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(54) SUPPORTED UNDERPINNING PIERS

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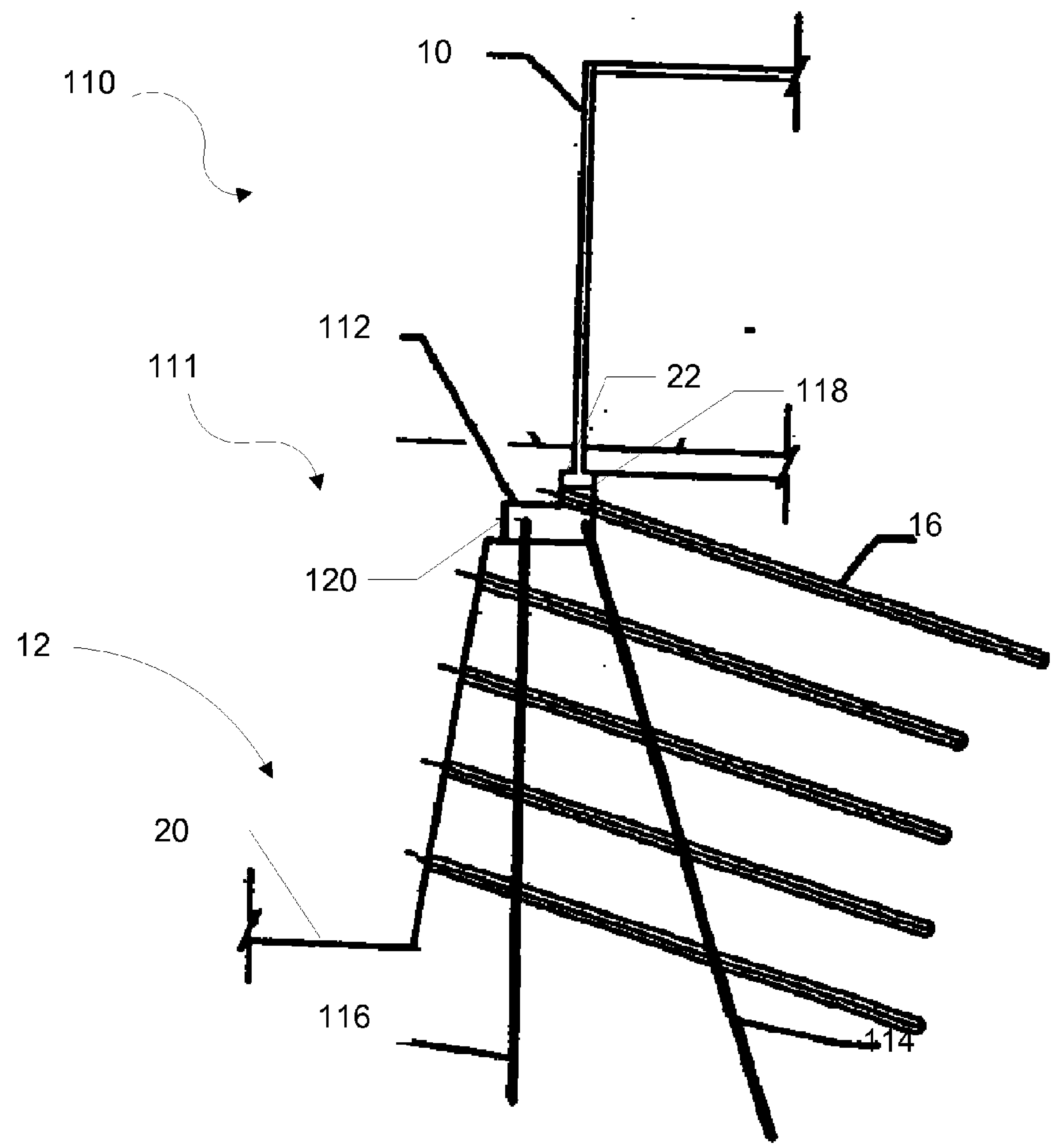
(57) ABSTRACT

An underpinning system is provided that includes a supported underpinning pier. The underpinning pier supports a structure's foundation and may have one or more elongated support members attached thereto. The elongated support members may be micropiles, driven piles or helical piles. The underpinning pier may have a variety of configurations. In one configuration, the underpinning pier extends laterally outside of the structure's existing foundation and is attached to one or more micropiles at an exterior region of the underpinning pier, which resists the application of bending moments to the underpinning pier. A method is also provided for installing the underpinning system and/or the micropile supported underpinning pier.



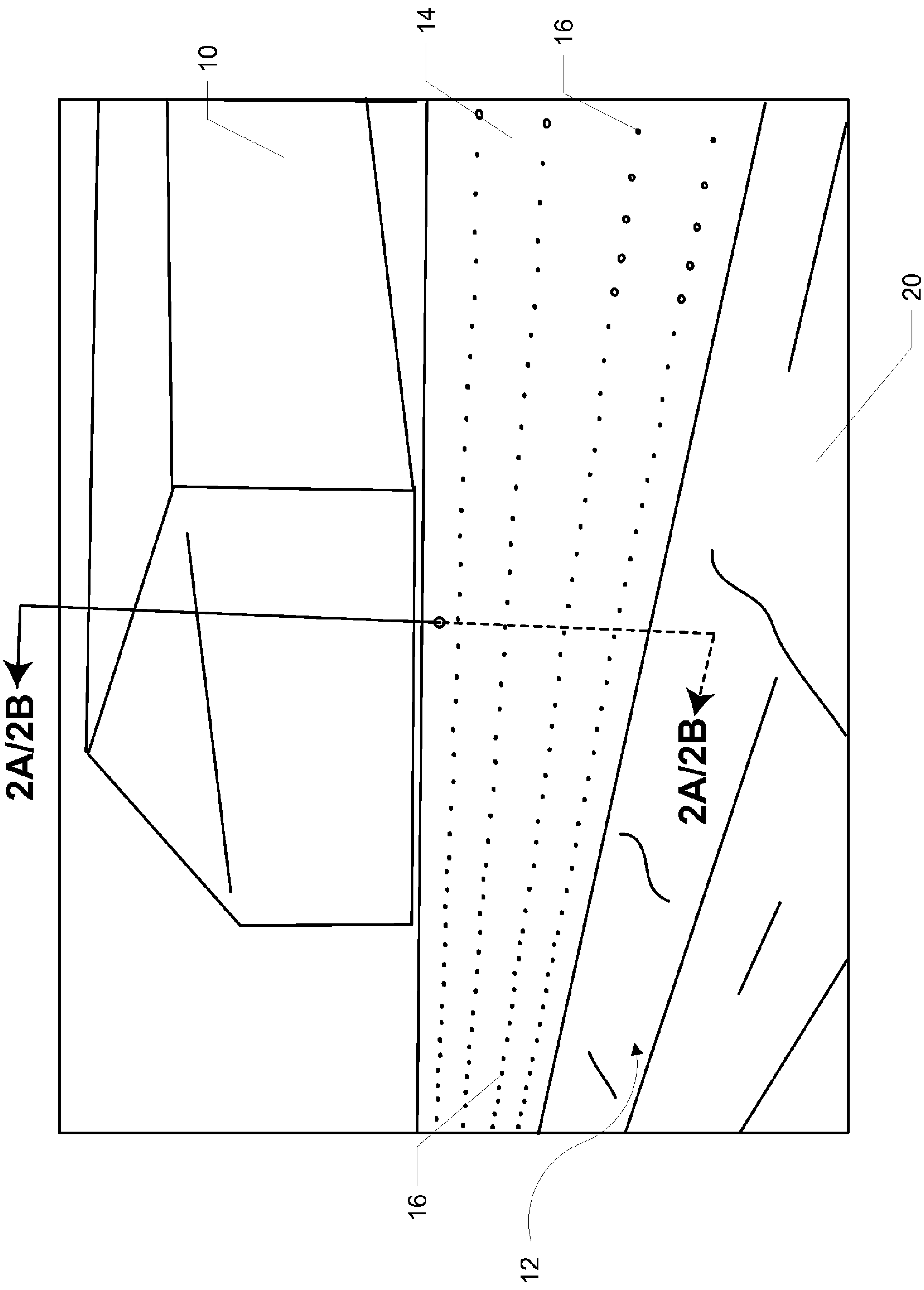


Figure 1

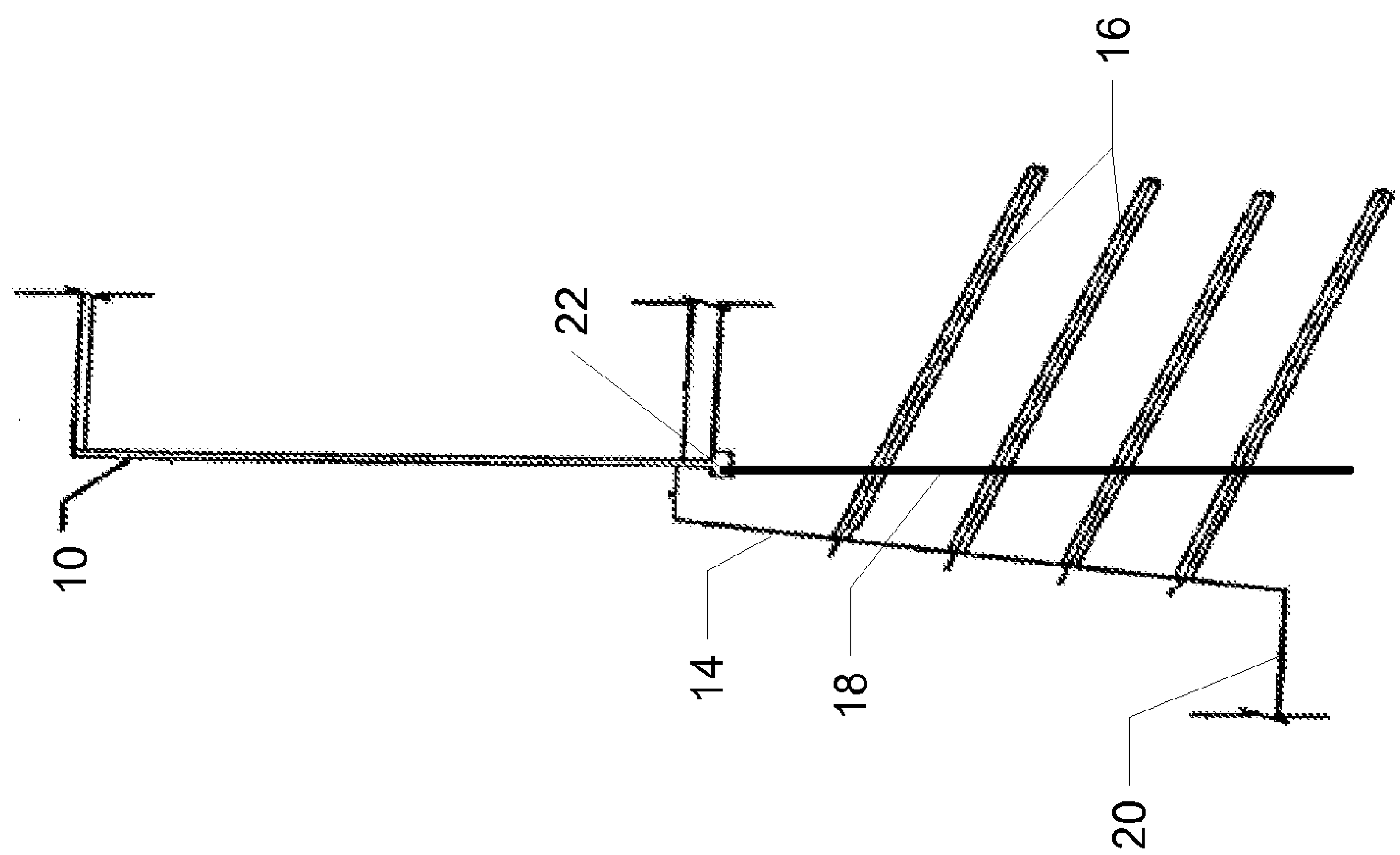


Figure 2B
PRIOR ART

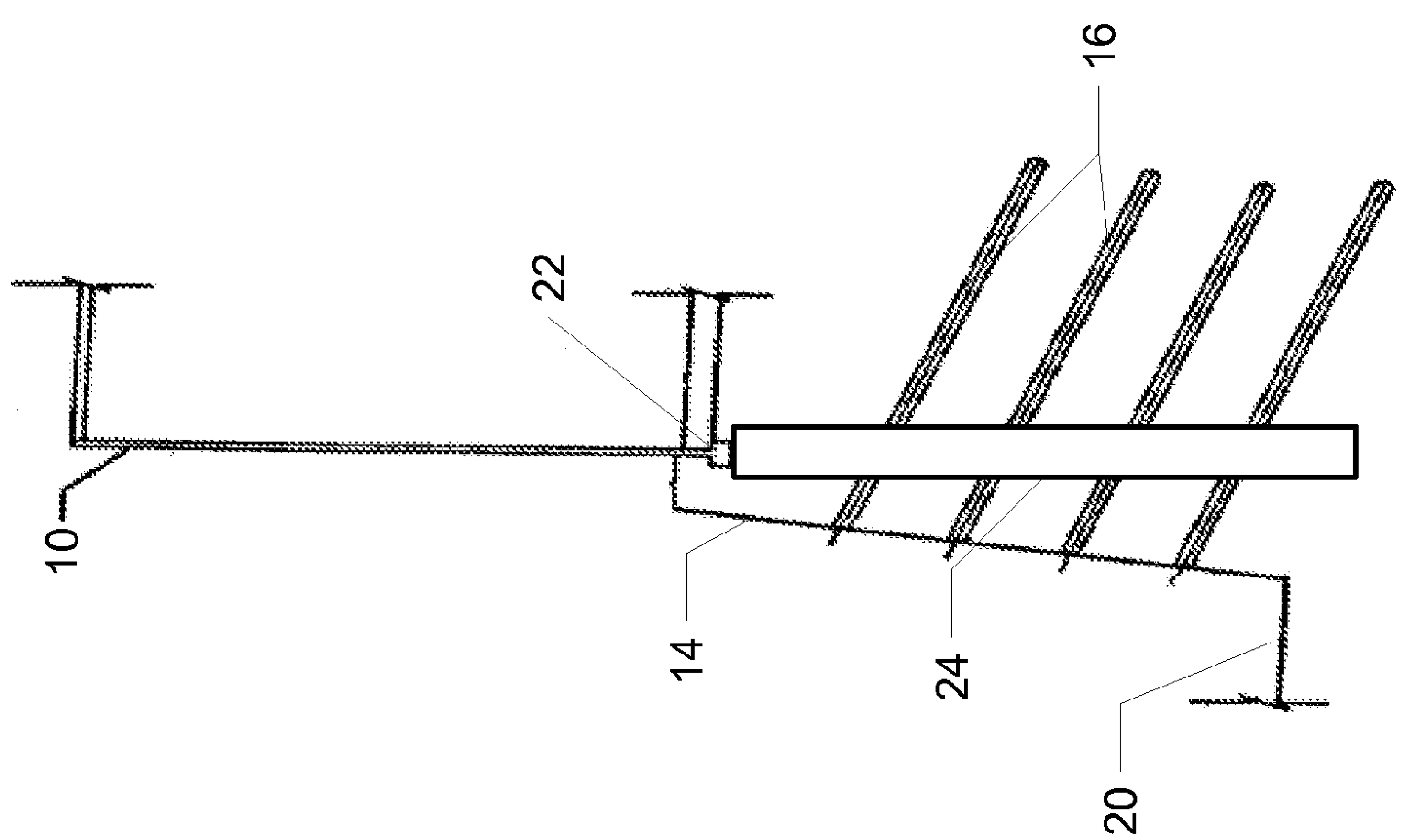


Figure 2A
PRIOR ART

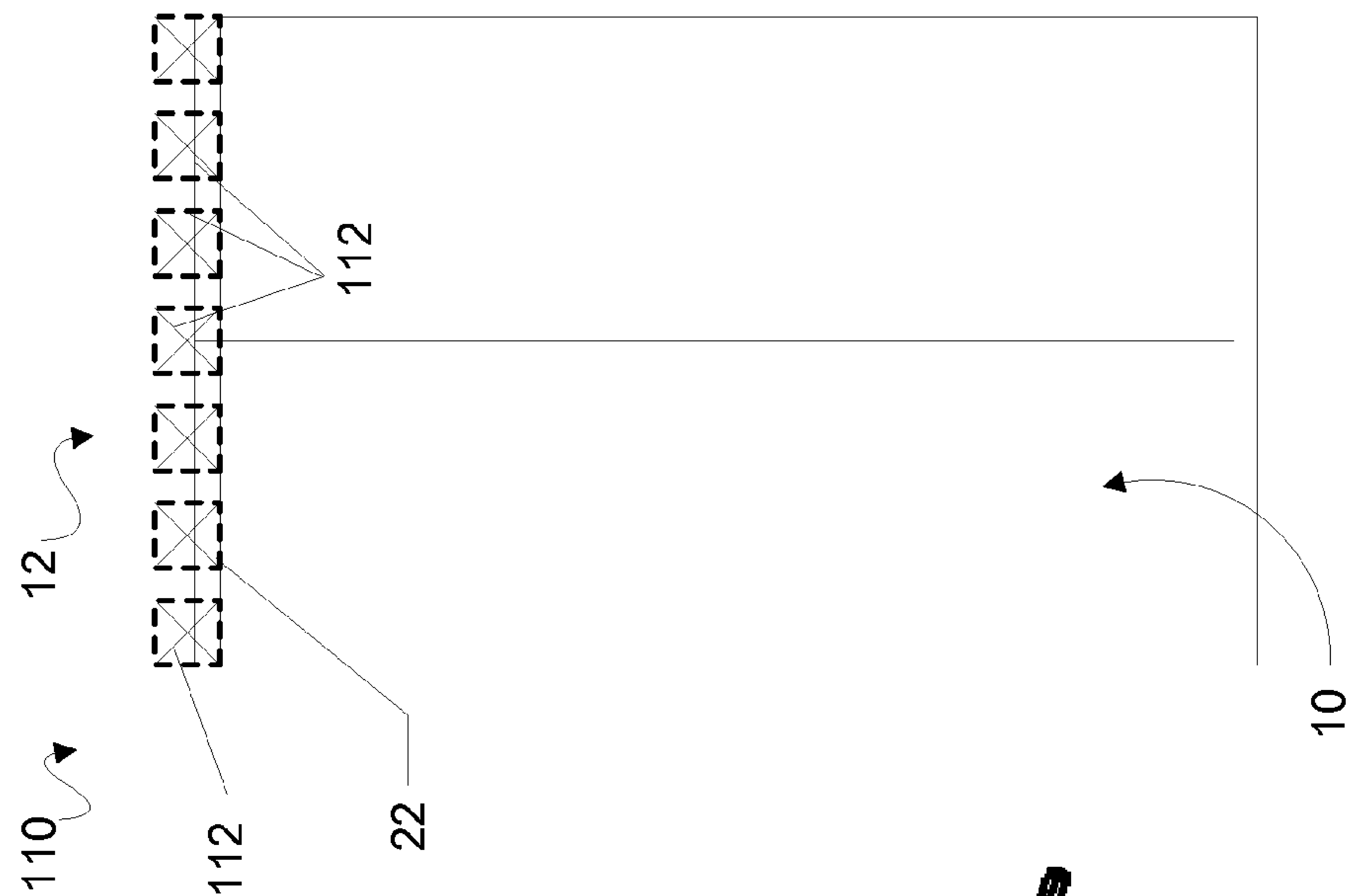


Figure 3B

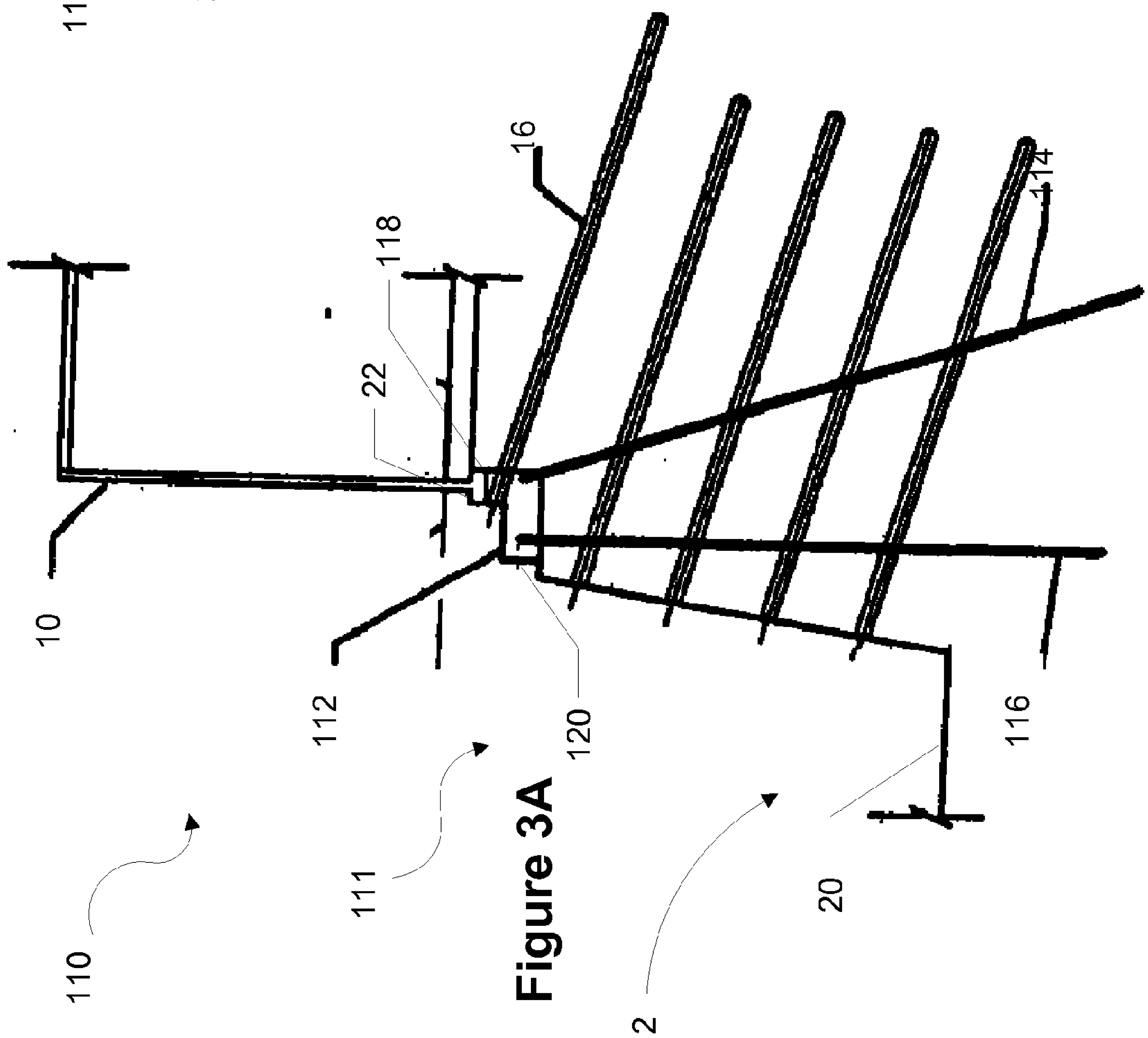


Figure 3A

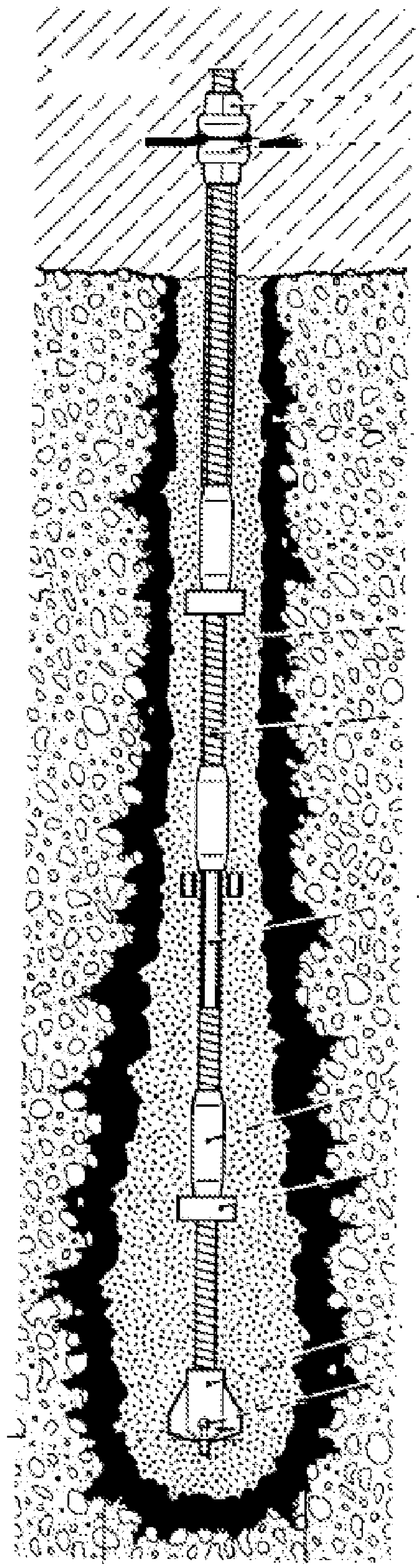


Figure 3C

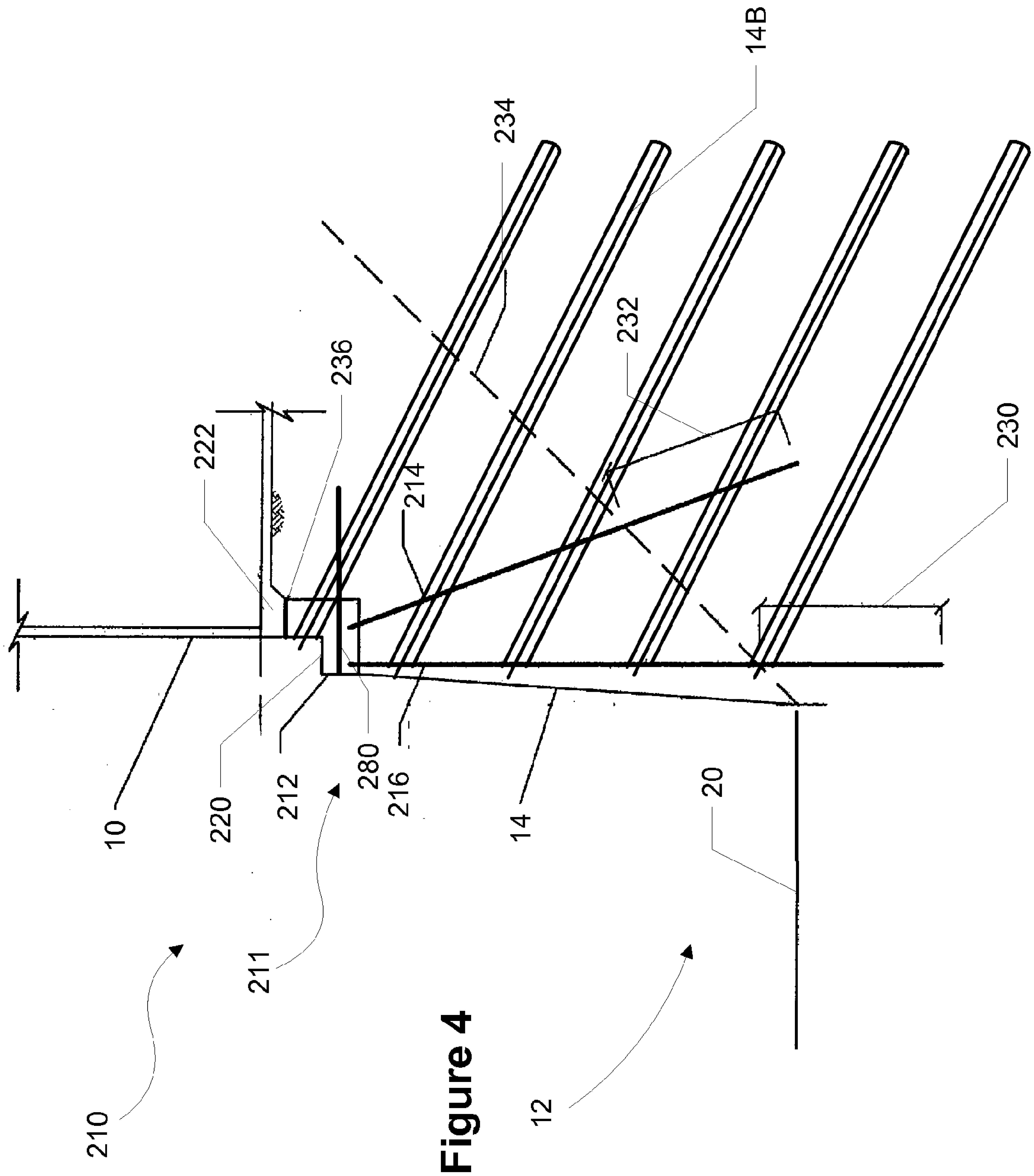


Figure 4

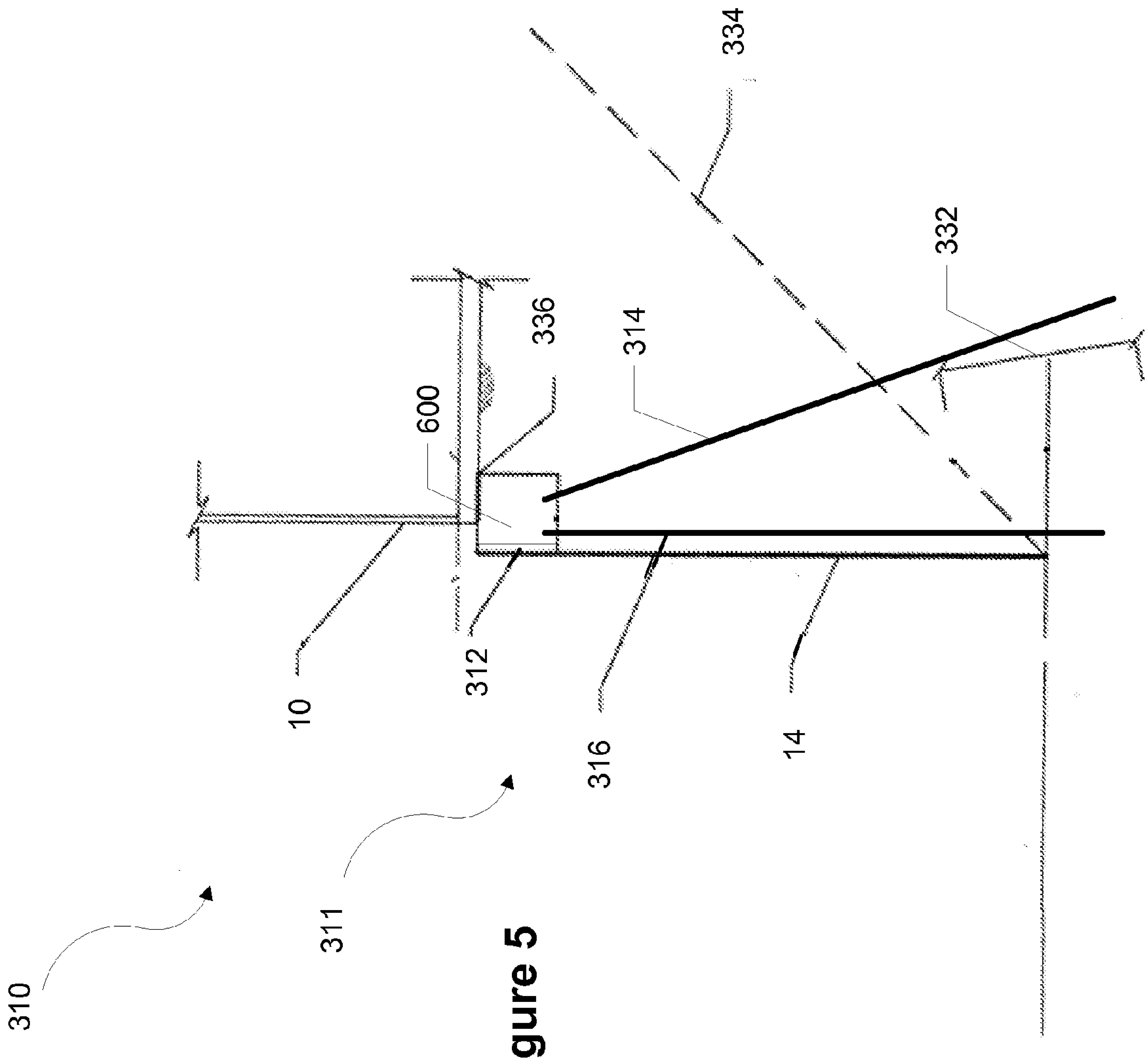


Figure 5

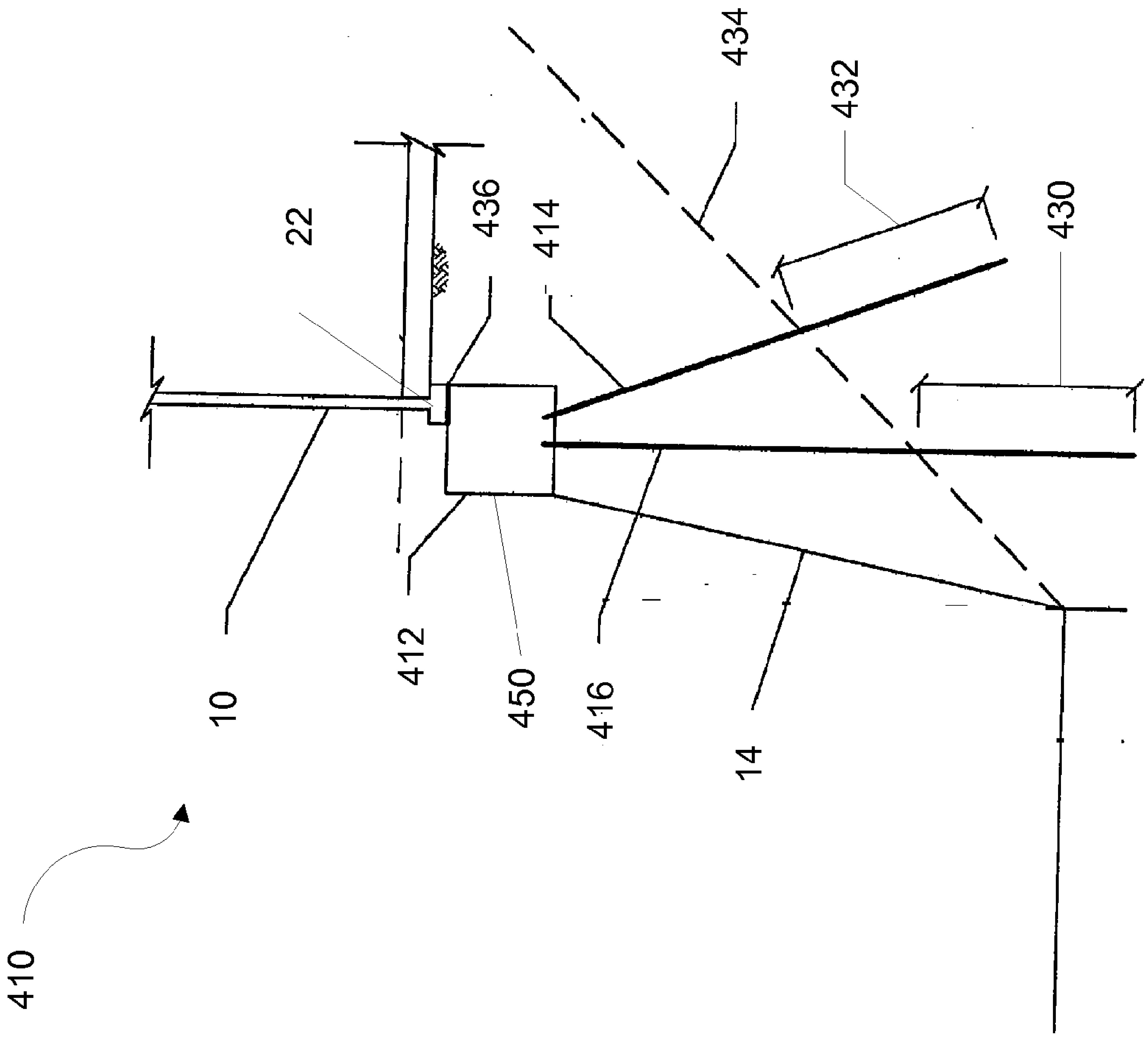


Figure 6

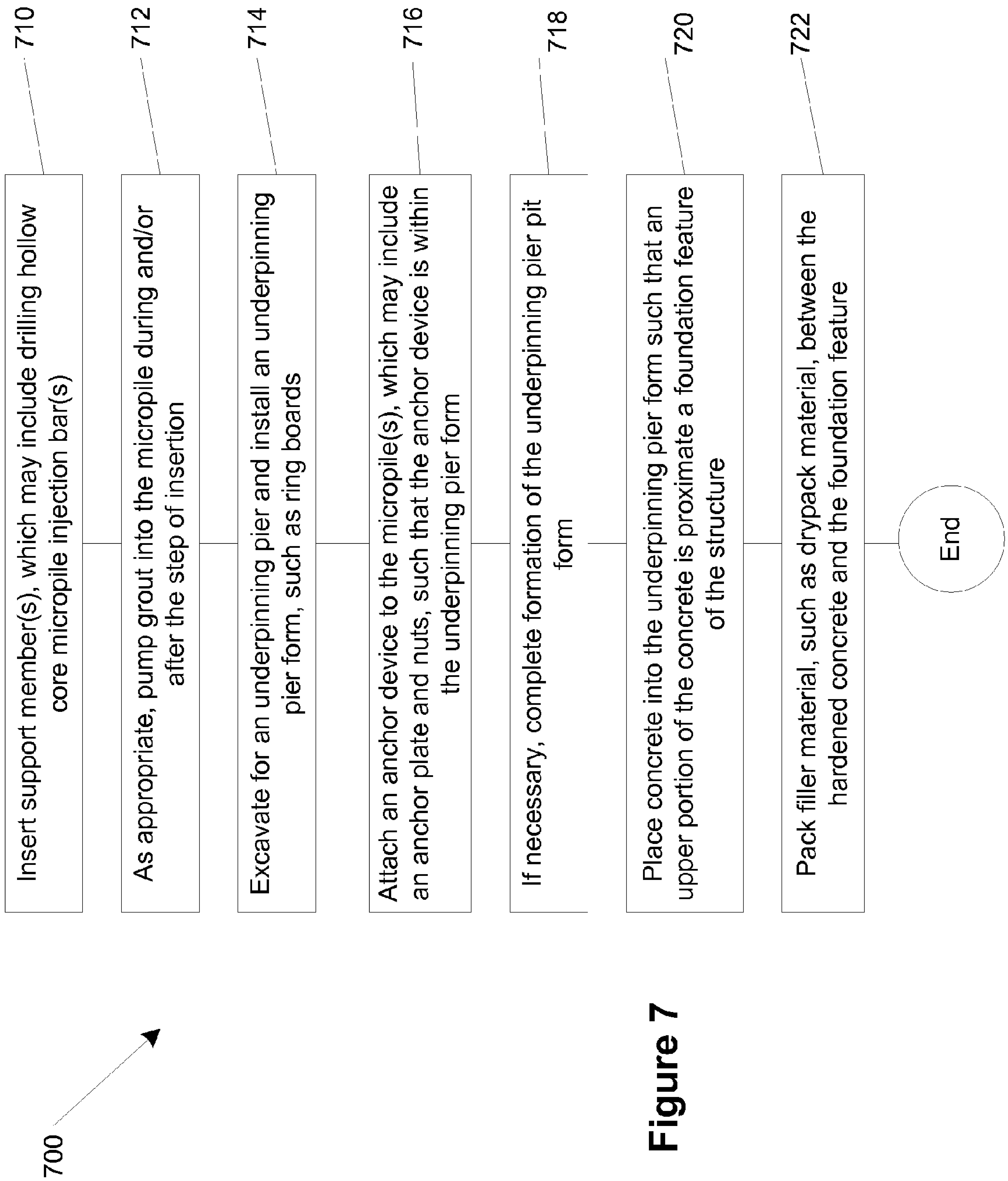

700
710
Insert support member(s), which may include drilling hollow core micropile injection bar(s)
712
As appropriate, pump grout into the micropile during and/or after the step of insertion
714
Excavate for an underpinning pier and install an underpinning pier form, such as ring boards
716
Attach an anchor device to the micropile(s), which may include an anchor plate and nuts, such that the anchor device is within the underpinning pier form
718
If necessary, complete formation of the underpinning pier pit form
720
Place concrete into the underpinning pier form such that an upper portion of the concrete is proximate a foundation feature of the structure
722
Pack filler material, such as drypack material, between the hardened concrete and the foundation feature
End

Figure 7

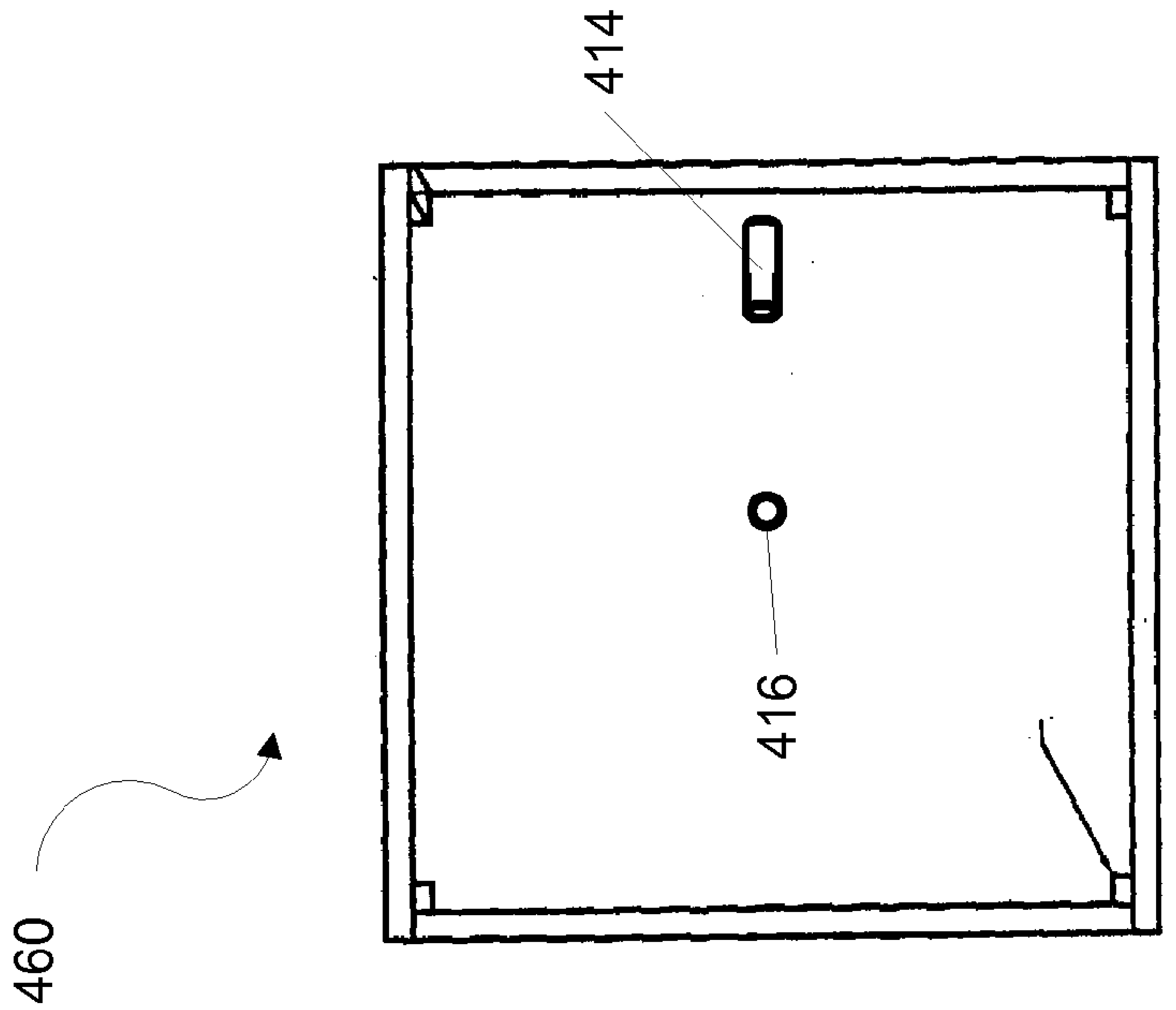


Figure 8B

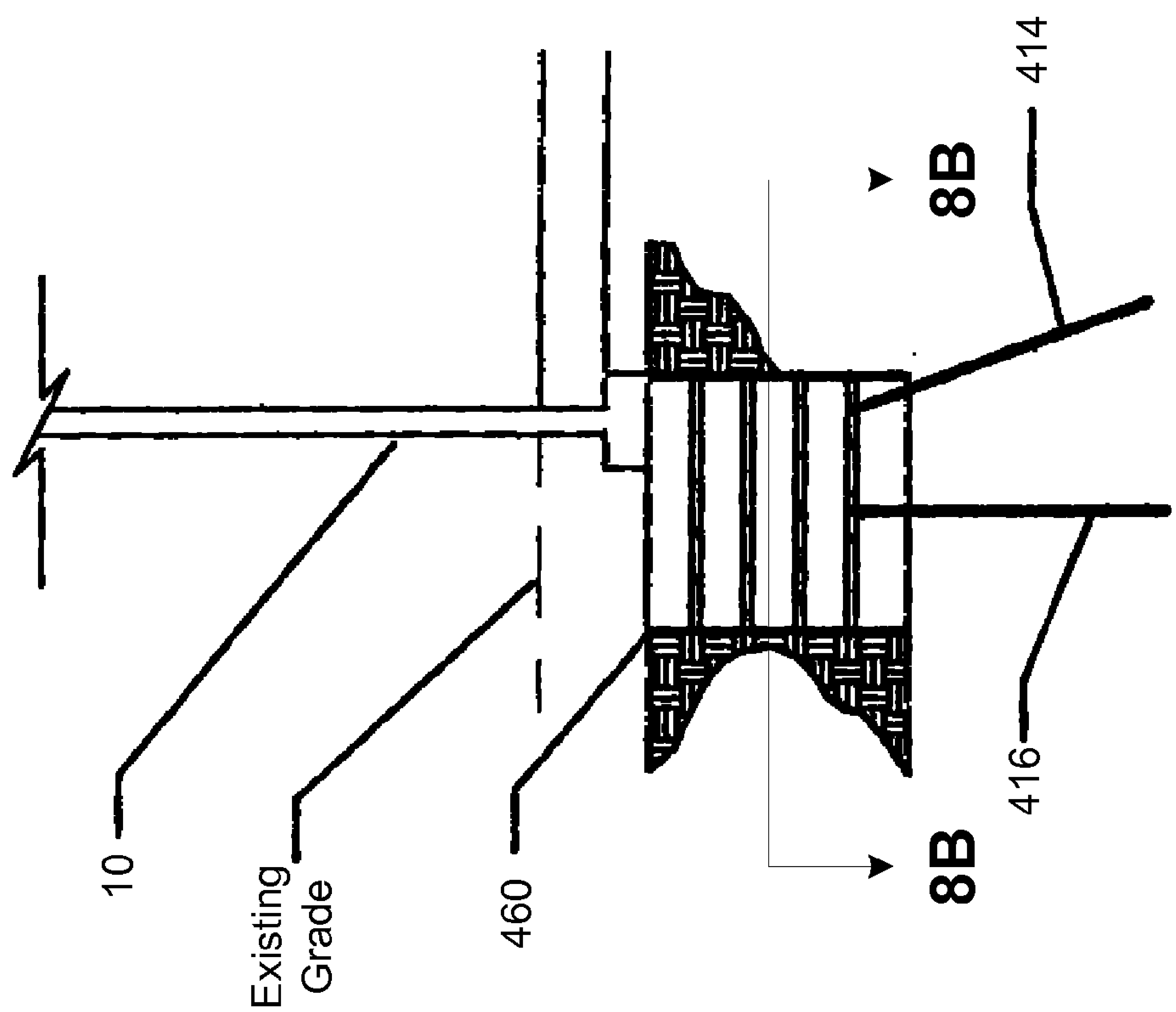


Figure 8A

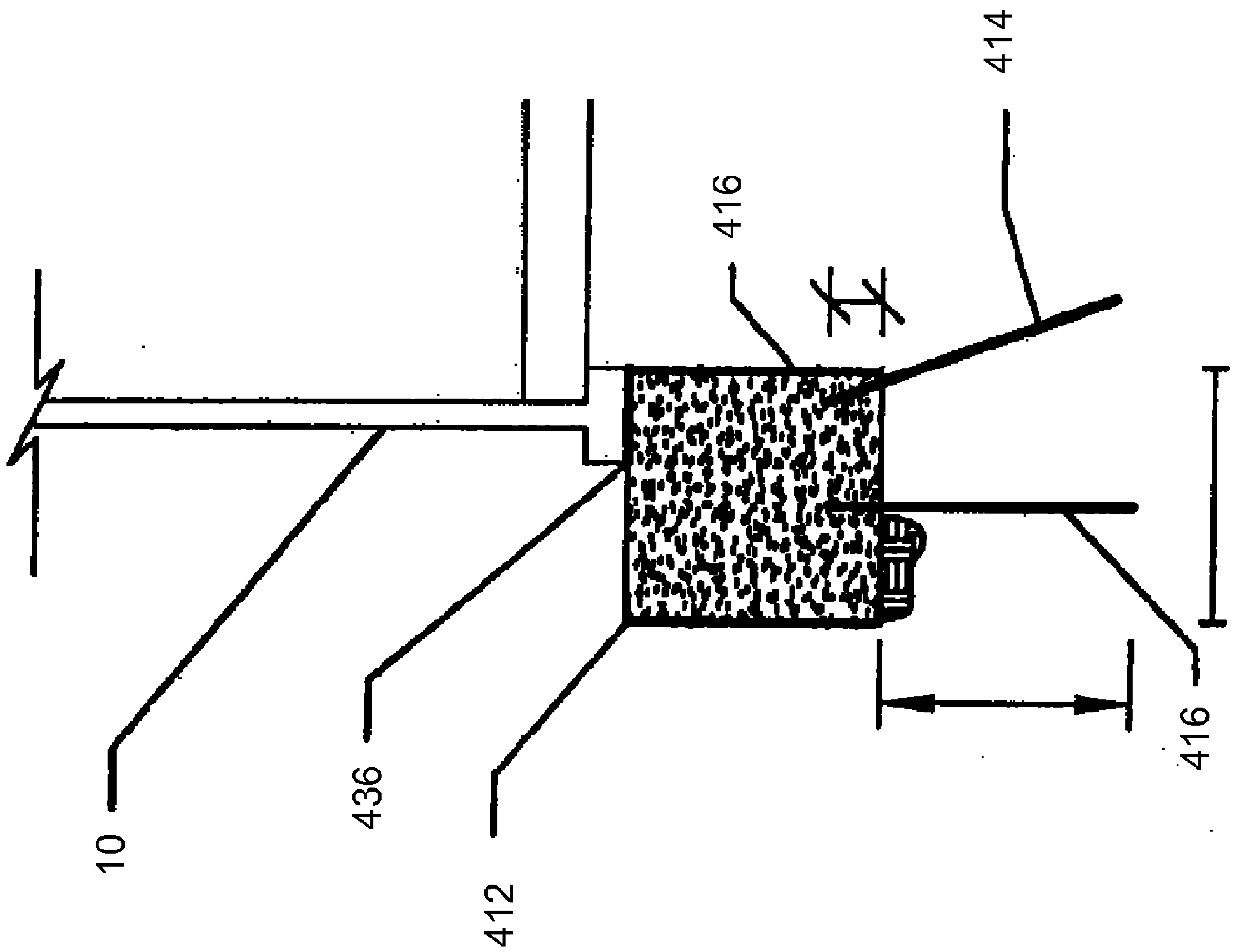


Figure 9B

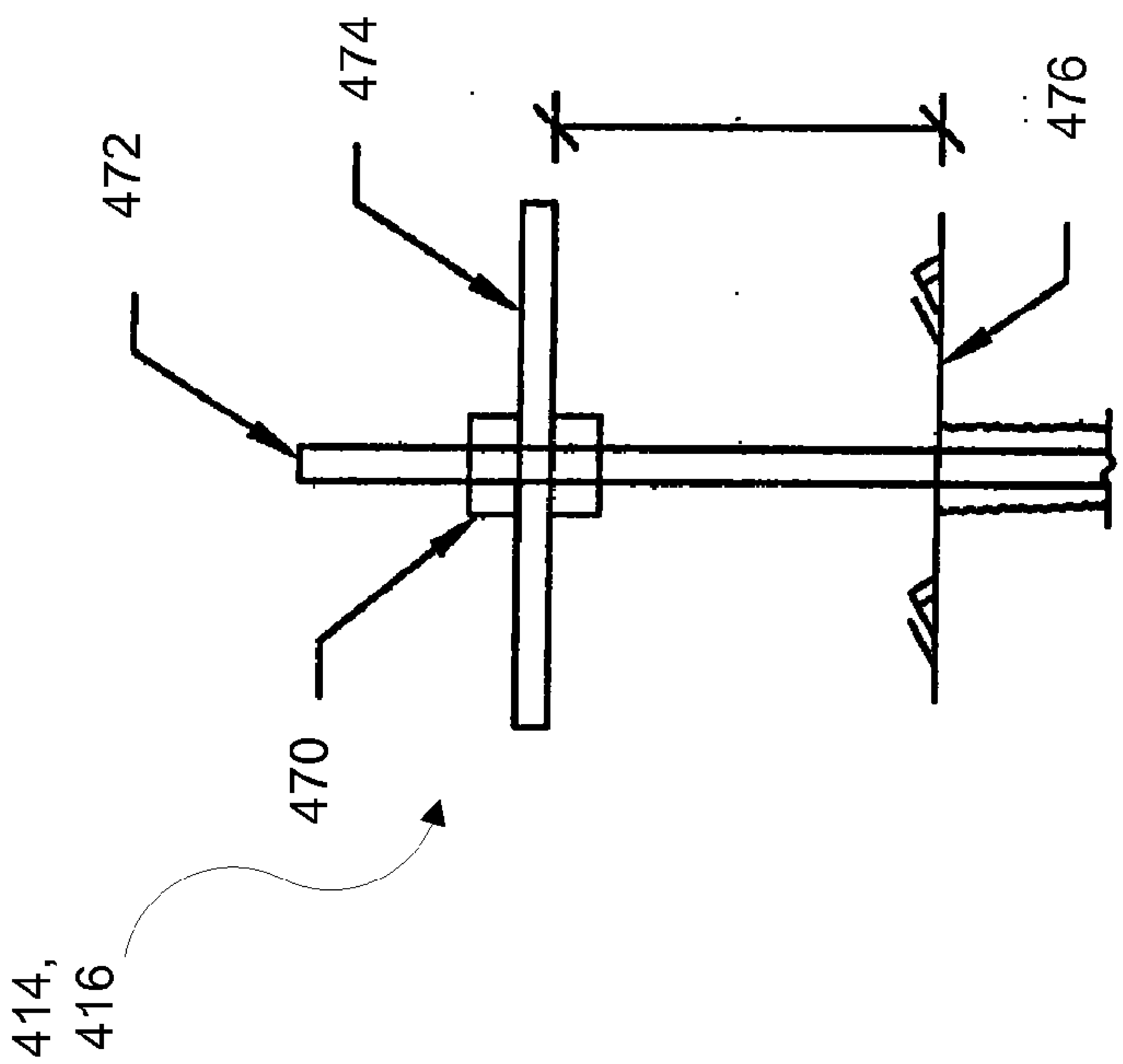


Figure 9A

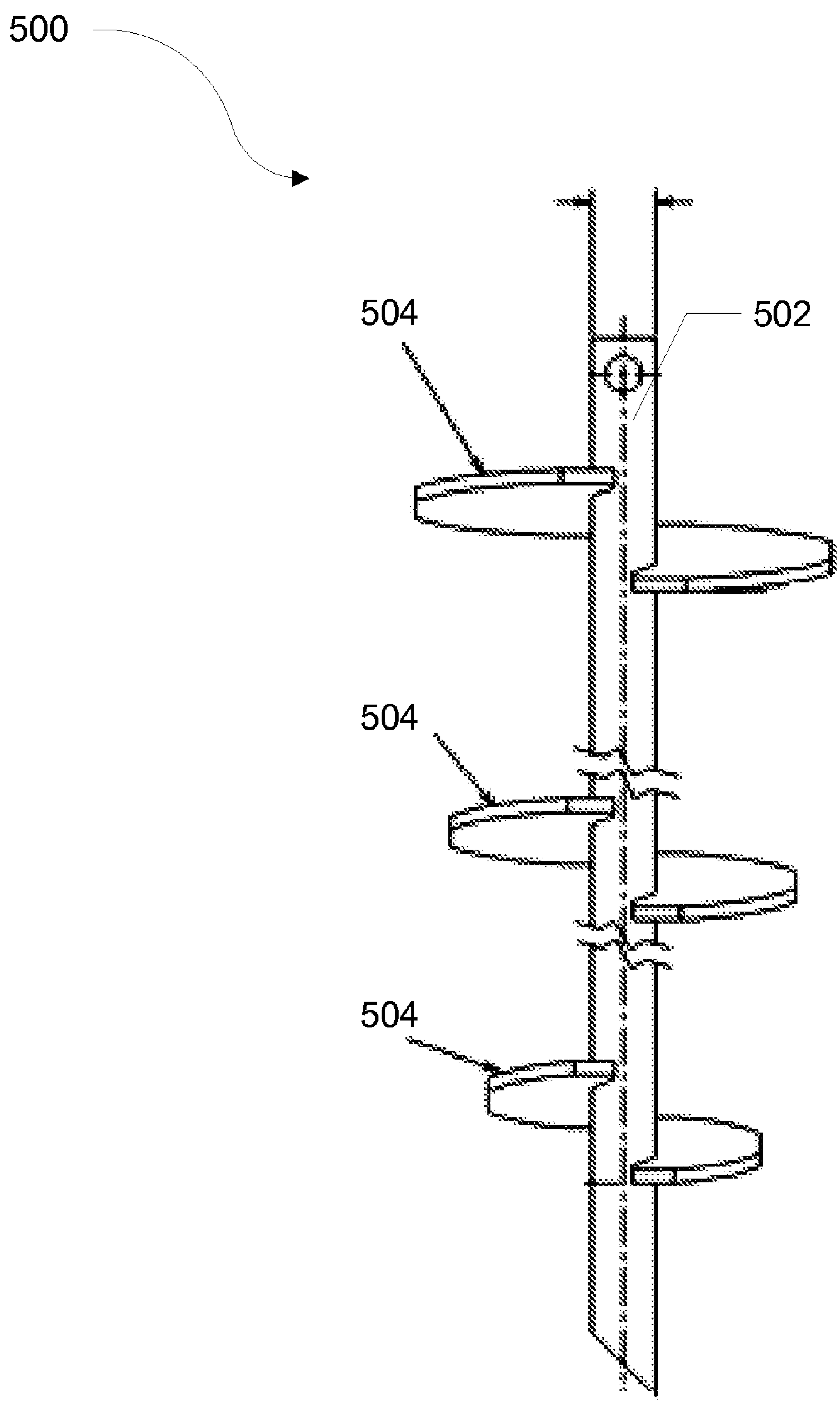


Figure 10

SUPPORTED UNDERPINNING PIERS

FIELD OF THE INVENTION

[0001] The present invention relates to foundation support of structures via the use of supported underpinning piers.

BACKGROUND

[0002] Foundation underpinning is a technology used for extending a structure's foundation to a deeper elevation. There are several methods of foundation underpinning.

[0003] Concrete pit underpinning consists of hand and/or machine excavated pits that are filled with concrete. The concrete pits are placed beneath an existing footing. A conventional underpinning concrete pit is a continuous concrete member that extends from the bottom of the footing to a suitable bearing stratum.

[0004] FIG. **2**A shows a conventional concrete pit underpinning system that utilizes concrete underpinning pits **24** placed below footings **22** to extend the building's foundation below the excavation bottom **20**. FIG. **2**A and **2**B is a sectional view of a portion of FIG. **1**, which shows a building **10** adjacent an excavation site **12**. As shown in FIG. **1**, soil within the excavation site has been removed to form an excavation **12** having an excavation face **14** adjacent to a wall of building **10**. Numerous soil nails **16** have been placed through face **14** to form a retaining wall that can resist lateral loads formerly resisted by the excavated earth. However, temporary and even permanent retaining walls may not provide sufficient resistance to vertical loads from adjacent structures. As such, excessive settlement of structures may occur. Foundation underpinning systems are useful for reinforcing a building's foundational support proximate an excavation site.

[0005] Concrete underpinning pits **24** of FIG. **2**A can be machine and/or hand dug and are filled with concrete. Concrete underpinning pits can be expensive to form and can be difficult to install through ground that is hard or contains cobbles and/or boulders. Underpinning pits **24** may also be difficult to install in ground that is below the groundwater table. Even when the ground does not contain rocks or other hard materials, extensive work is needed to excavate for the pits below existing footings **22**.

[0006] Another type of foundation underpinning uses jack piles, which are sectional metal piles installed beneath an existing footing and attached to the footing. The jack pile is typically made of steel. The jack pile is pushed into the earth using a jack that reacts against the bottom of the existing footing. Additional sections are attached to increase the length of the jack pile. After suitable bearing stratum has been reached, the footing load is transferred to the jack piles and the jack assembly is removed. Jack piles with hollow sections may be filled with concrete or cementitious grout.

[0007] A further type of foundation underpinning uses bracket piles, which are piles installed adjacent to an existing footing. The bracket pile is typically made of steel. A steel bracket attaches to the pile and extends beneath the footing to transfer load from the footing to the pile. Bracket piles are driven into the ground or are placed into a previously drilled hole and extend to a suitable bearing stratum. A bracket pile must have a section modulus large enough to support the bending moment applied by the bracket.

[0008] Yet another type of foundation underpinning uses helical piles. Helical piles are sectional piles that can be installed beneath or adjacent to an existing footing. The helical piles may be made of steel. The helical piles may include a center bar around which intermittent helical plates may be connected. The helical piles may be installed by rotating the pile into the ground until a suitable bearing stratum is reached. The footing load can then be transferred to the helical pile.

[0009] Similar to bracket piles, jack piles or helical piles, micropiles are also piles that may be attached to a footing. Micropiles are typically made of steel pipe filled in with cementitious grout and/or steel bars surrounded by cementitious grout, which are attached to the footing. Micropiles can be installed using rotary drilling methods. Conventional micropiles have a small diameter relative to traditional wooden or concrete piles. Hollow core injection bars, shown in FIG. **3**C are a type of micropile that uses grout pumped through the hollow core to enable drilling and to bond the steel bar to the ground. Conventional micropile underpinning practice is to install micropiles adjacent to existing footings or through holes bored in existing footings. Micropiles are installed adjacent to existing footings when access for boring through the footing is limited or when the footing is too small to be bored through or too small to make an adequate connection without enlarging the footing. When placed adjacent to a footing, the micropile can be fastened to the footing via laterally extending the footing to encapsulate the upper portion of the micropile. When a micropile extends through a bored hole in a footing, a top portion of the micropile is mechanically affixed to the footing or the bored hole is grouted to affix the micropile to the footing.

[0010] FIG. **2**B illustrates a conventional micropile underpinning system that includes a micropile **18** extending through a footing **22** of a building **10**. For the conventional micropile underpinning system shown in FIG. **2**B, micropiles **18** have been placed through footings **22** of the building to extend the building's foundation to a location where adequate vertical support exists, such as below excavation bottom **20**. Micropiles **18** may include drilled, driven, or jacked micropile formed from steel and cementitious grout. These micropiles depend upon shear transferred through a bored hole in the footing to provide support to the footing. In other configurations in which micropiles **18** are placed adjacent to the footings **22**, the footings require extensive work to laterally extend them to encapsulate a top portion of the micropile or to otherwise fasten the micropile to the footing.

[0011] For the conventional micropile underpinning system of FIG. **2**B, any seismic events or lateral movement in the soil adjacent to the excavation face **14** may cause large bending moments to occur along the micropiles **18**, which degrades structural support to the building. In particular, such moments can be high where the micropiles **18** connect with the footings **22** or otherwise connect to the building's foundation.

[0012] U.S. Pat. No. 6,012,874 to Groneck et al. discloses a micropile casing and method according to the conventional micropile method of FIG. **2**B, but which improves the connection between the micropile and the building's footing to enhance load transfer and resistance to bending moments. The Groneck system uses micropiles placed through existing footings, which nonetheless can experience high bending moments where they connect to the footings and can, thus, degrade the footings and their connection therewith over time.

SUMMARY

[0013] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0014] Aspects of the present invention relate to supported underpinning pits and related systems and to methods of foundation underpinning for a structure. According to aspects of the invention, an underpinning system may include one or more elongated support members, such as a micropile, extending from an underpinning pier below a structure's foundation. A plurality of micropiles may be coupled with the underpinning pier to substantially vertically extend the depth of the structure's foundation, as well as to reduce the potential of bending moments being applied to individual micropiles.

[0015] Aspects of the invention further include methods for installing micropile supported underpinning piers and related systems. The foregoing summary of aspects of the invention, as well as the following detailed description of various embodiments, is better understood when read in conjunction with the accompanying drawings, which are included by way of example, and not by way of limitation with regard to the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is an elevational perspective view of a sample building and a portion of a sample excavation site, in which the prior art systems of FIGS. **2**A and **2**B and aspects of the present invention may be implemented.

[0017] FIGS. **2**A and **2**B are sectional views of the building of FIG. **1** showing conventional concrete pit and micropile underpinning systems.

[0018] FIGS. **3**A and **4**-**6** are sectional views of the building of FIG. **1** illustrating micropile supported underpinning piers according to various aspects of the invention.

[0019] FIG. **3**B is a top plan view of the building of FIG. **1** showing example locations for the micropile supported underpinning piers of FIGS. **3**A and **4**-**6**.

[0020] FIG. **3**C is a sectional view of a hollow core injection bar that may be used with the supported underpinning piers.

[0021] FIG. **7** illustrates a method for providing micropile supported underpinning to a structure according to aspects of the invention.

[0022] FIG. **8**A is a sectional view of the building of FIG. **1** and an underpinning pit and ring boards, according to aspects of the invention.

[0023] FIG. **8**B is a plan view of the ring boards of FIG. **8**A.

[0024] FIG. **9**A is an elevational view of a top portion of a micropile that may be used when the underpinning pier concrete is poured after installing the micropiles.

[0025] FIG. **9**B is a sectional view of a micropile supported underpinning pier after the temporary earth support frame of FIGS. **8**A and **8**B has been filled with concrete.

[0026] FIG. **10** is a sectional view of a helical pile according to another aspect of the invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0027] Aspects of the present invention relate to a supported underpinning pier and system, and to methods for forming the same. Referring now to FIG. **3**A, a supported underpinning pier system **110** illustrating various aspects of the invention is shown that includes one or more elongated support member **116** with underpinning piers **112**. Elongated support members **116** can be members such as micropiles, helical piles or driven piles. For ease of understanding, the invention will be described using a micropile support member. The use of micropiles can provide advantages in some environments. However, a variety of support members can be used in various configurations.

[0028] Each micropile supported underpinning pier **111** generally includes an underpinning pier **112** and at least one micropile **114** or **116**. A back micropile **114** and a front micropile **116** are used in the example configuration of FIG. **3**A to balance the moments about the footing **22**. As with conventional concrete underpinning pits **24** of FIG. **2**A, underpinning pier **112** provides support to footing **22** of building **10**. However, the depth of underpinning pier **112** is substantially reduced in comparison with a conventional concrete underpinning pit. For example, underpinning pier **112** preferably has a depth between 3 feet and 6 feet. In one example, the underpinning pier **112** has a depth of between 4 feet and 5 feet. Such depths can be excavated relatively easily for forming the underpinning pier, yet provide a structurally sound underpinning pier. Rather than extending downward below the level of trench bottom **20**, underpinning pier **112** extends a comparatively short distance downward and extends outward, away from building **10**. Micropiles **114** and **116** extend downward from underpinning pier **112** to transmit the footing load to a greater depth as desired, such as a depth below the bottom of the adjacent excavation.

[0029] Micropile supported underpinning piers according to the aspects illustrated in FIGS. **3**A and **4**-**6**B generally provide the advantages of conventional concrete underpinning pits, but can be formed with much less effort and expense. Micropiles installed through and below the shallow underpinning piers shown in these figures allow the footing load to be carried to a greater depth through almost any ground condition, including ground that is hard or contains cobbles and/or boulders, and that may be below the groundwater table, with relatively little difficulty and at a reasonable cost. Although micropiles are used in conjunction with the shallow underpinning pier, coring through existing footings is not required nor is enlarging the footings necessary for connecting the micropiles to the building reinforced by them. As discussed below and illustrated by FIGS. **7**-**9**B, a top portion of the micropiles are easily encapsulated within their respective underpinning pier. In addition, the use of a plurality of micropiles along with laterally extending the underpinning piers away from the building can further enhance structural stability of the building and counteract anticipated moments applied to the underpinning system.

[0030] The configuration of FIG. 3A includes a generally L-shaped underpinning pier **112** that provides a robust support pedestal **118** and an arm **120** extending outward from the building **10**. Back micropile **114** extends downward from an inner portion of the underpinning pier to transmit the footing load to a greater depth, which is preferably below the bottom of the adjacent excavation. Back micropile **114** also extends inward toward building **10** and away from excavation site **12**. The back micropile **114** preferably engages the underpinning pier at a location generally behind the centerline of the structural wall of building **10** that is supported by the pier.

[0031] Front micropile **116** also extends downward from the underpinning pier. However, it does so from a distal portion of arm **120**. As such, front micropile **116** cooperates with arm **120** of the micropile to balance the forces applied to the underpinning system from downward loads from building **10**. Thus, underpinning pier system **110** provides a versatile system that can be custom configured for a variety of soil and loading conditions and for a variety of existing foundations. For instance, although shown with two micropiles, additional micropiles may extend from underpinning pier **112** in various orientations and to various depths as desired to provide robust structural support to building **10**. In addition, the L-shaped configuration of the underpinning pier can provide the advantages discussed above, such as sturdy support below the footing and the ability to counteract bending moments provided by its arm **120**, while reducing the quantity of concrete required in comparison with a rectangular configuration.

[0032] As shown in FIG. 3B, a plurality of underpinning piers **112** may be spaced apart along the wall of building **10** proximate excavation site **12**. Depending upon the structural design of the building and its configuration, the underpinning piers **112** may support the same or different footings or other structural feature of the building. In order to avoid adversely affecting the structural integrity of building **10** while forming the underpinning pier system **110**, no two adjacent underpinning pier locations should be excavated at the same time. Further, open pits should be spaced apart a certain minimum distance, as determined by site-specific conditions.

[0033] Referring now to FIG. **4**, another micropile underpinning pier system **210** is shown that illustrates various aspects of the invention. System **210** generally includes the same features described along with system **110**, except as discussed below. System **210** includes one or more micropile supported underpinning piers **211**, which each include an underpinning pier **212**, a back micropile **214** and a front micropile **216**. As shown, the arm **220** of underpinning pier **212** extends to excavation face **14** of the excavation site **12** to provide a large moment arm for the underpinning pier and to take advantage of structural support provided by the retaining wall at the trench face. In addition, the floor slab of building **10** includes a thickened region that forms its footing **222**. As such, the pedestal of pier **212** is thickened to match the footing width.

[0034] Back micropile **214** engages the underpinning pier at a location generally behind the structural wall of building **10** that is supported by the underpinning pier. In addition, back micropile **214** is angled away from the excavation site **12**.

[0035] Front and back micropiles **216** and **214** preferably extend an embedment length **230** and **232** respectively beyond a projection line **234**. Projection line **234** represents the location of a potential sliding surface that defines the wedge of soil supported by the lateral shoring, in this case soil nails **14**B. For example, immediately adjacent to the excavation face **14**, structural supports should extend below the excavation bottom to ensure they provide adequate vertical support below the projection line **234**. However, adequate vertical support can be obtained at increasingly shallower depths as the distance from the excavation face **14** increases. Preferably, embedment lengths **230** and **232** are at least 10 feet below projection line **234** to provide robust structural support to footing **222**.

[0036] As further shown in FIG. **4**, a fill material **236** is preferably placed between underpinning pier **212** and footing **222**. For example, the material may be a non-shrink type material. The fill material enables the load to be transferred from the footing to the underpinning pier by filling the gap between the underpinning pier and the footing. The fill material is preferably a moist mixture of cement and sand, such as dry pack, which, when packed between the concrete surfaces, fills the gap therebetween and hardens into a volumetrically stable material between the structures.

[0037] In addition, FIG. **4** also shows a lateral support member **280**. The lateral support member **280** may be generally horizontal, as seen in FIG. **4**, or may be inclined or declined. In one arrangement, the lateral support member **280** may be inclined 15-20 degrees from the horizontal. The lateral support member **280** may be drilled through the underpinning pier **212** and into the soil behind underpinning pier **212** in order to aid in resisting horizontal loads or moments applied to underpinning pier **212**. For example, the lateral support member **280** can be utilized to resist against earth pressure loads or seismic loads.

[0038] Referring now to FIG. **5**, another micropile supported underpinning pier system **310** is shown that illustrates various aspects of the invention. System **310** generally includes the same features described along with system **210**, except as discussed below. System **310** includes one or more micropile supported underpinning piers **311**, which each include an underpinning pier **312**, a back micropile **314** and a front micropile **316**. As shown, underpinning pier **312** is generally rectangular, which conforms with the substantially vertical orientation of excavation face **14**. Because excavation face **14** is substantially vertical, front micropiles are spaced apart along the excavation face and are part of the retaining wall. As such, front micropile **316** contributes to the stability of the excavation face **14**.

[0039] As shown in FIG. **5**, building **10** does not include footings, or at least does not do so at the location of pier **312**. Thus, underpinning pier **312** provides support to the slab. As with piers **112** and **212**, back micropile preferably engages the underpinning pier behind the structural wall it supports.

[0040] Referring now to FIGS. **6**, another micropile underpinning pier system **410** is shown that illustrates various aspects of the invention. System **410** generally includes the same features described along with systems **110**, **210** and

310, except as discussed below. System **410** differs from system **110** of FIG. **3**A in that underpinning pier is generally rectangular and a front face **450** of the underpinning pier forms part of the excavation face **14**.

[**0041**] Referring now to FIG. **7** and FIGS. **8**A to **9**B, a method **700** for forming micropile supported underpinning pier **412** is generally shown to illustrate aspects of the present invention. The method includes the step **710** of inserting one or more micropile, which may include drilling hollow core micropile injection bar(s), and as appropriate, step **712** including pumping grout through the injection bar during and/or after the step **710**. The method further includes the step **714** of excavating for an underpinning pier and installing an underpinning pier form, if necessary, such as ring boards **460** of FIG. **8**B and the step **716** of attaching an anchor device to the micropile, which may include an anchor plate **474** and nuts **470** as shown in FIG. **9**A such that the anchor device is within the underpinning pier form. If necessary, the step **718** of completing forming the underpinning pier form may be performed. The method further includes the step **720** of placing concrete into the underpinning pier form such that an upper portion of the concrete is proximate a foundation feature of the structure as shown in FIG. **9**B. After the concrete has set, such as a day later, the method includes the step **722** of packing filler material, such as the material known as drypack, between the hardened concrete and the foundation feature.

[**0042**] In an alternate configuration of the method of FIG. **7**, the drilling and excavation steps may be performed in reverse order. For example, step **714** of excavating for an underpinning pier may be performed prior to step **710** that can include drilling a micropile injection bar. Once these steps have been performed, concrete may be placed in the underpinning pier form, as in step **720**.

[**0043**] In another alternate configuration of the method of FIG. **7**, step **714** of excavating for an underpinning pit may be performed just prior to step **720** of placing concrete into an underpinning pier form. Once the concrete has set, step **710** of drilling a micropile may be performed. As shown in FIG. **5**, such drilling may include placing a sleeve **600** in the pier at installation to accommodate the passage of the drill bit and drill string during the drilling step, **710**.

[**0044**] Although the invention has been described using micropiles, other alternate support members may be used with the invention. For instance, FIG. **10** depicts one such alternate support member, a helical pile **500**. Helical piles **500** are can be installed beneath or adjacent to an existing footing and are generally made of steel. The footing load can then be transferred to the helical pile **500** similar to micropile **116** in FIG. **3**A.

[**0045**] Other alternate support members can include driven piles. The type of support member used can be selected based on soil conditions and other ground parameters.

[**0046**] Although the invention has been defined using the appended claims, these claims are illustrative in that the invention may be intended to include the elements and steps described herein in any combination or sub combination. Accordingly, there are any number of alternative combinations for defining the invention, which incorporate one or more elements from the specification, including the description, claims, and drawings, in various combinations or sub combinations. It will be apparent to those skilled in the relevant technology, in light of the present specification, that alternate combinations of aspects of the invention, either alone or in combination with one or more elements or steps defined herein, may be utilized as modifications or alterations of the invention or as part of the invention. It may be intended that the written description of the invention contained herein covers all such modifications and alterations.

We claim:

1. An underpinning system for a structure, the system comprising:

an underpinning pier having an upper portion engaging a foundation of the structure and receiving downward forces from the foundation, the underpinning pier having a depth less than that of a predetermined bearing stratum; and

a first elongated support member extending from a bottom portion of the underpinning pier and extending downward from the underpinning pier, the elongated support member transmitting downward forces from the underpinning pier to the predetermined bearing stratum.

2. The underpinning system of claim 1, wherein the elongated support member is a micropile.

3. The underpinning system of claim 1, wherein the elongated support member is a helical pier.

4. The underpinning system of claim 1, wherein the elongated support member is a driven pile.

5. The underpinning system of claim 1, further comprising a lateral support member installed through the underpinning pier and anchored to a portion of soil behind the underpinning pier.

6. The underpinning system of claim 1, further comprising a vertical sleeve inserted into the underpinning pier.

7. The underpinning system of claim 1, wherein the underpinning pier laterally extends beyond an end of the foundation of the structure.

8. The underpinning system of claim 1, further comprising a second elongated member extending from the bottom portion.

9. The underpinning system of claim 8, wherein the first elongated member is at a first angle and the second elongated is at a second angle, the second angle being different from the first angle.

10. The underpinning system of claim 8, further comprising a first and second plurality of elongated support members.

11. The underpinning system of claim 1, wherein the underpinning pier is formed of concrete.

12. A method for forming an underpinning structure, the method comprising:

inserting one or more elongated support members in a downward direction below a foundation of a structure;

excavating an underpinning pier below the foundation to include a top portion of the one or more elongated support members;

forming an underpinning pier form within the underpinning pier excavation;

placing concrete within the underpinning pier form such that an upper portion of the concrete is proximate the foundation and a gap is formed between the upper portion of the concrete and the foundation; and

packing a filler material in the gap to form a substantially continuous structural interface between the foundation and the concrete.

13. The method of claim 12, wherein the elongated support members include micropiles.

14. The method of claim 12, wherein the elongated support members include helical piles.

15. The method of claim 12, wherein the elongated support members include driven piles.

16. The method of claim 12, wherein the step of excavating for the underpinning pier form is done after the step of inserting one or more support members and the step of placing concrete is done after the step of excavating.

17. The method of claim 12, wherein the step of inserting one or more support members is performed after the step of excavating for the underpinning pier.

18. The method of claim 12, wherein the step of excavating for the underpinning pier is performed first, the step of placing the concrete is done second and the step of inserting one or more support members is done third.

19. The method of claim 18, wherein a sleeve is inserted into the underpinning pier concrete.

20. An underpinning system for a structure, the system comprising:

an underpinning pier having an upper portion engaging a foundation feature of the structure and a lower portion below the upper portion and extending laterally away from the structure, the lower portion having a greater width than the upper portion, the underpinning pier receiving downward forces from the foundation feature; and

a plurality of elongated support members extending downward from the underpinning pier, the elongated support members transmitting downward forces from the underpinning pier into the earth at a greater depth than the underpinning pier.

21. The underpinning system of claim 20, wherein the plurality of elongated support members are micropiles.

22. The underpinning system of claim 20, wherein the plurality of elongated support members are helical piles.

23. The underpinning system of claim 20, wherein the plurality of elongated support members are driven piles.

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