEW

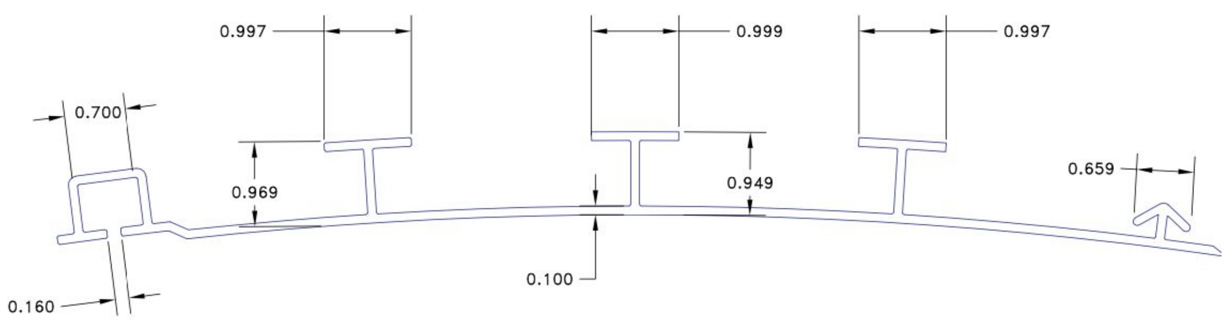


Footprint Engineering Inc.		
Feng	FeHDPlank	SK3
	CSP Culvert Rehab 75-Year	
	Dwg : RT	Jan 23, 2022



2/25/22 0.100" Option

Footprint Engineering Inc.		
Feng	FeHDPlank	SK4
	CSP Culvert Rehab 75-Year	
	Dwg : RT	Jan 23, 2022



2/25/22 0.100" Option

Footprint Engineering Inc.		
Feng	FeHDPlank	SK5
	CSP Culvert Rehab 75-Year	
	Dwg : RT	Jan 23, 2022

Avis du commissaire - Demande jugée acceptable
Commissioner's Notice - Application Found Allowable

TEITELBAUM & BOUEVITCH
officemail@patents.org

Détails de l'avis / Notice Details

Date de l'avis: Notice Date:	2023-03-10
Nº de la demande: Application Nº:	**3,125,165**
Votre nº de référence: Your Reference Nº:	328-9 CA
Date d'échéance de l'avis: Notice Due Date:	2023-07-10
Montant dû:	153,00$
Amount Due:	$153.00

Date de dépôt/Filing Date:	2021-07-20				
Demandeur(s)/Applicant(s):	HC PROPERTIES INC.				
Inventeur(s)/Inventor(s):	HALLIWELL, JOHN MARTIN				
Titre de l'invention:	SYSTEME ET METHODE DE REMISE EN ETANT D`UNE CONDUITE D`ACCUEIL				
Title of invention:	SYSTEM AND METHOD FOR REHABILITATING A HOST PIPE				
Revendications/Claims:	024				
Pages en sus : Excess Pages:		Taxe:		Fee:	
Revendications excès:: Excess Claims:		Taxe:		Fee:	
Examinée tel que modifiée: Examined as amended:	2022-10-17				

Le présent avis du commissaire aux brevets vise à informer le demandeur que la demande de brevet a été jugée acceptable et que le paiement de la taxe finale réglementaire doit être fait au plus tard le 2023-07-10.

Si la taxe finale, dont le montant est indiqué ci-dessus, n'est pas payée au plus tard le 2023-07-10, la demande sera réputée abandonnée.

Lorsque la taxe finale sera payée, votre demande de brevet donnera lieu à la délivrance d'un brevet.

Veuillez vous assurer de l'exactitude des renseignements au dossier avant de faire le paiement de la taxe finale, car peu de modifications sont autorisées après le paiement de la taxe finale et après la délivrance d'un brevet. Veuillez consulter le site web de l'OPIC concernant les taxes générales pour les brevets:

https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/fra/wr00142.html

Références pertinentes:
* par. 86(1) des *Règles sur les brevets*
* par. 87(1) des *Règles sur les brevets*

Pour de plus amples renseignements concernant cet avis ou la façon de rétablir une demande de brevet abandonnée, veuillez consulter le *Recueil des pratiques du Bureau des brevets* (RPBB) accessible au canada.ca/brevets ou téléphoner au 1 819 997-2839.

This is a Notice from the Commissioner of Patents to inform the applicant that the application for a patent has been found allowable and payment of the prescribed final fee is required before the end of 2023-07-10.

If the final fee, in the amount indicated above, is not paid before the end of 2023-07-10 , the application will be deemed to be abandoned.

Once the final fee is paid, your patent application will proceed to grant.

Please ensure the accuracy of the information on file before payment of the final fee as there are limited modifications that are allowed after payment of the final fee and post grant. For more information regarding fees, please refer to the CIPO Patent Fees website:

https://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/wr00142.html

Relevant references:
* s.86(1) of the *Patent Rules*
* s.87(1) of the *Patent Rules*

For more information regarding this notice or on how to reinstate an abandoned patent application, please refer to the *Manual of Patent Office Practice* (MOPOP) at canada.ca/patents or phone 1-819-997-2839.

Rehabilicrete™ System Steps & Layers

FeHDPlank Feng RS 283-212B

Please refer to Manufacturer Technical Data Sheets before application process and refer to RSG 223-212B Installation Guide for details of key QA inspection steps.

RSS 283-212B FeHDPlank

This RS System provides large diameter CSP rehabilitation to extend life to 75 years by wall restoration, waterproofing, and abrasion resistance. See RSS QA Tools to this Installation Guide for details of the system implementation to see any QA inspection steps.

1-1 SURVEY SITE CONDITIONS

Prior to any work being initiated, the owner must survey the site conditions. The owner should look for any abnormalities or additional problems that may exist on site. The owner must also provide the bypass of water into the culvert.

Use Lidar survey to provide evidence of conditions to be compared with final results. Key survey points to resolve at 12 pm, 3 pm, 6 pm, 9 pm clock positions.

1-2 PREPARE AND CLEAN SUBSTRATE

Substrate where works are taking place must be prepared for the Rehabilicrete™ System. The substrate is prepared with high pressure water blasting to remove all bond breaking substances. Clean substrate with a pressure washer at 3000-5000 psi (5000 psi preferred). Remove all dust and debris from areas to be treated, anchored or supported.

1-3 CLOSED FOAM FILL CSP ID RIBS

Proceed in good weather with a one-day plan of 30 m / day. Pump foam into culvert corrugations. Do not fill entire corrugation. Leave a one-inch gap.

2-1 INSTALL SHEAR KEYS

Install shear keys at every sequential metre of the culvert. Shear keys are to be installed at the 1, 3, 5, 7, 9, and 11 o'clock positions. These will be used to tie in corrugations of the culvert and provide increased shear strength. Pucks will not be square shaped. Utilize Tek Screws as needed.

3-1 APPLY REPAIR MORTAR VELOSIT RM202

Apply to ¼ V max to level. Do not smooth. This will increase shear strength.

Use legs of HDPE (Part B to have Part C) and struts HDPE or Basaltic bar.

Use rated 200 lb snap ties of plastic as needed Basaltic / Urethane (shop 10 m long mock ups before start in June 2021).

This QA RSS exact ID goal involves three key elements: 1) grout mixing method (pump type), 2) multiple stages of grouting result in lower risk, 3) QA oversight by Verdi.

4-1 APPLY WATERPROOFING VELOSIT WP120

Velosit WP 120 is a polymer modified cementitious waterproofing slurry with increased abrasion resistance. An excellent waterproofing solution for coating of trafficable flat roofs and parking structures. Helps against rising dampness and is a good barrier against carbon dioxide. Highly flexible, with a tensile elongation >100% and resists 50m (160 ft.) of water pressure. Achieves sufficient adhesive strength as a coating after 3 hours at 70°F, open to foot traffic after 3-4 hours.

Pour the B-component into a suitable bucket and mix in the A-component powder with a slow speed drill (300 – 600 rpm) until a lump free mix is achieved. Add up to 1 litre of water to adjust to desired consistency. Water addition extends the cure time and should be kept to a minimum. 2 mm coats of WP 120 can be applied 30-45 minutes apart. Coats are to be applied by roller, wet brush, or trowel. WP 120 has a pot life of 45-60 minutes.

1.7 kg of mixed Velosit WP 120 will typically cover 1 m^2 (3.5 lbs. per $10ft^2$) at 1 mm on smooth surface. Apply with a magic trowel (RSG) at 2 mm thick. Do not smooth. This will increase sheer strength.

5-1 COMPLETE INSTALLATION OF 10 M BARS

Install 10M spiral bars running along the inner surface of the culvert. The spiral bars should be installed with a right lay and a left lay beginning at the discharge end of the culvert. The two spiral bars will run in opposite directional rotations from one another so that they cross and overlap periodically. The rebar is to be run through the culvert at a 22.5 degree angle thus "sprialling".

6-1 INSTALL FEHDPLANK

The FeHDPlank is to be installed in a full circle on clock positions in a staggered overlap. This system is also to be installed into the correct positions while 'dry' before grouting.

The plastic extrusion Part A (HDPlank – pre camber) receives another extrusion shaped as an end female also with pre cambered H (Part B of the FeHDPlank End). This will be detailed per each CSP diameter to enable a seal of the grout at every 4 ft stagger joint. The first planks installed will connect to the bulkhead at the entrance of the culvert. Therefore, every second plank in the initial loop at the bulkhead will be half the length of a usual plank (2 ft instead of 4 ft) to ensure the planks remain staggered for the entirety of the pipe.

Each plank will be measuring 4 ft long to enable a man to reach with his arm to assemble both Part A and Part B. This will enable a systematic 360 degree coverage. The FeHDPlank can be installed at 20 m portions as each detail is ready.

7-1 INSTALL WEDGES TO SECURE FEHDPLANKS IN PLACE

Apply wedges so as to put equal pressure on all points around the complete plank structure and hold it in place. The wedge will be used only at joints in the middle of the basaltic bar hoop to help with pre-loading. The wedges will be applied outside of the hoops. The wedges will be utilized at every other position around the clock starting at 12 o'clock (12, 2, 4, 6, 8, 10).

8-1 ATTACH FEHDPLANK PART 'C' TO SPIRAL REBAR

Clip part 'C' of FeHDPlank to rebar as they align. The opening of part 'C' has been specially designed to fit perfectly with 10 m rebar ensuring a perfect and secure fit.

9-1 INSTALL INFLATEABLE BULKHEAD AND GROUT

At the end of every work day grout will be installed to finish off the 30 metre section that was completed. 20 mm grout hoses are to be wrapped at 45-degree angles through the interior of the culvert. 2 hoses are to be used, one right lay and one left lay. Pumping is to be done through an inflateable bulkhead. The bulkhead will be installed at the 10 and 2 o'clock positions. Bulkhead will be inflated and attached. End points will be the 4 and 7 o'clock positions of the bulkhead. These will act as ports on grout. Valves will control a 'T' in the grout lines. Grouting will take 2 hours to complete. Grout tubes will not be pulled out after use.

Vent ports will be used at the 11 and 1 o'clock positions at the 30-metre point. Vent ports will show the progress of the grout.

Avoid voids, leaks and form movement during the placement of the grout.

Note: use transition solution to match survey OD and desired ID and these steps can include

A) A customized Basaltic System to match saddle CSP size specific as well as a Part C HDPE (column feet) on any T rib will be useful. Part 'C' Feet (HDPE .009) to match saddle CSP Size.

B) 10 M Basaltic bar to every Part B with 150 mm splice end at 22.5 degree mm spiral spacing.

C) A Wedge joint, HDPE
At each of 12, 2, 4, 6, 8 and 10 O'clock positions to each FeHDPlank End (Part B and Part C).

D) 75-year lifespan with Zero corrosion. Good factor of safety on grout and HDPE layer at .150 Thick HD (Std QW is .050 thick) but never one failure in that joint to date.

10-1 SURVEY FINAL RESULTS

Owner to survey with Lidar to analyze before and after results.

Improve to 30 metres per week by training (Tension Ties and Wedges System to be made perfect through mock up phase and on first field trials). This is utilizing a good weather window.

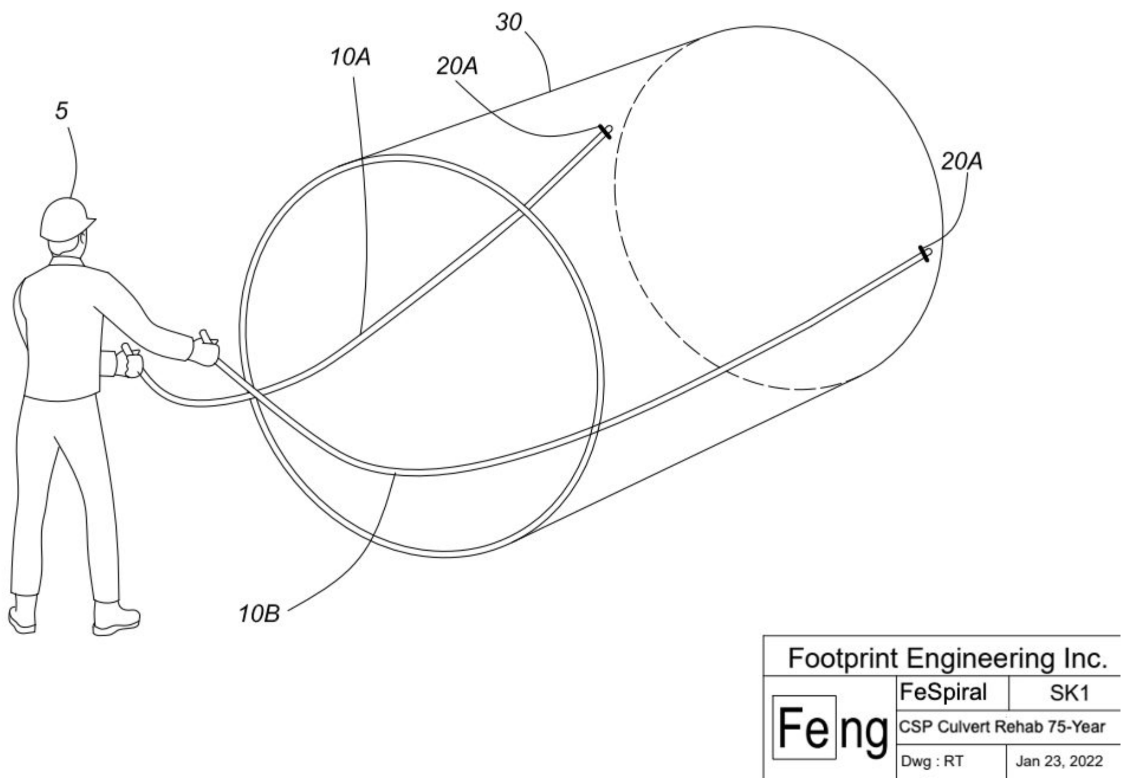
Supplement this with observational methods of precision survey to enhance accuracy.

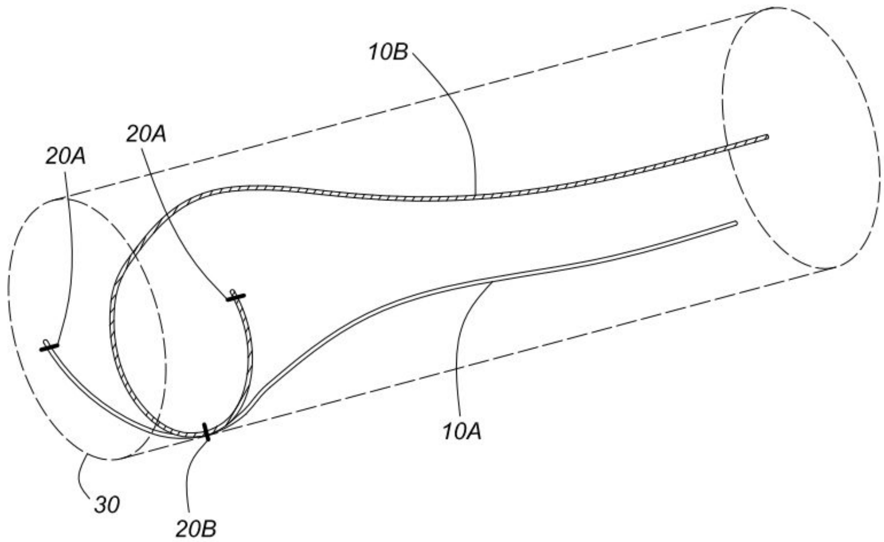
Full Time non working QA is recommended to be by Licensed Contractor as a non working field engineer who can assist Lidar or observational points while grouting.

Ensure FeHDPlank is installed correctly every step and in a slight compression ring manner with 100% as pre camber (.9 times 2400 mm is 90% of Plan 2150 mm). See actual HD Plank details in cross section(s) figures.

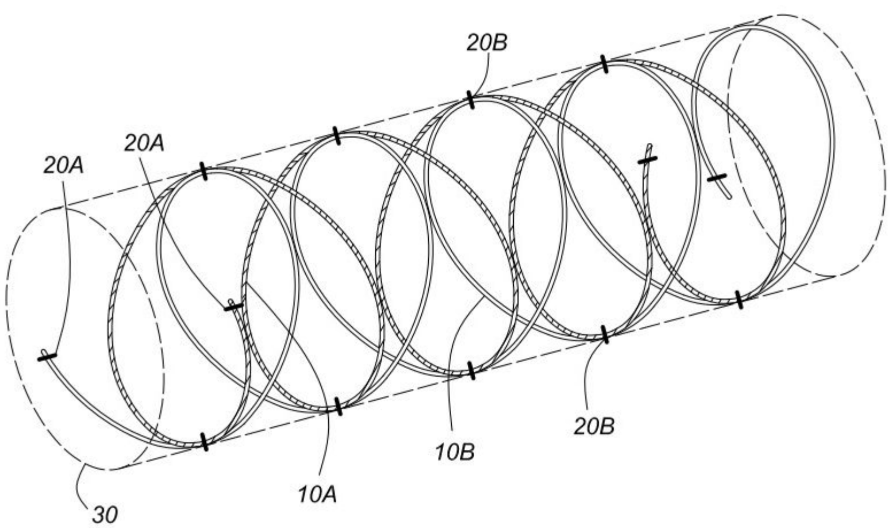
FeSprial™

Two lengths of basaltic, or FRP rebar are formed into spirals and coupled at cross over locations to form a structure to be embedded into a cementitious material or covered in a cementitious material for repairing a form or in new construction.

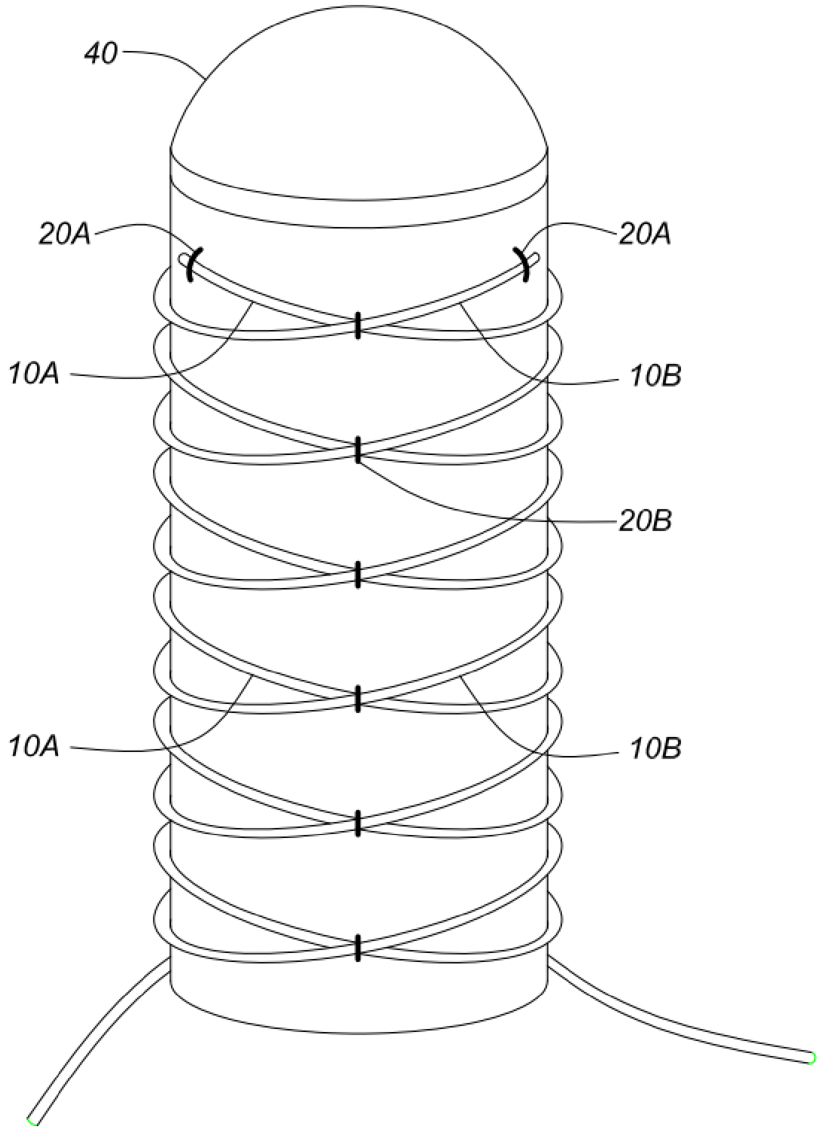




Footprint Engineering Inc.		
Feng	FeSpiral	SK2
	5-mm Basaltic Bar	
	Dwg : RT	Jan 23, 2022



Footprint Engineering Inc.		
Feng	FeSpiral	SK3
	5-mm Spiral Basaltic Bar	
	Dwg : RT	Jan 23, 2022



Footprint Engineering Inc.		
Feng	FeSpiral	SK4
	5-mm Spiral Basaltic Bar	
	Dwg : RT	Jan 23, 2022

FeHeligent™

The present invention relates to pile systems and methods and more particularly to a pile wall system and method for constructing shoring walls using two types of helical, which is both fast, and effective in shoring up to 20 feet deep.

The method may be used in a variety of situations involving a deep excavation, including excavation projects in constrained sites, excavation projects that extend close to a property line, and/or excavation projects that are adjacent to an existing structure.

In addition, the method may be used in areas in which the water table is high, and is lower in cost relative to the use of traditional tangent or secant walls which are typically more expensive and require greater volumes of cement to complete.

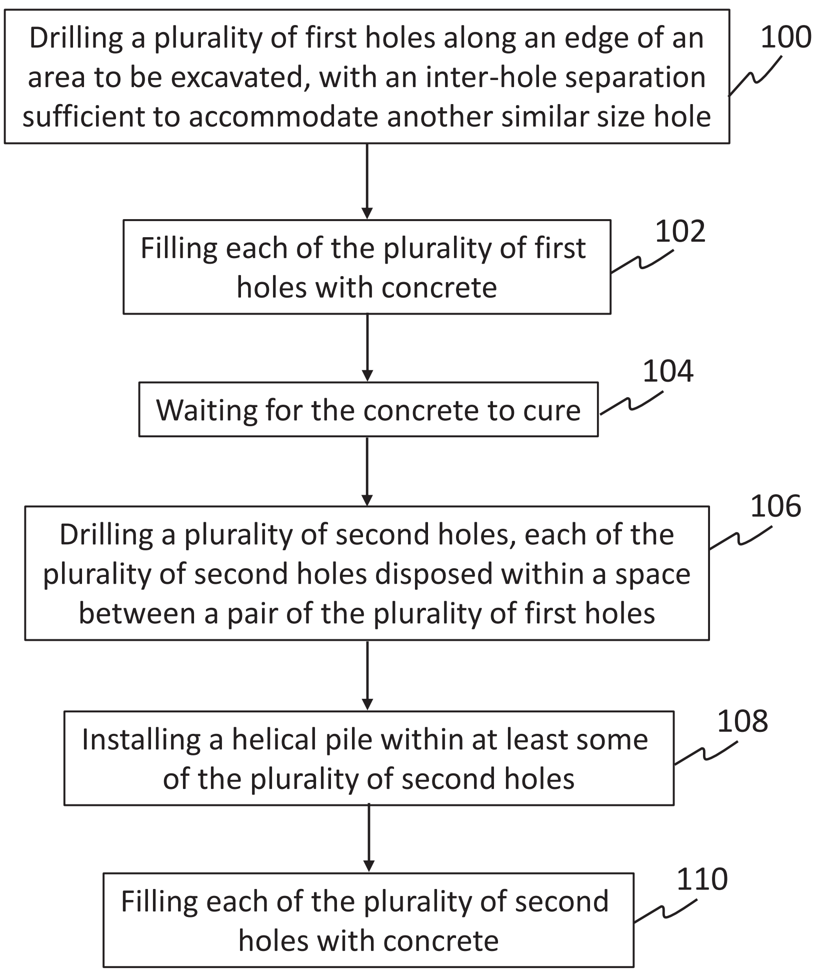
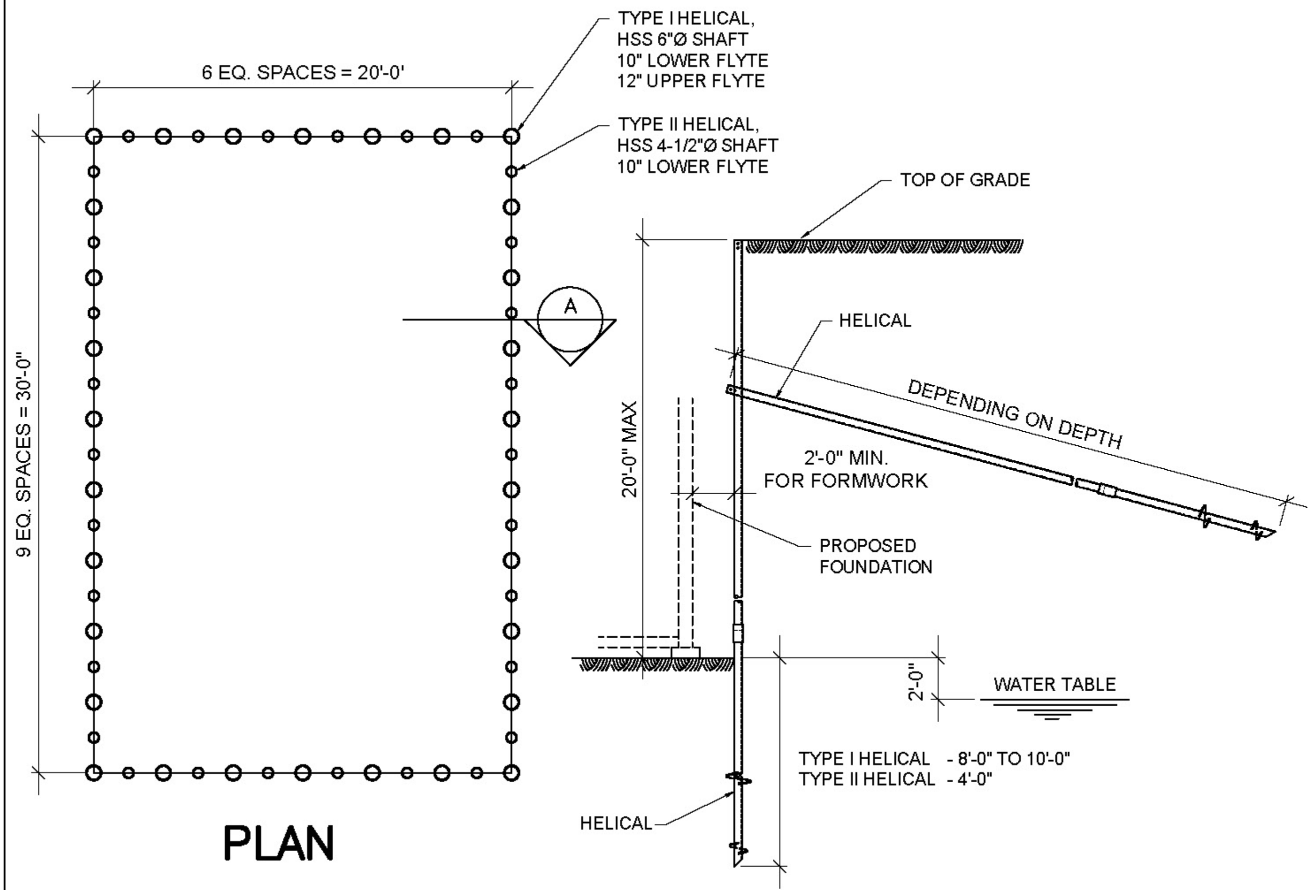


FIG. 1



NOTES:

1. NO CONCRETE REQUIRED.
2. REMOVE HELICALS AFTER COMPLETION.
3. FOR USE IN TYPE 2 SOILS OR BETTER.
4. LOWER CO_2 SYSTEM, HIGH WATER TABLE.
5. ALLOW 2'-0" WORKING ROOM FOR FORMWORK.

Footprint Engineering Inc.		
Fe ng	FeHeliGENT™	SK1
	Excavation Support Systems	
	Dwg : RT	Jan 23, 2022

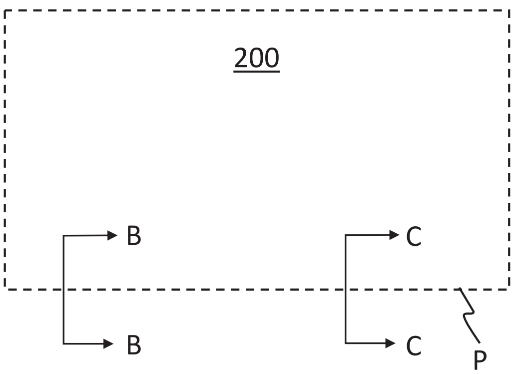


FIG. 2A

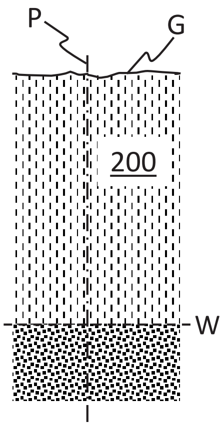


FIG. 2B

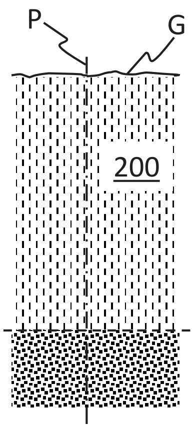


FIG. 2C

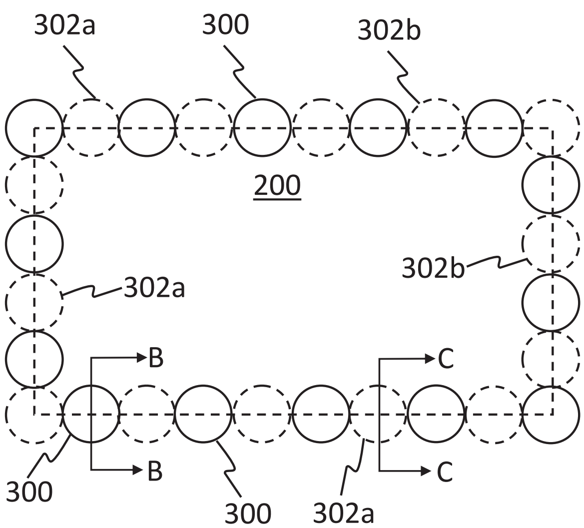


FIG. 3A

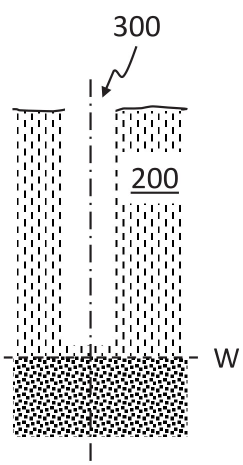


FIG. 3B

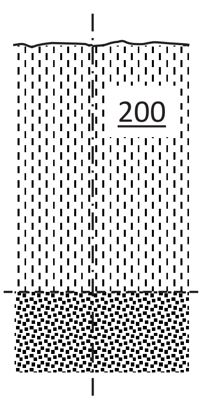


FIG. 3C

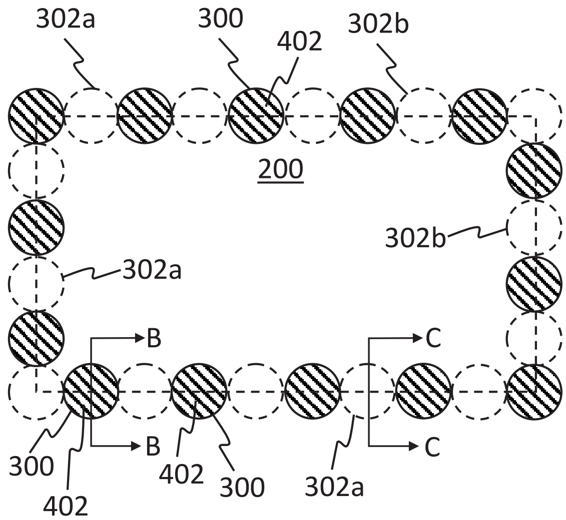


FIG. 4A

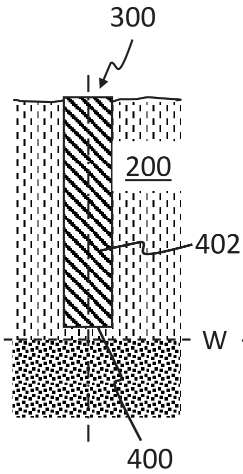


FIG. 4B

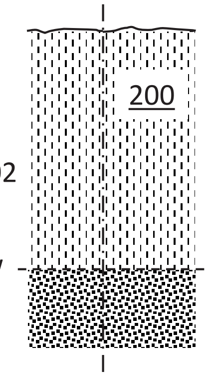


FIG. 4C

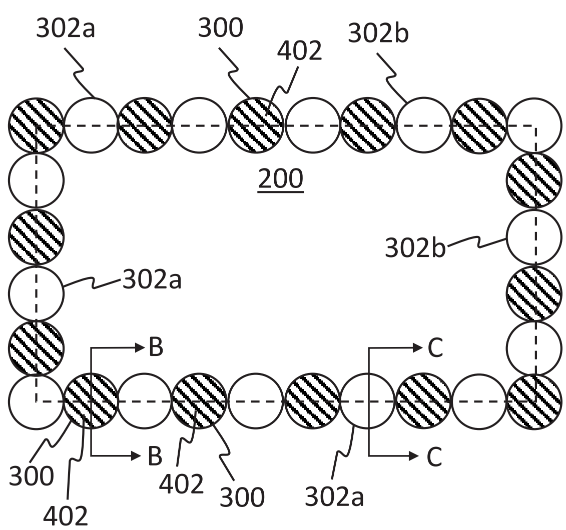


FIG. 5A

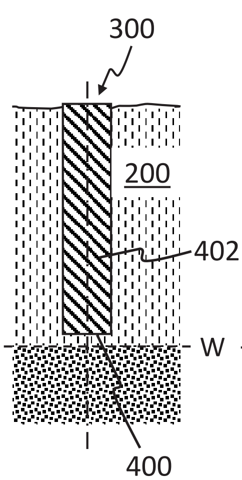


FIG. 5B

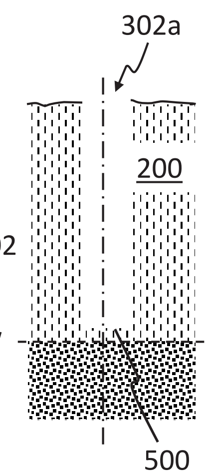


FIG. 5C

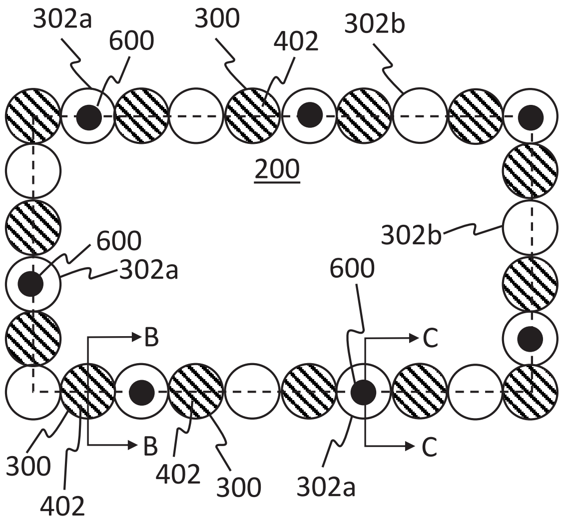


FIG. 6A

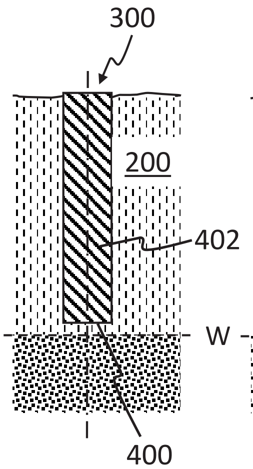


FIG. 6B

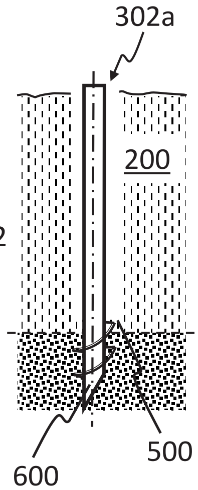


FIG. 6C

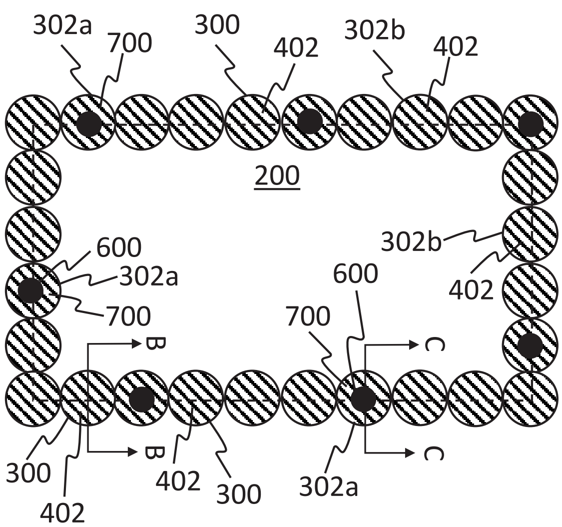


FIG. 7A

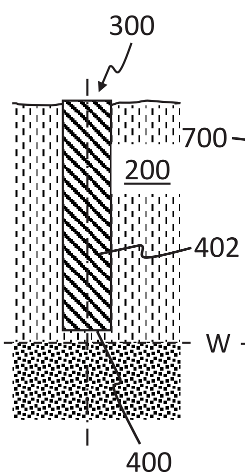


FIG. 7B

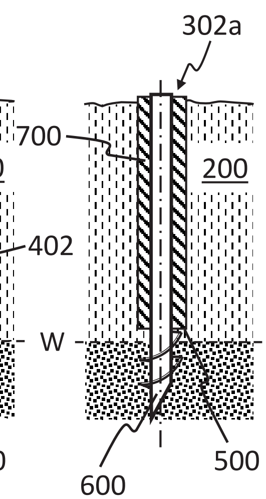


FIG. 7C

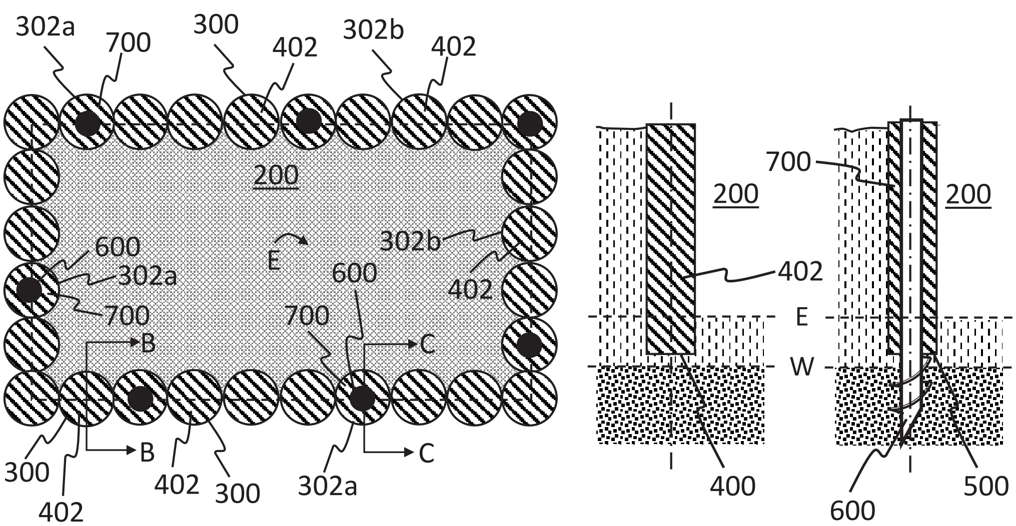


FIG. 8A FIG. 8B FIG. 8C

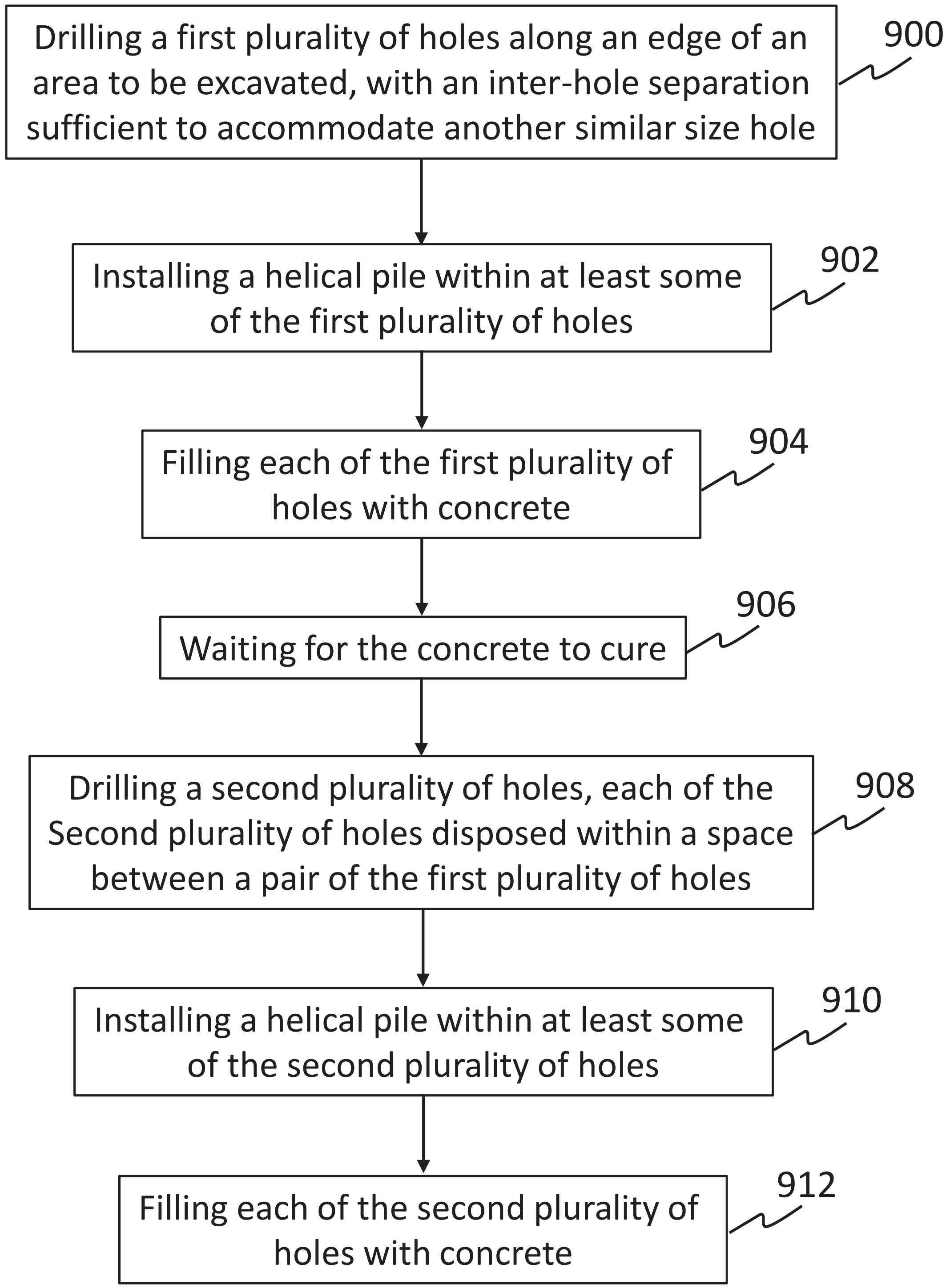
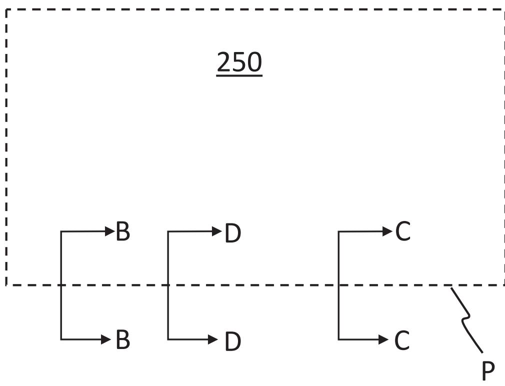

Drilling a first plurality of holes along an edge of an area to be excavated, with an inter-hole separation sufficient to accommodate another similar size hole
900
Installing a helical pile within at least some of the first plurality of holes
902
Filling each of the first plurality of holes with concrete
904
Waiting for the concrete to cure
906
Drilling a second plurality of holes, each of the Second plurality of holes disposed within a space between a pair of the first plurality of holes
908
Installing a helical pile within at least some of the second plurality of holes
910
Filling each of the second plurality of holes with concrete
912

FIG. 9



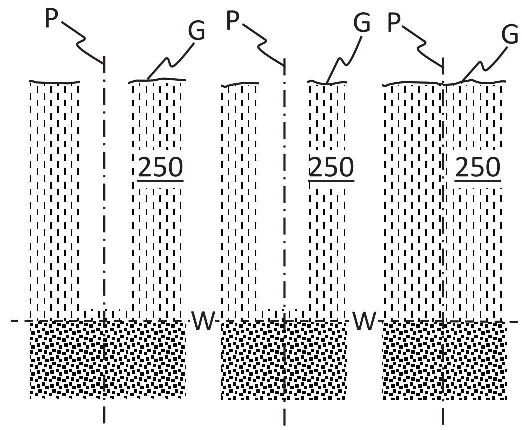
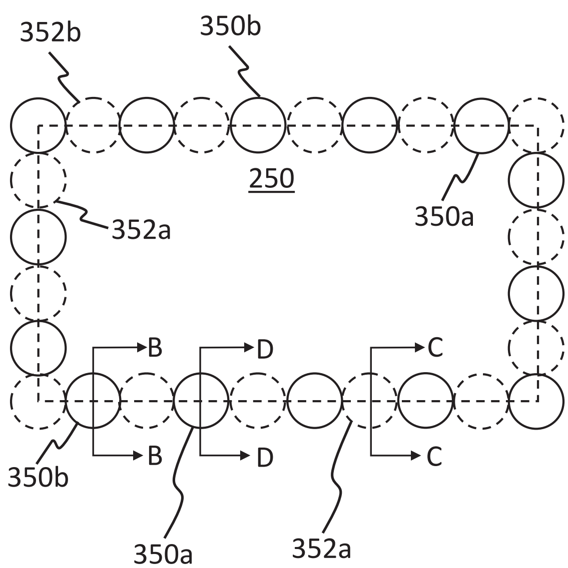


FIG. 10A

FIG. 10B FIG. 10D FIG. 10C



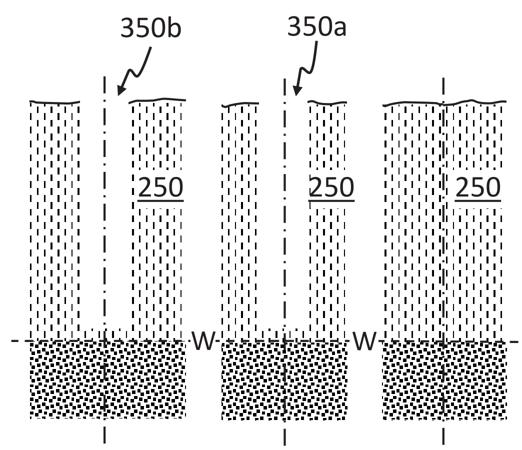


FIG. 11A

FIG. 11B FIG. 11D FIG. 10C

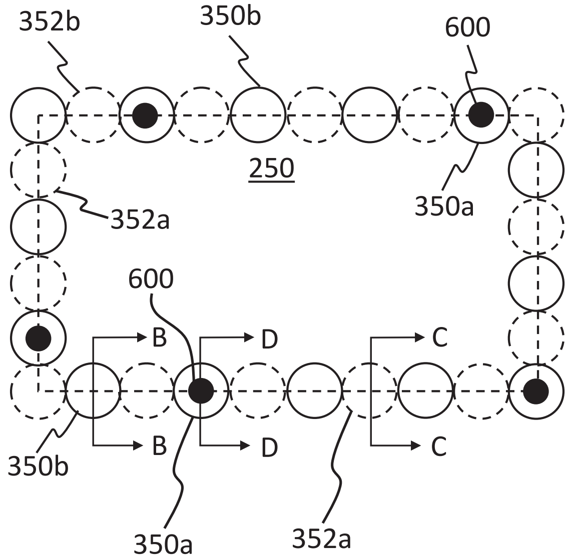


FIG. 12A

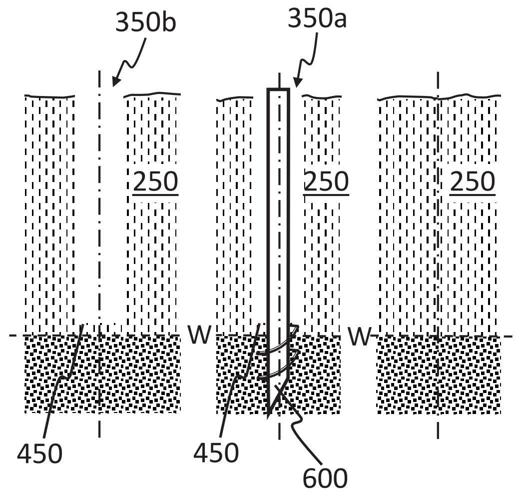


FIG. 12B FIG. 12D FIG. 12C

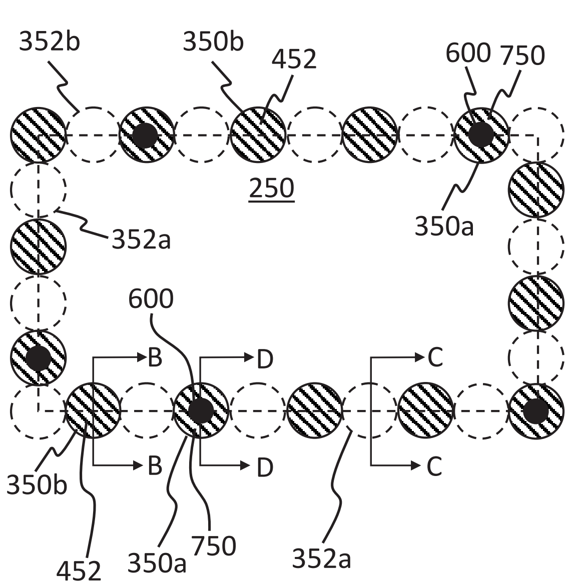


FIG. 13A

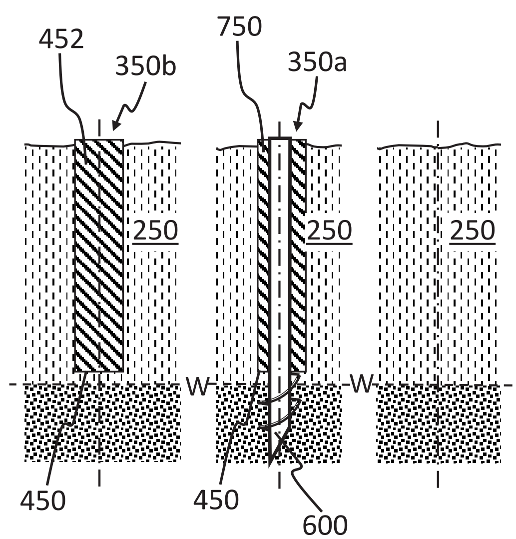


FIG. 13B FIG. 13D FIG. 13C

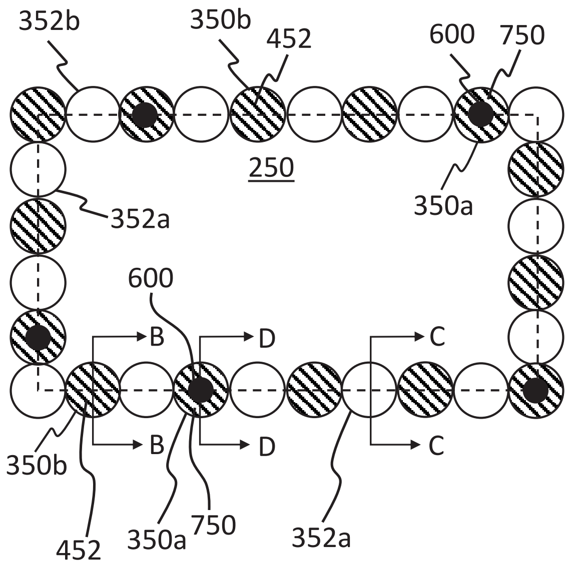


FIG. 14A

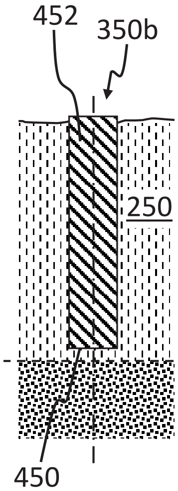


FIG. 14B

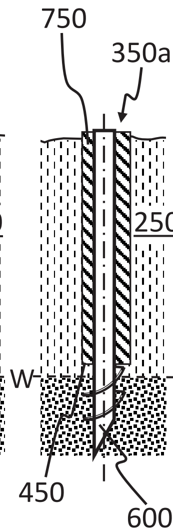


FIG. 14D

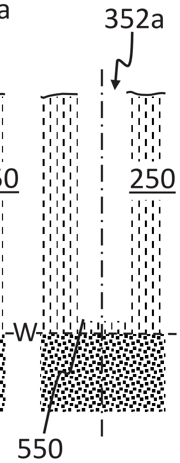


FIG. 14C

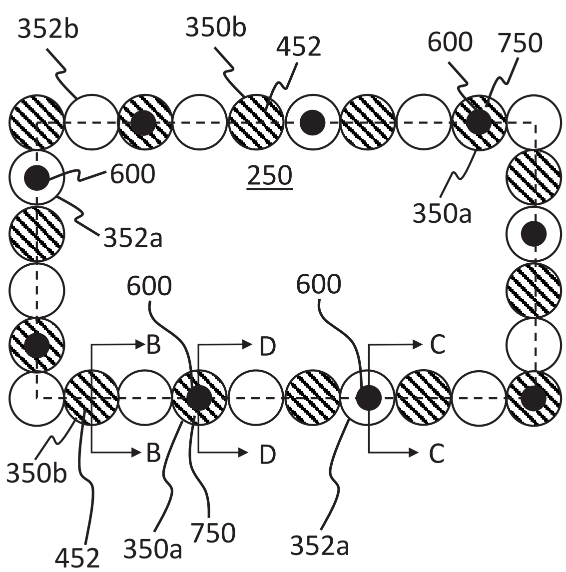


FIG. 15A

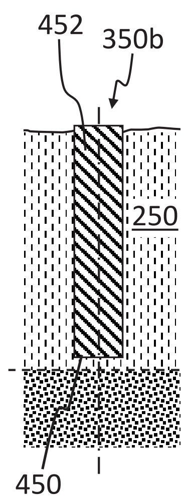


FIG. 15B

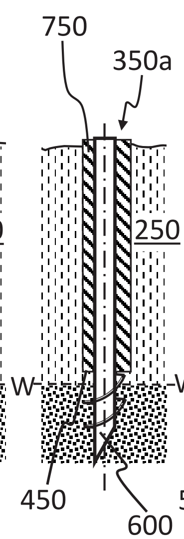


FIG. 15D

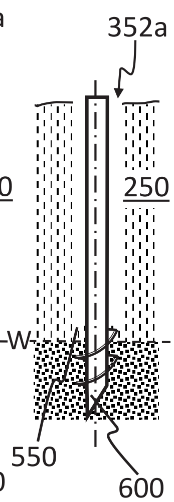


FIG. 15C

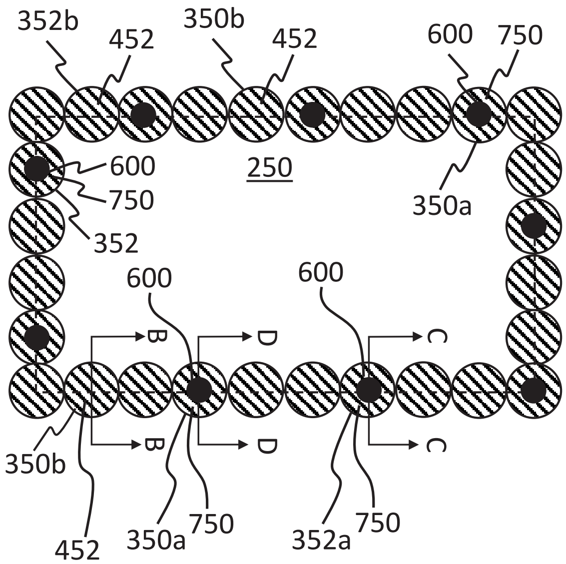


FIG. 16A

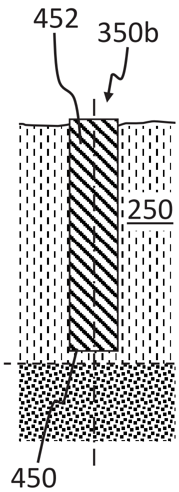


FIG. 16B

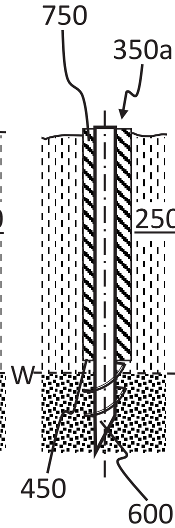


FIG. 16D

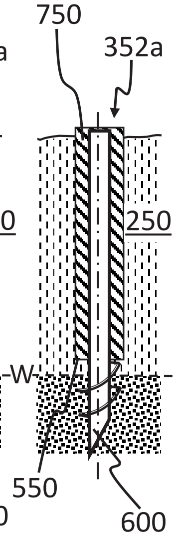


FIG. 16C

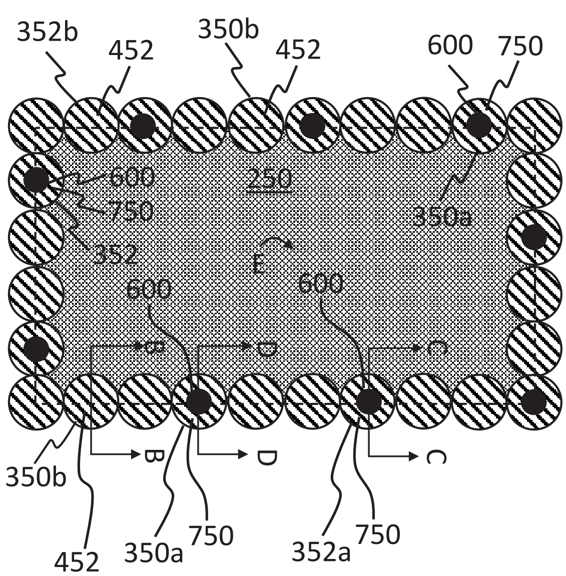


FIG. 17A

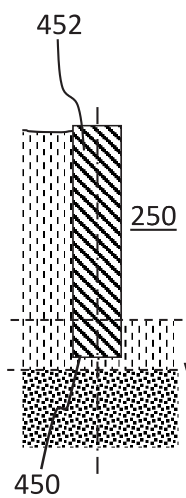


FIG. 17B

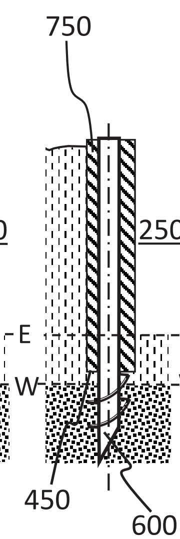


FIG. 17D

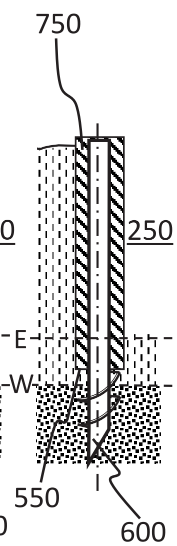


FIG. 17C

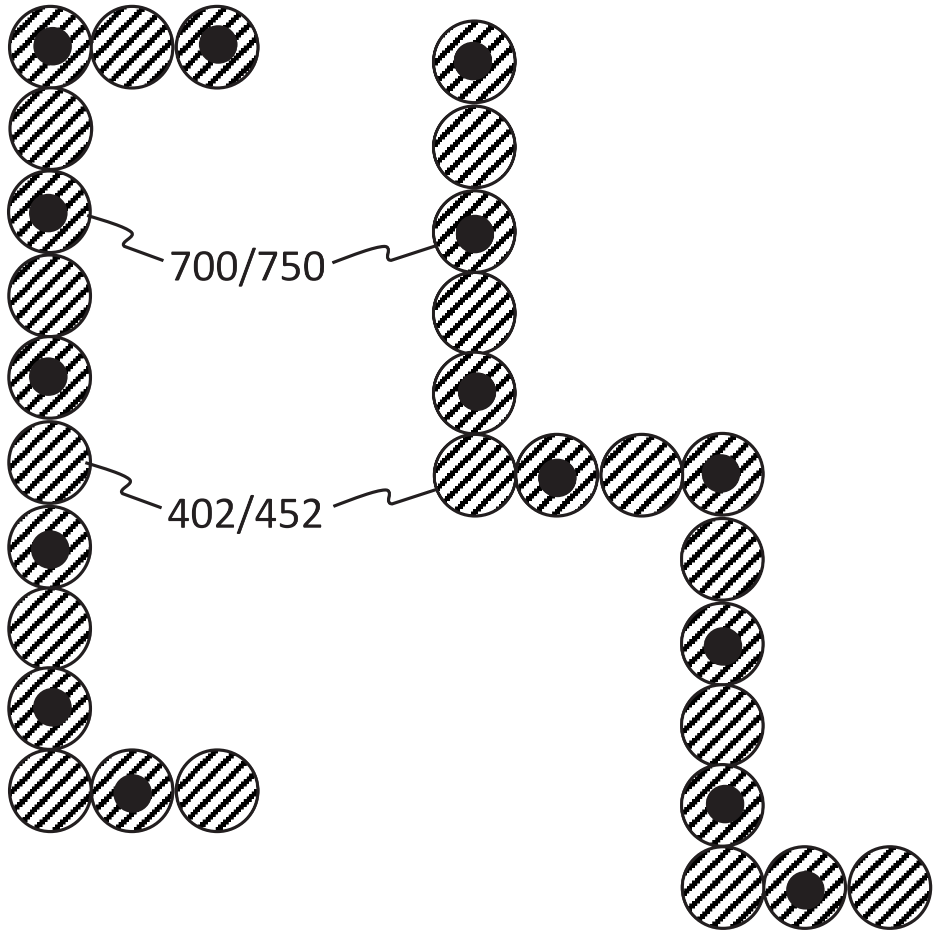


Fig. 18A

Fig. 18B

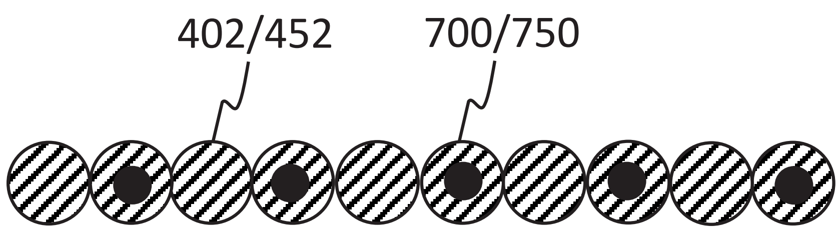


Fig. 18C

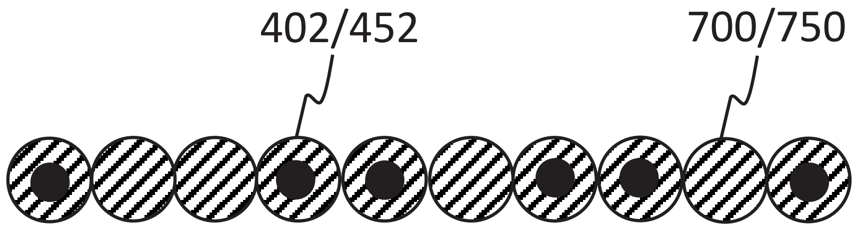


Fig. 19A

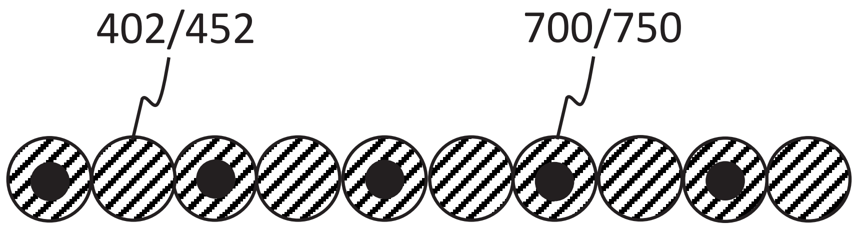


Fig. 19B

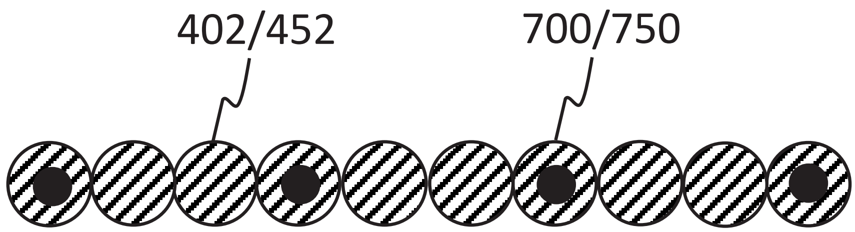


Fig. 19C

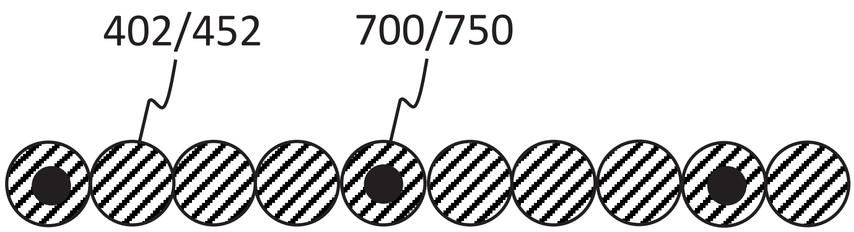


Fig. 19D

FeSolarCurb™

Footprint Engineering has designed the FeSolarCurb. This specialized frame holds an array of photovoltaic cells while featuring a pathway for warm air to keep the cells clear of cover. The air is circulated in a tube throughout the frame with outlets to strategically direct it at the solar cells. The movement of air can be easily controlled by the owner manually or automatically to reduce waste and excess costs. The elevated frame also reduces the need to adhere panels directly onto a roof or other surface.

A true game changer, the FeSolarCurb is the solution owners and the planet need at the time it's needed most.

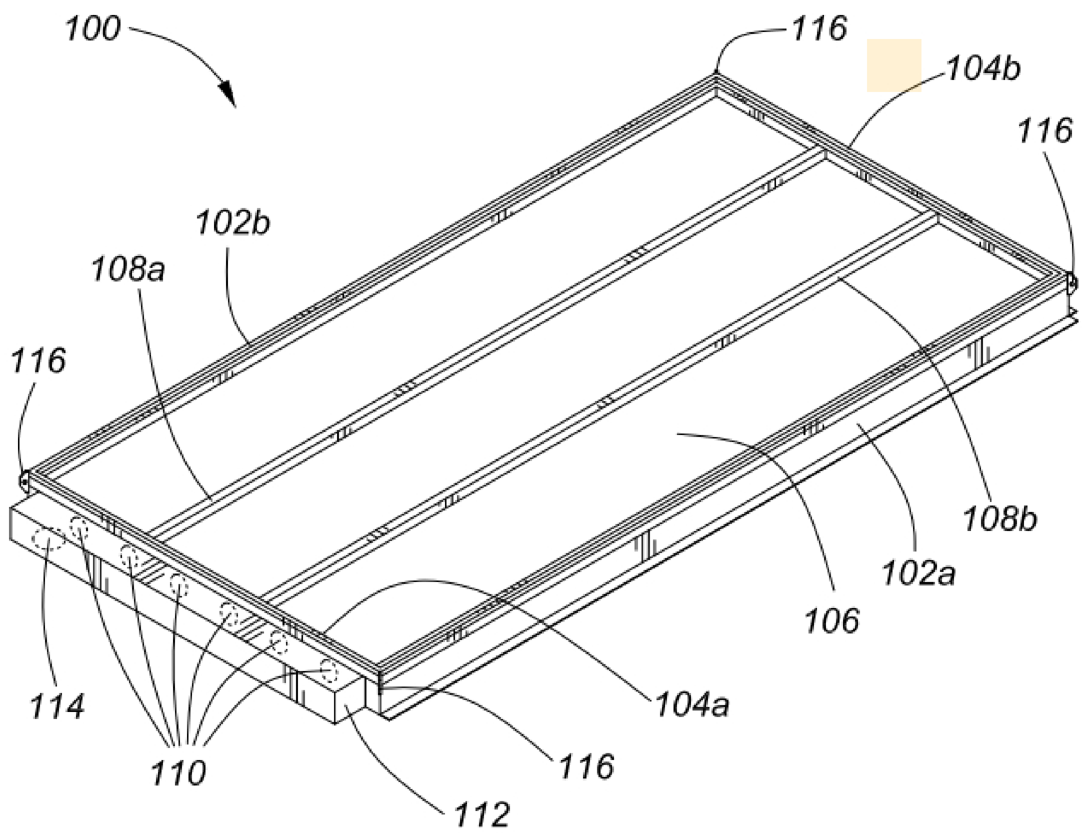


FIG. 1

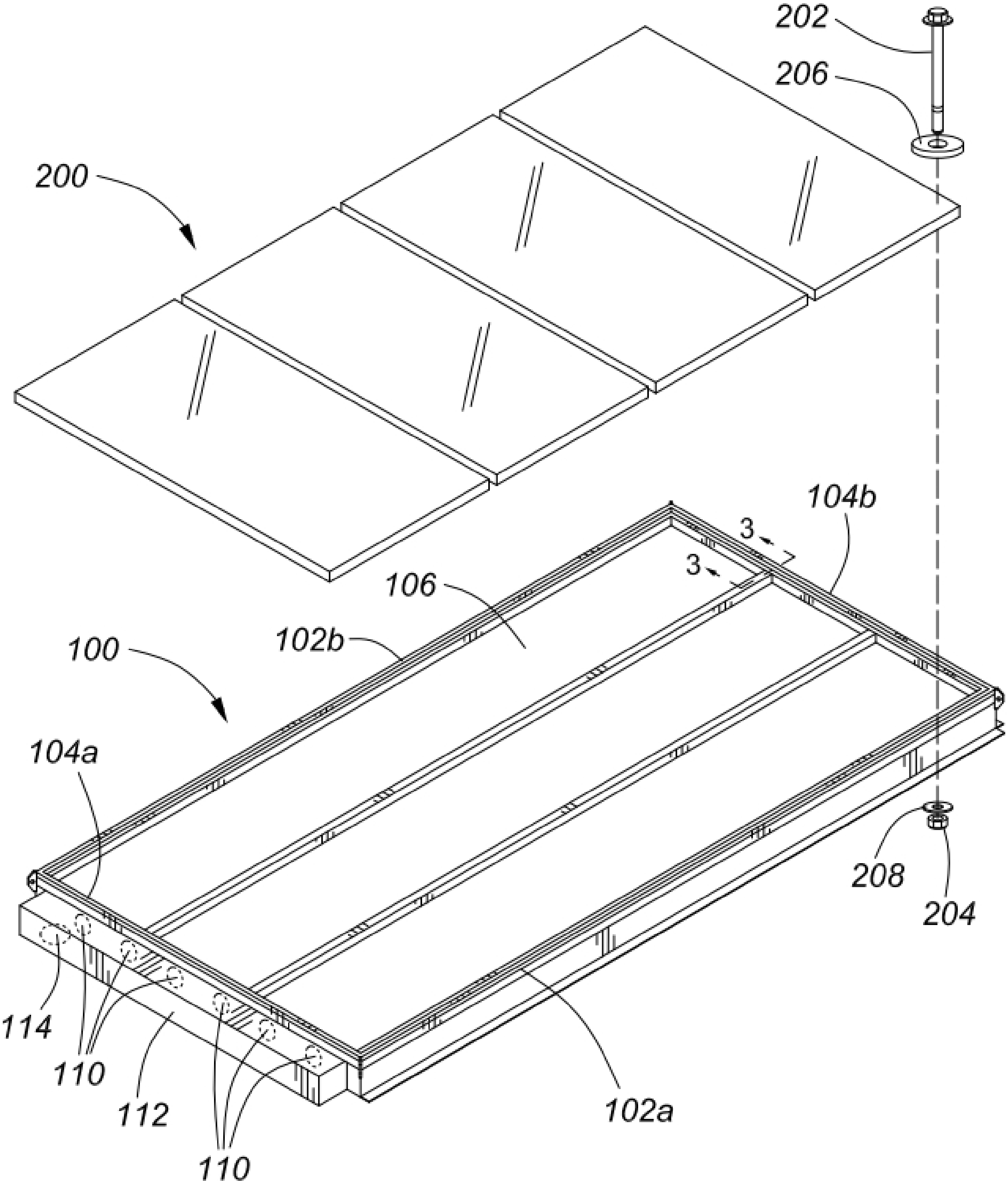

202
206
200
104b
3
3
106
102b
100
104a
208
204
114
110
112
110
102a

FIG. 2

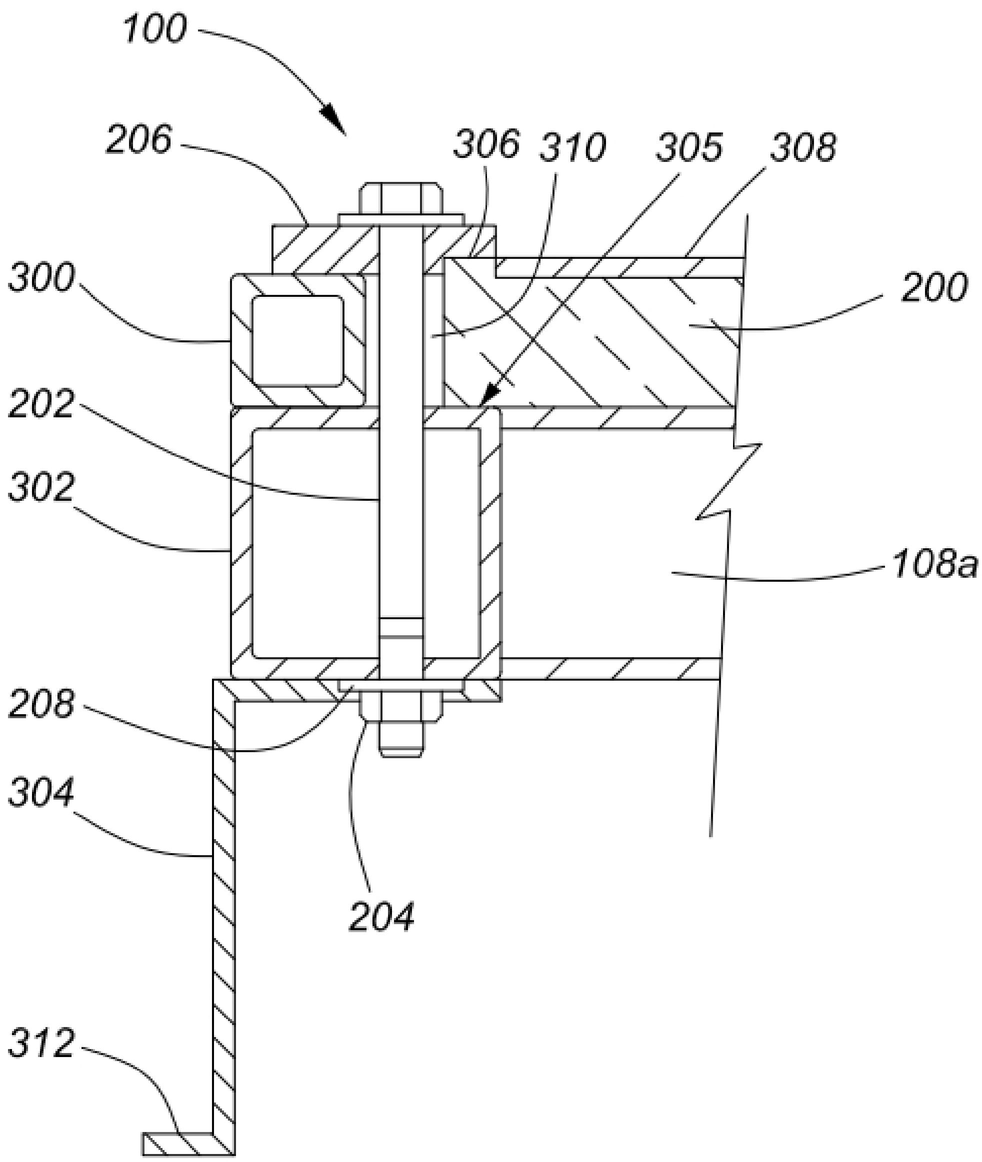


FIG. 3

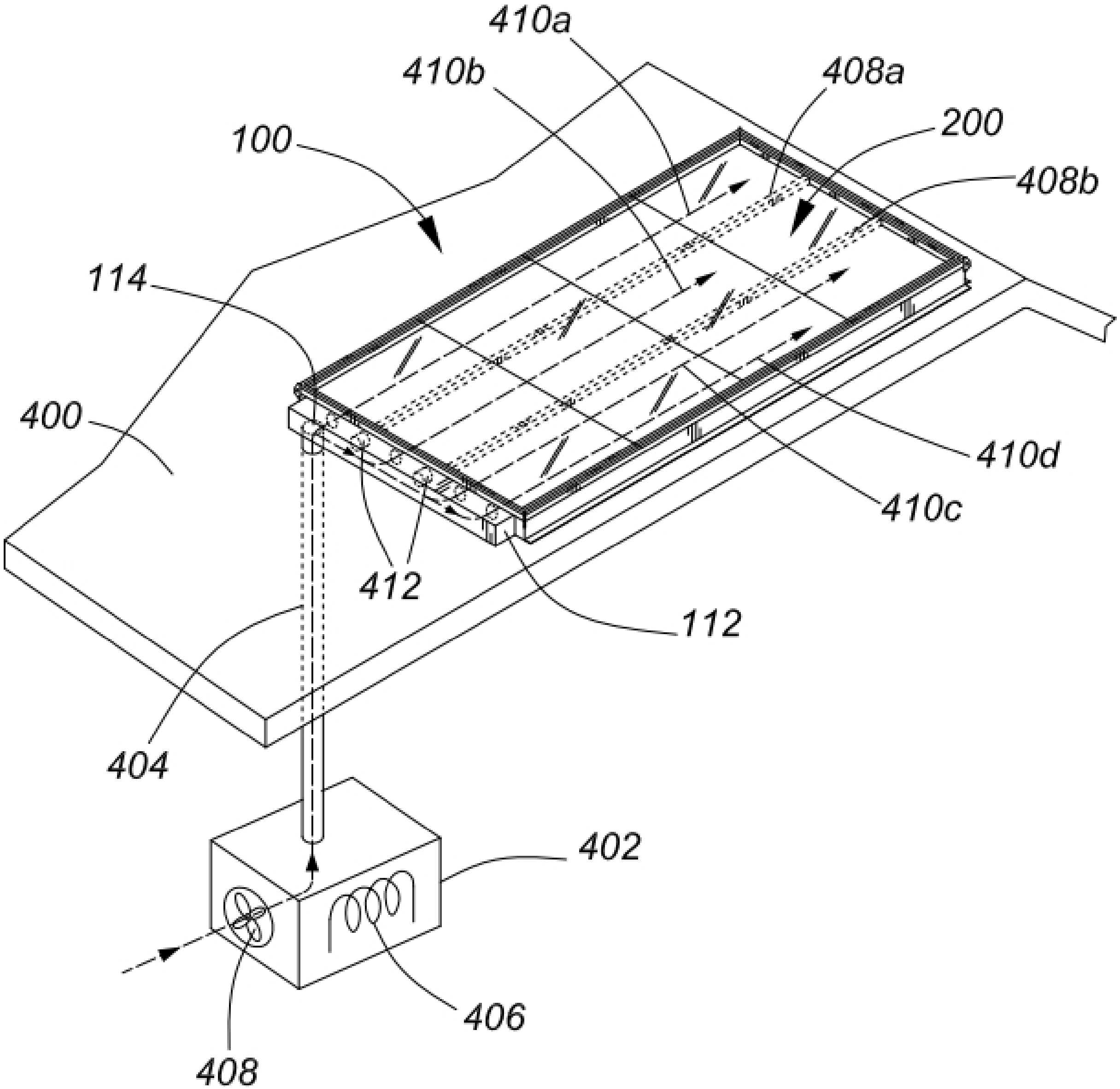

410a
410b
408a
200
100
408b
114
400
410d
410c
412
112
404
402
406
408

FIG. 4

Dessin industriel / Industrial Design

AVIS D'ENREGISTREMENT / NOTICE OF REGISTRATION

202960

Numéro d'enregistrement
Registration number

Conformément à la Loi sur les dessins industriels, le demandeur est par la présente avisé de l'enregistrement du dessin industriel identifié ci-contre et représenté en annexe.

Pursuant to the Industrial Design Act, the applicant is hereby notified of the registration of the industrial design identified hereto and depicted in annex.

Numéro d'enregistrement international / International registration number
N/A

Date d'enregistrement / Date of registration
04 NOV / NOV 2022

Date de dépôt de la demande / Filing date of the application
21 AVR / APR 2021

Date d'accessibilité au public / Date application made available to the public
04 NOV / NOV 2022

Nom de l'objet fini / Name of the finished article
SOLAR PANEL FRAME WITH PLENUM

Propriétaire(s) inscrit(s) / Registered proprietor(s)
HC PROPERTIES INC.
81019 MAITLAND LINE RR2
CLINTON, ON N0M 1L0
CANADA

Membre du personnel du bureau du commisaire aux brevets
Officer of the Office of the Commissioner of Patents

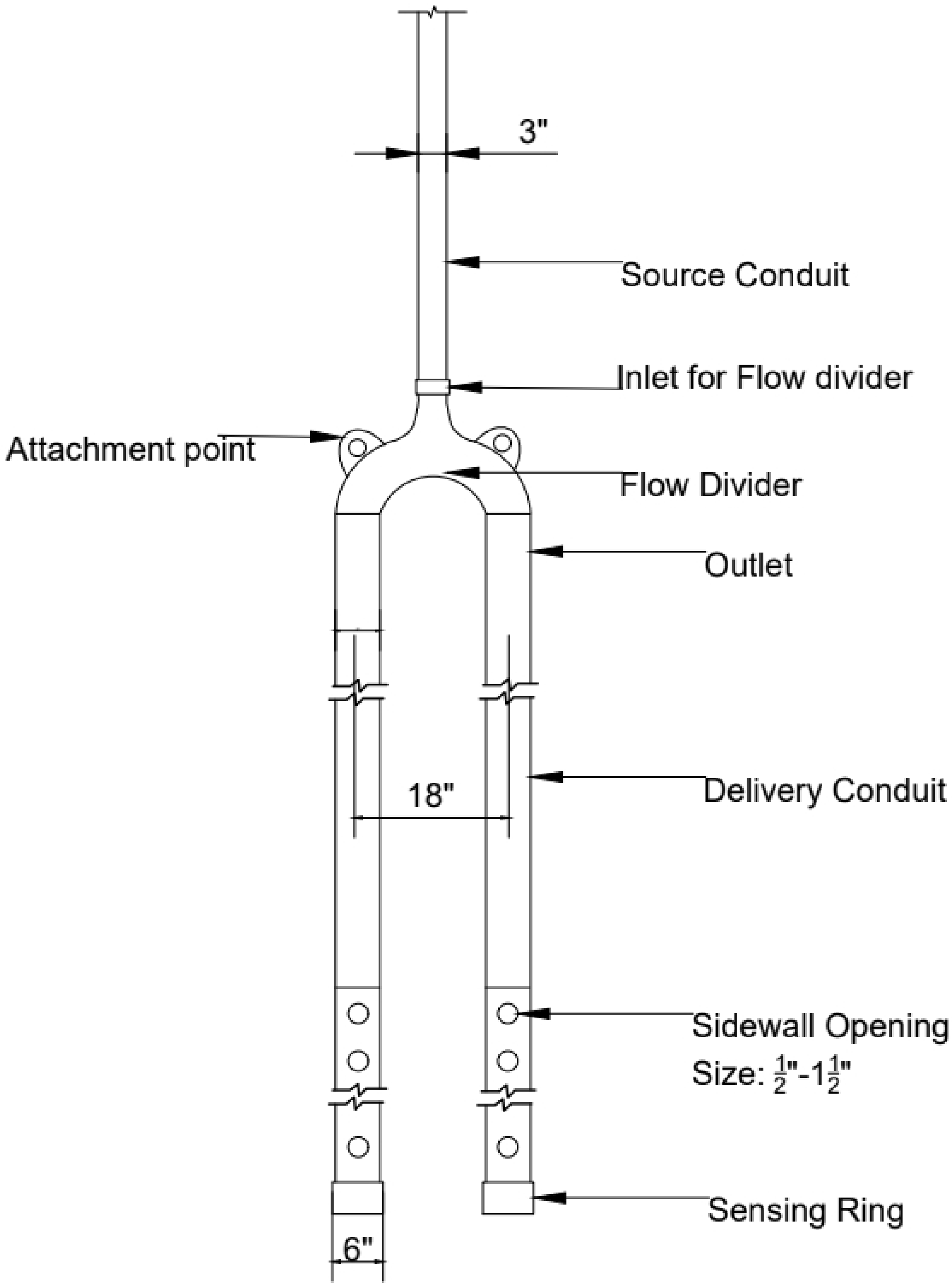
Canada

FeTremie™

A system for forming a permeable reactive barrier includes a source conduit for providing a substantially dry barrier-forming material at an initial flow velocity, at a markedly lower cost in hard rock and clay soils. This is for the site contaminant management of iron sand typically.

A delivery conduit arrangement is in fluid communication with the source conduit and includes a first delivery conduit and a second delivery conduit. The first and second delivery conduits each have an outlet end for being positioned proximate a bottom of respective spaced-apart boreholes in the ground. The first and second delivery conduits each have one or more openings defined in respective sidewalls thereof proximate the outlet ends thereof, for venting air that is entrained in the flow of the material.

A total cross-sectional area of a flow path increases between the source conduit and the outlet ends of the first and second delivery conduits. During operation a final flow velocity of the barrier-forming material is at least about 30% less than the initial flow velocity.



Footprint Engineering Inc.

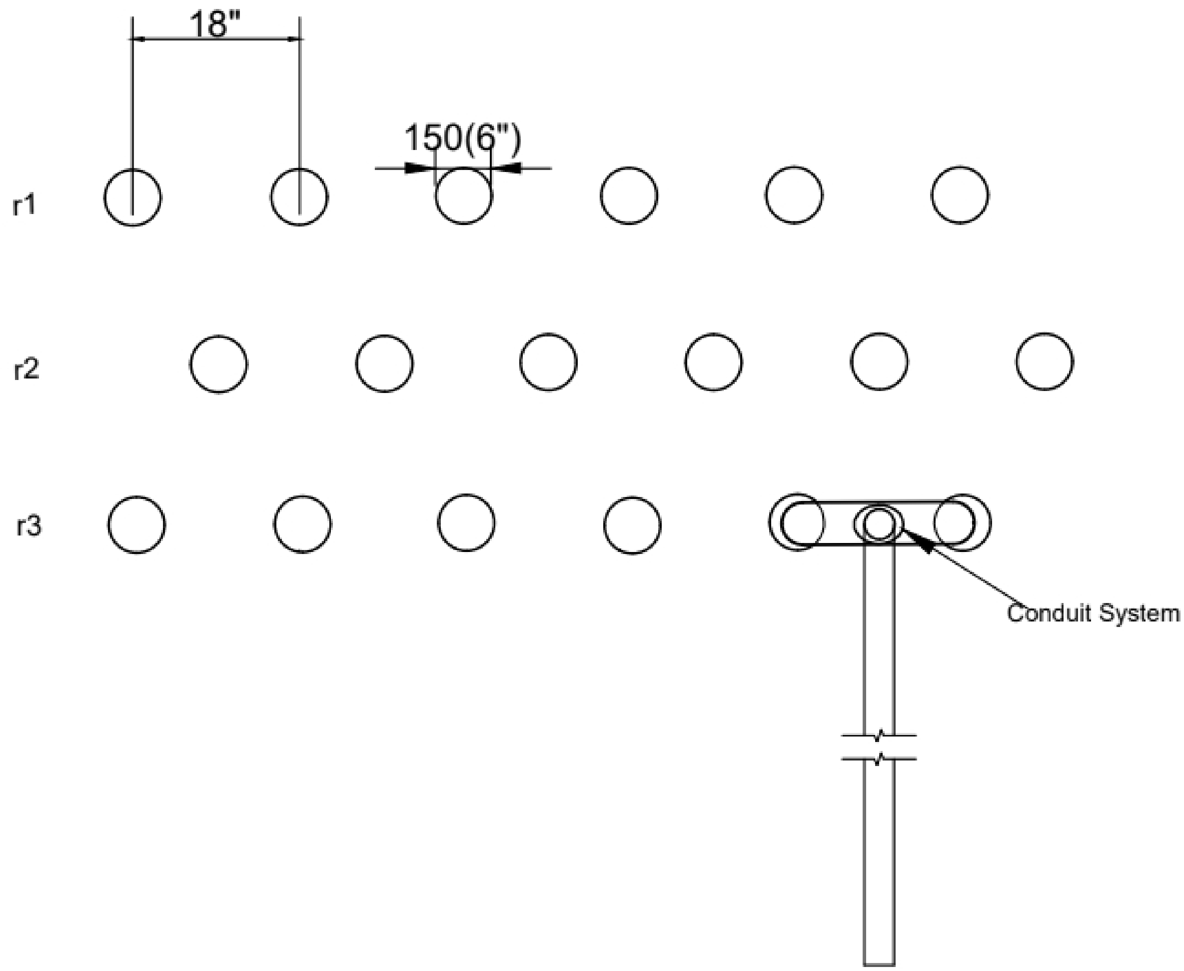
Feng

FeTremie (Fig 1)

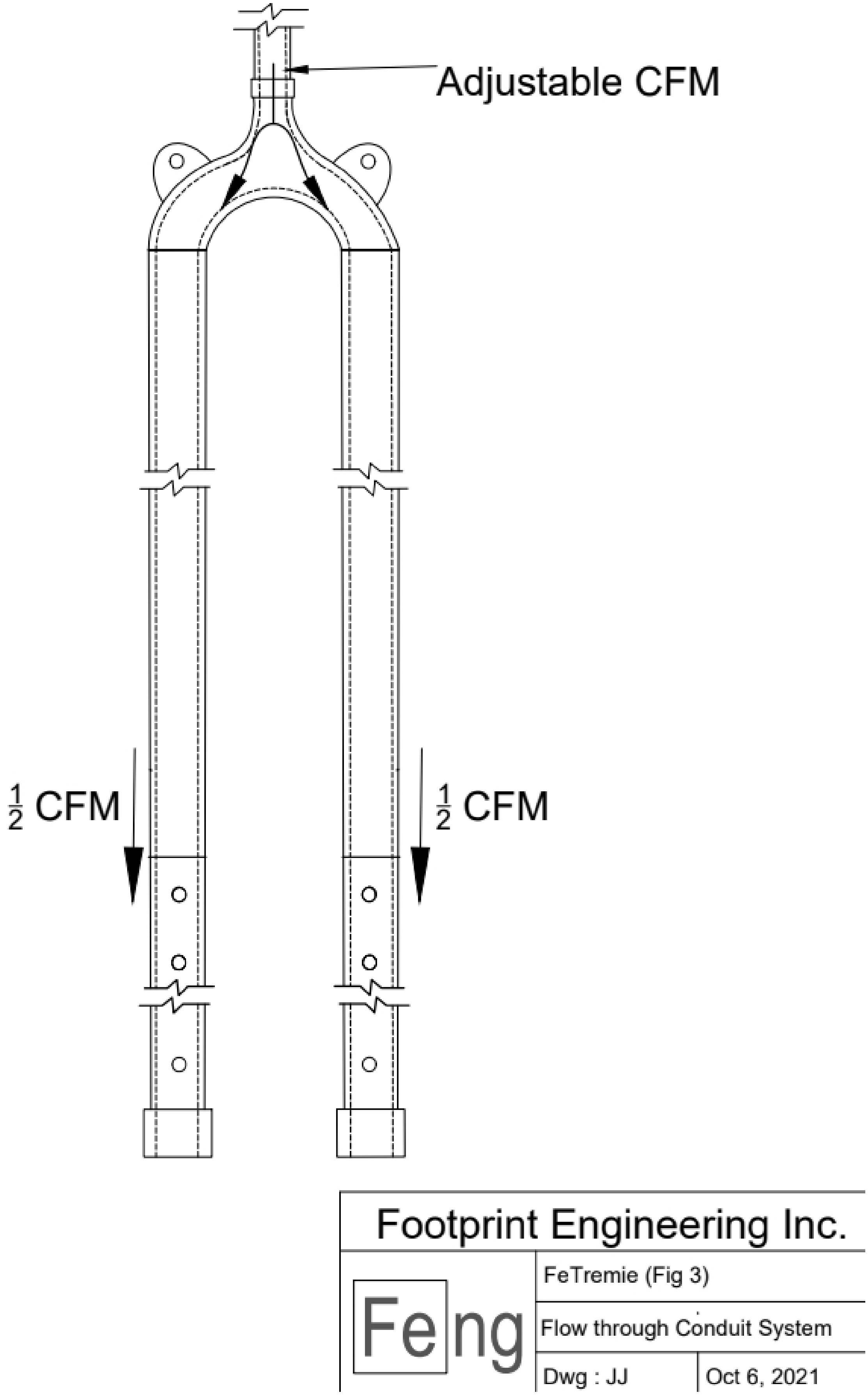
Conduit Arrangement

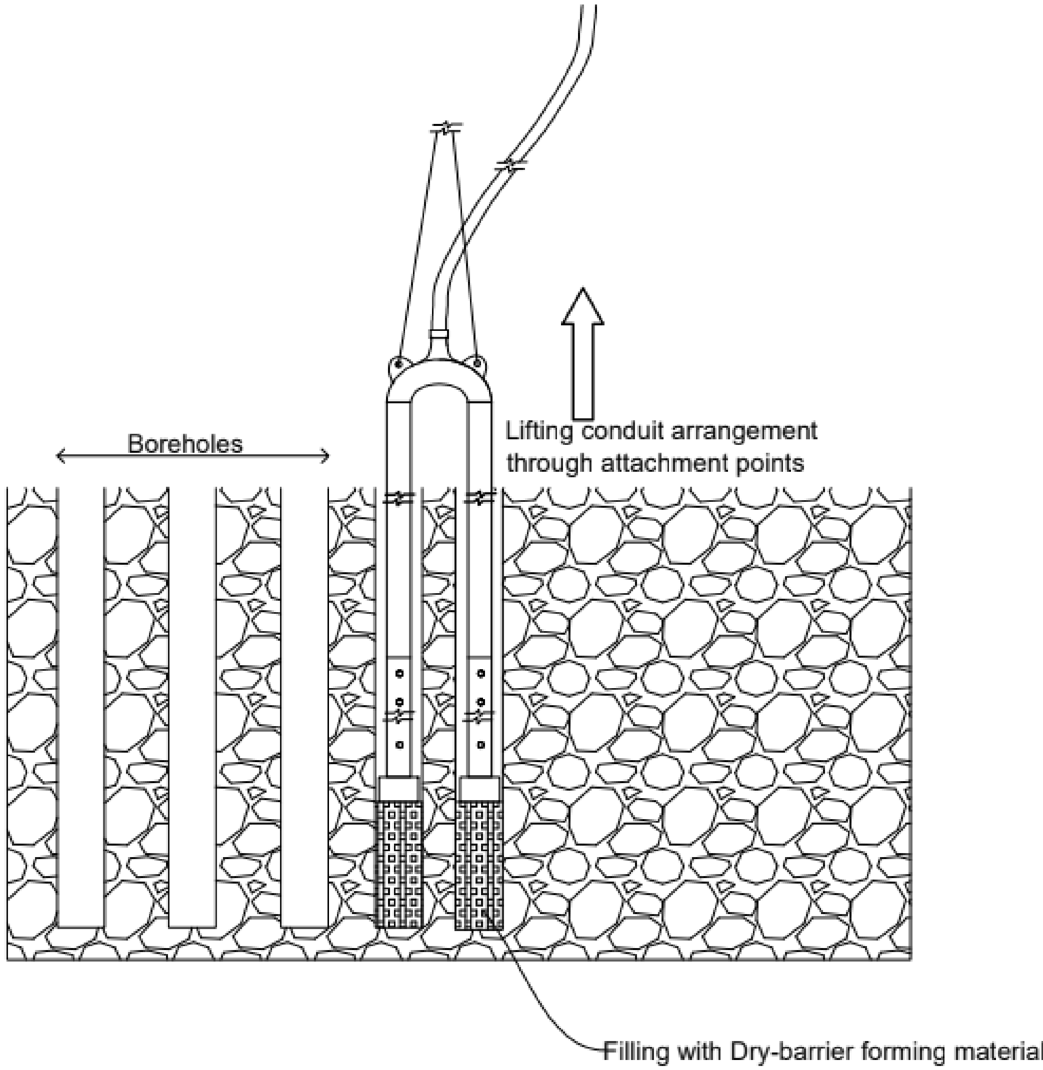
Dwg : JJ

Oct 6, 2021



Footprint Engineering Inc.	
Feng	FeTremie (Fig 2)
	Plan: Tremie Operation
	Dwg : JJ / Oct 6, 2021


Adjustable CFM
½ CFM
½ CFM
Footprint Engineering Inc.
Feng
FeTremie (Fig 3)
Flow through Conduit System
Dwg : JJ
Oct 6, 2021



Footprint Engineering Inc.

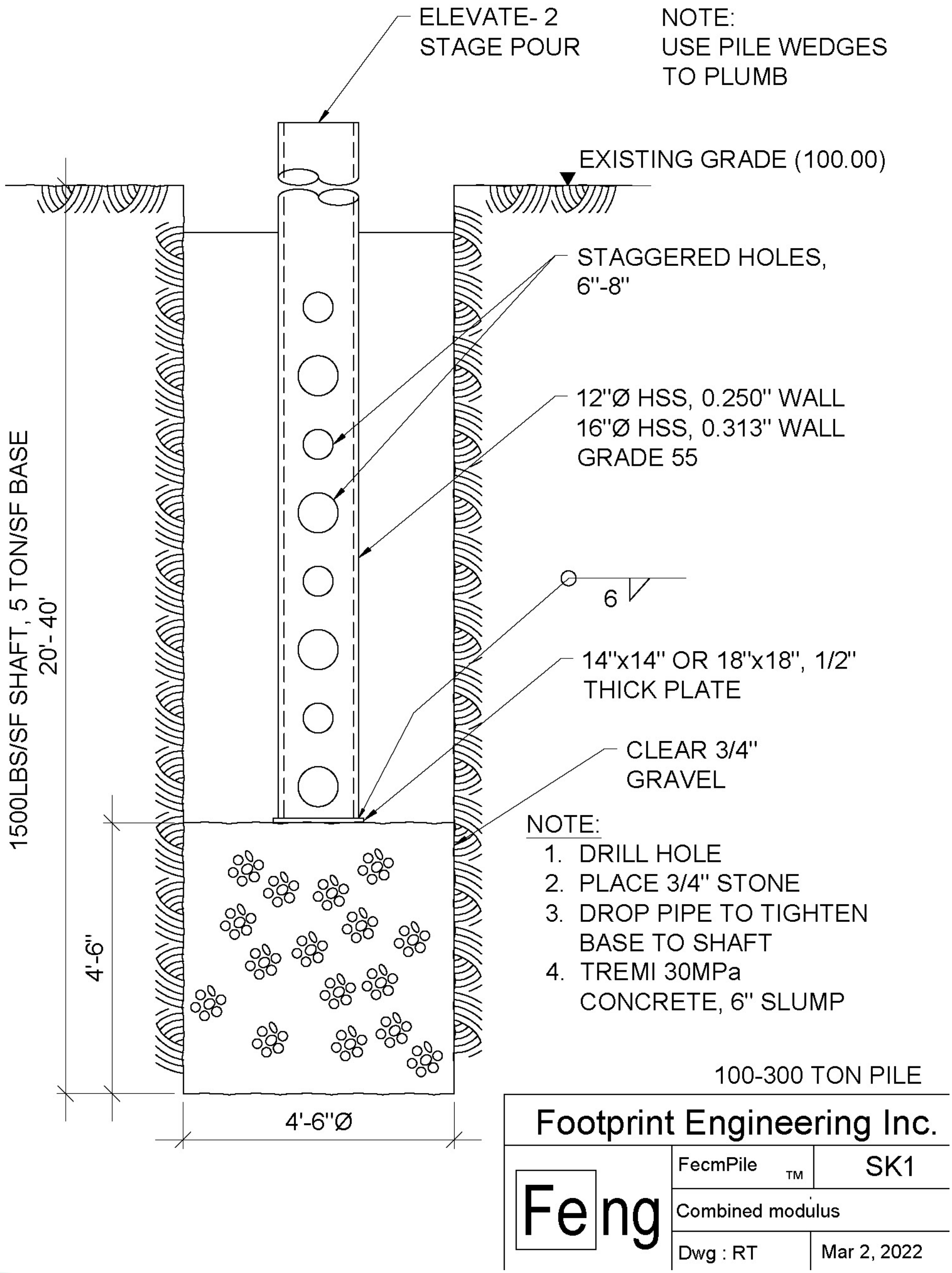
Feng	FeTremie (Fig 3)	
	Elevation: Tremie Operation	
	Dwg : JJ	Sep 28, 2021

FeCMPile

The Footprint Engineering Combined Modulus Pile (FeCMPile) is a method of forming an elongated support column in the ground. Specifically, our method comprises of drilling a hole of a predetermined depth and diameter.

The bottom of the drilled hole is then filled with 3 to 8 feet of gravel. A hollow driving tube with several pre-cut holes at the bottom near a welded end cap is then used to compress the ground below the gravel as it is inserted into the drilled hole with the gravel below the column to secure the driving tube in place. Essentially, the base and shaft friction are mobilized together in “drill open soil” conditions. Once the driving tube is secured in place and plumbed, liquid concrete is then poured into the top end of the driving tube. The concrete that accumulates at the bottom end of the driving tube then passes through the radial apertures onto exposed gravel and into a space between an exterior wall of the drilled hole and the soil wall.

The driving tube and gravel become one, thus allowing it to be considered as a single entity which is friction fit into the hole. As such, the pile is robust to pull-out, and superior in down load resistance as greater shearing forces at the hole/pile, and pipe/gravel interfaces combine to move as one combined modulus unit. This then ensures that capacities in the range of 100-250 tons are achieved.


ELEVATE- 2
STAGE POUR
NOTE:
USE PILE WEDGES
TO PLUMB
EXISTING GRADE (100.00)
STAGGERED HOLES,
6"-8"
12"Ø HSS, 0.250" WALL
16"Ø HSS, 0.313" WALL
GRADE 55
6
14"x14" OR 18"x18", 1/2"
THICK PLATE
CLEAR 3/4"
GRAVEL
1500LBS/SF SHAFT, 5 TON/SF BASE
20'- 40'
4'-6"
4'-6"Ø
NOTE:
1. DRILL HOLE
2. PLACE 3/4" STONE
3. DROP PIPE TO TIGHTEN
BASE TO SHAFT
4. TREMI 30MPa
CONCRETE, 6" SLUMP
100-300 TON PILE
Footprint Engineering Inc.
Feng
FecmPile TM
SK1
Combined modulus
Dwg : RT
Mar 2, 2022

FinalCrete FeCs MEDA Mix

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TXON GRIZZLY REINFORCEMENT PRODUCTS®

MEDA Engineers Windsor
David Lawn - Canada/USA
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FINALCRETE FeCs MEDA SLAB FLOORING

150 MM SLUMP

	M3	Yard
Cement	350 kg	706 lbs
Water	95 kg	190 lbs
Basaltic 32mm	9 kg	18.2 lbs
Sand	630 kg	1271 lbs
15mm stone	1290 kg	2610 lbs

FeCs (Site Slump Adjust)
C Silica 8-10 oz/100lbs cement

FINALCRETE FeCs MEDA - WALL - SHOTCRETE

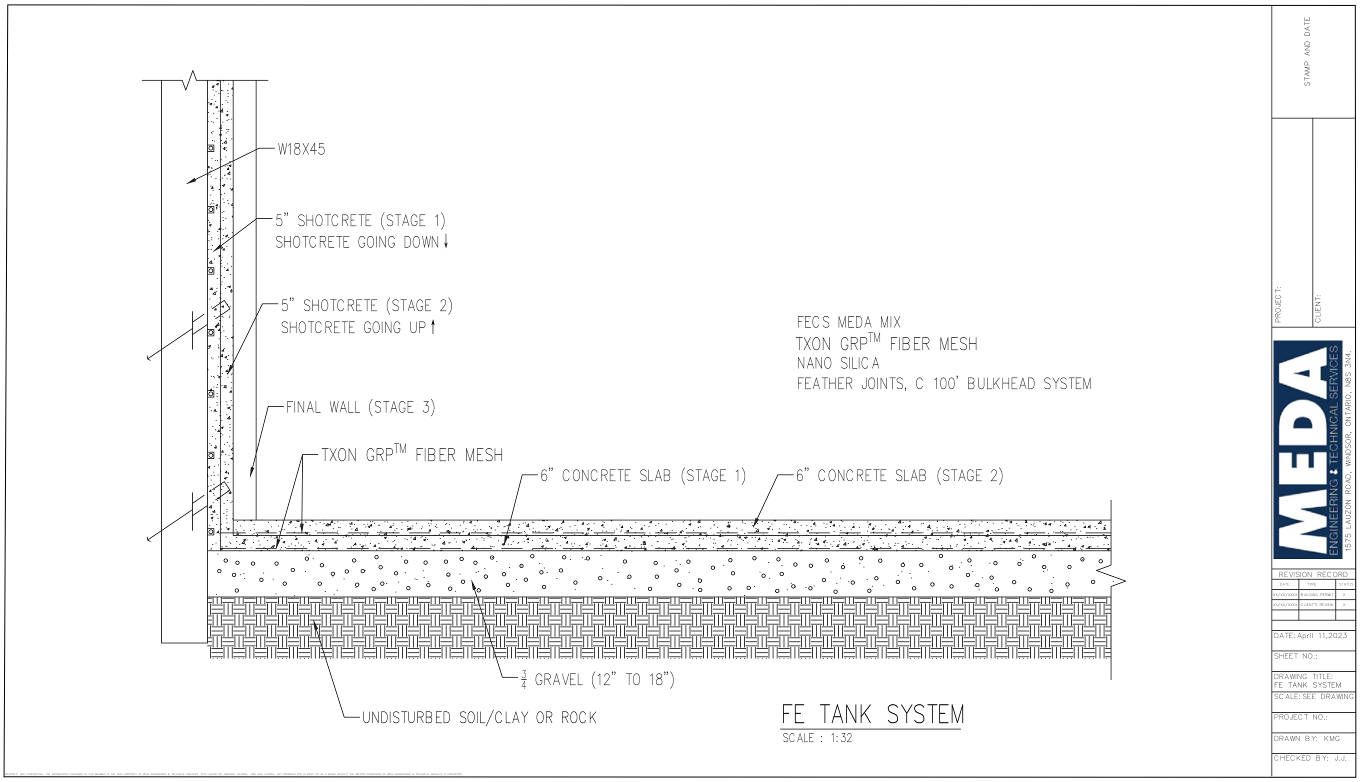
100 MM SLUMP

Cement	375 kg	756 lbs
Water	90 kg	180 lbs
Basaltic 32mm	9 kg	18.1 lbs
Sand	675 kg	1250 lbs
10mm stone	1245 kg	2500 lbs

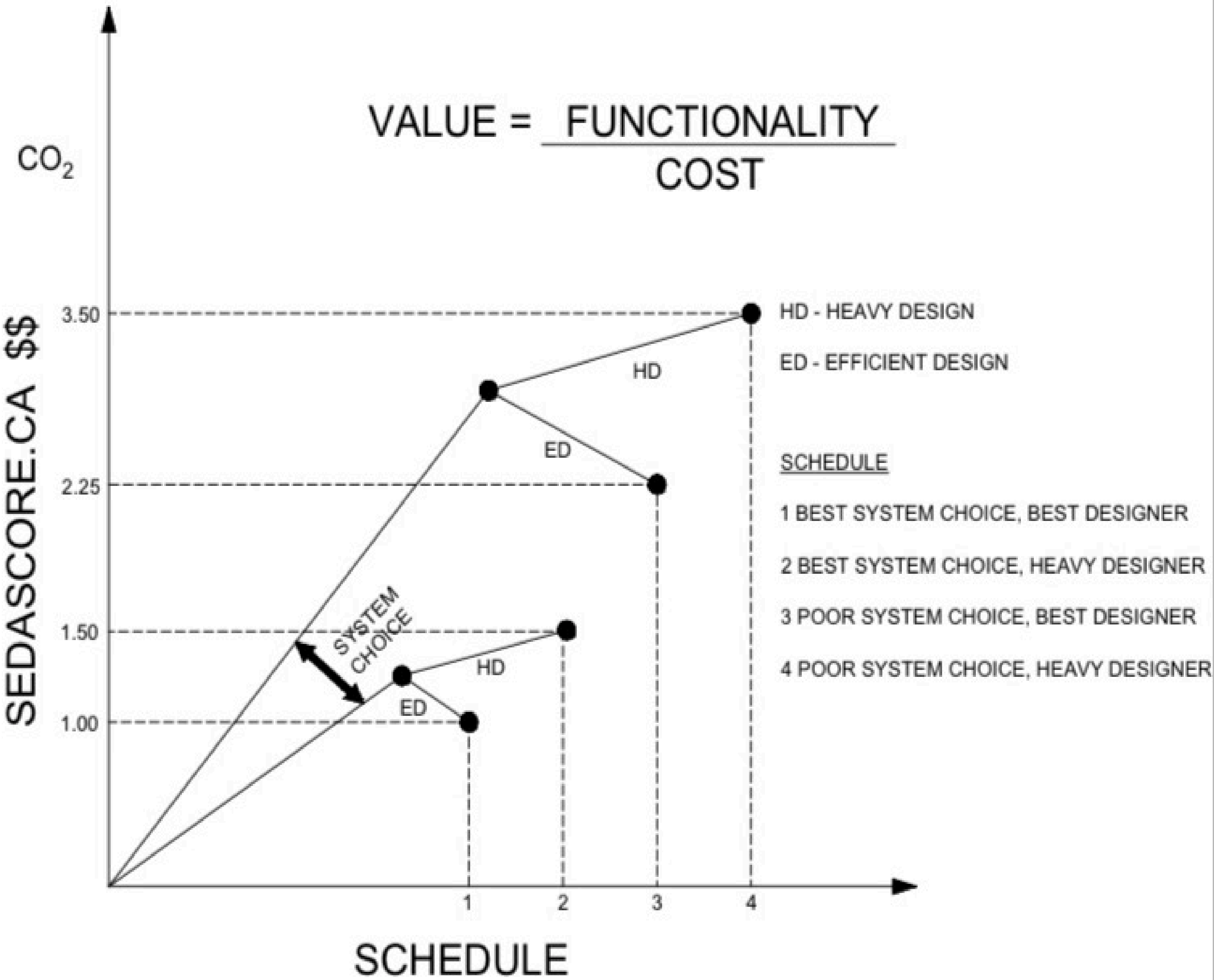
FeCs (Site Slump Adjust)
C Silica 8-10 oz/100lbs cement

50th ANNIVERSARY MEDA ENGINEERING & TECHNICAL SERVICES solutions driven

FeTank



W18X45
5" SHOTCRETE (STAGE 1)
SHOTCRETE GOING DOWN
5" SHOTCRETE (STAGE 2)
SHOTCRETE GOING UP
FINAL WALL (STAGE 3)
TXON GRPTM FIBER MESH
6" CONCRETE SLAB (STAGE 1)
6" CONCRETE SLAB (STAGE 2)
FECS MEDA MIX
TXON GRPTM FIBER MESH
NANO SILICA
FEATHER JOINTS, C 100' BULKHEAD SYSTEM
¾" GRAVEL (12" TO 18")
UNDISTURBED SOIL/CLAY OR ROCK
FE TANK SYSTEM
SCALE : 1:32
STAMP AND DATE
PROJECT:
CLIENT:
MEDA
ENGINEERING & TECHNICAL SERVICES
1575 LAUZON ROAD, WINDSOR, ONTARIO, N8S 3N4.
REVISION RECORD
DATE
TYPE
STATUS
XX/XX/XXXX
BUILDING PERMIT
X
XX/XX/XXXX
CLIENT'S REVIEW
X
DATE: April 11,2023
SHEET NO.:
DRAWING TITLE:
FE TANK SYSTEM
SCALE: SEE DRAWING
PROJECT NO.:
DRAWN BY: KMG
CHECKED BY: J.J.



FSVE - FENG SYSTEM VALUE ENGINEERING CHART

WE LOWER YOUR CARBON FOOTPRINT

YOU LOWER PROJECT COST & PROJECT SCHEDULE

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FSVE - FENG SYSTEM VALUE ENGINEERING CHART

DRAWN BY: MH | REVISION: R2
ISSUE DATE: 05 JAN 2023
VALUE ENGINEER: MH
FILE NAME: FSVE

Feng