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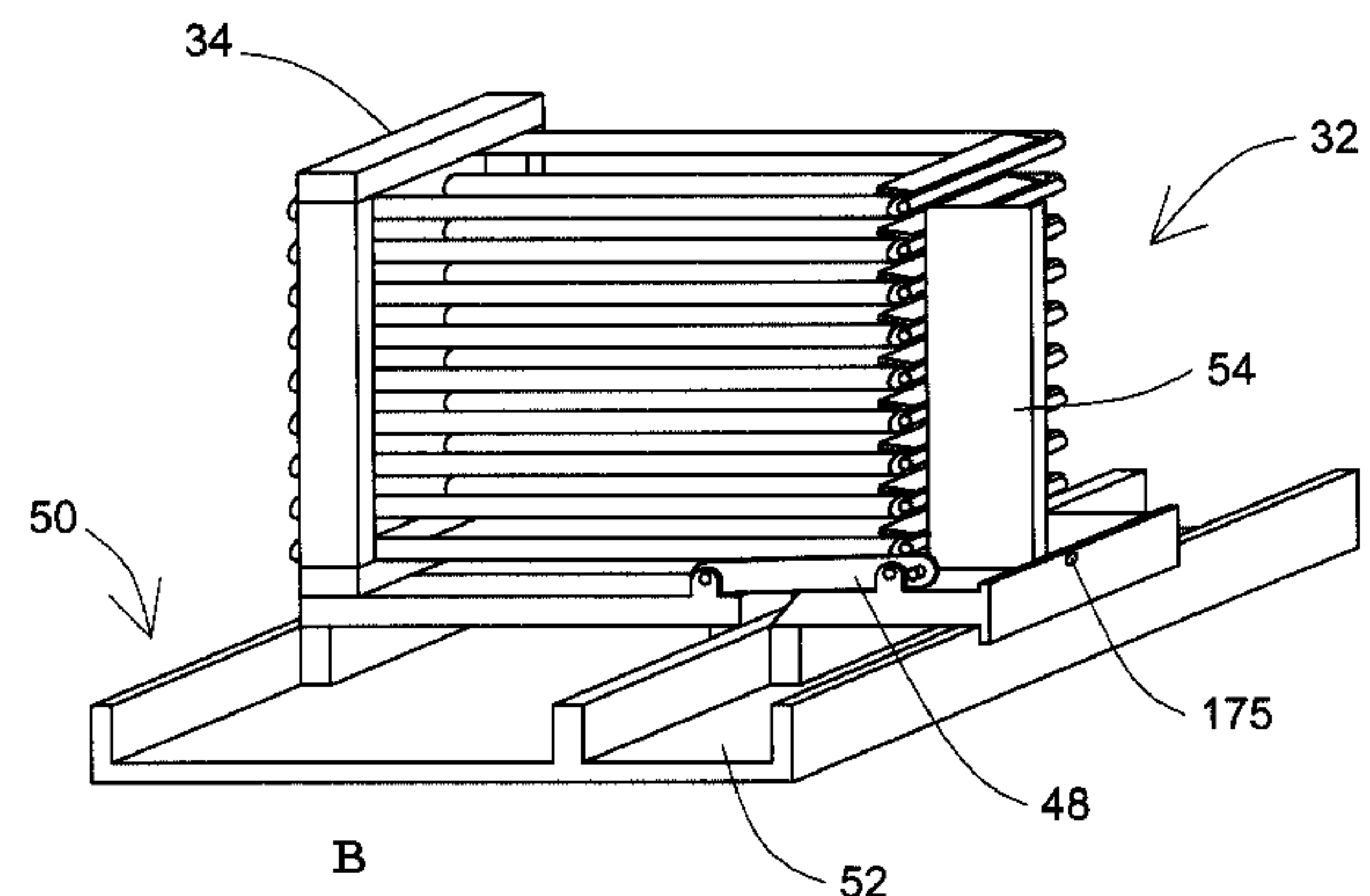
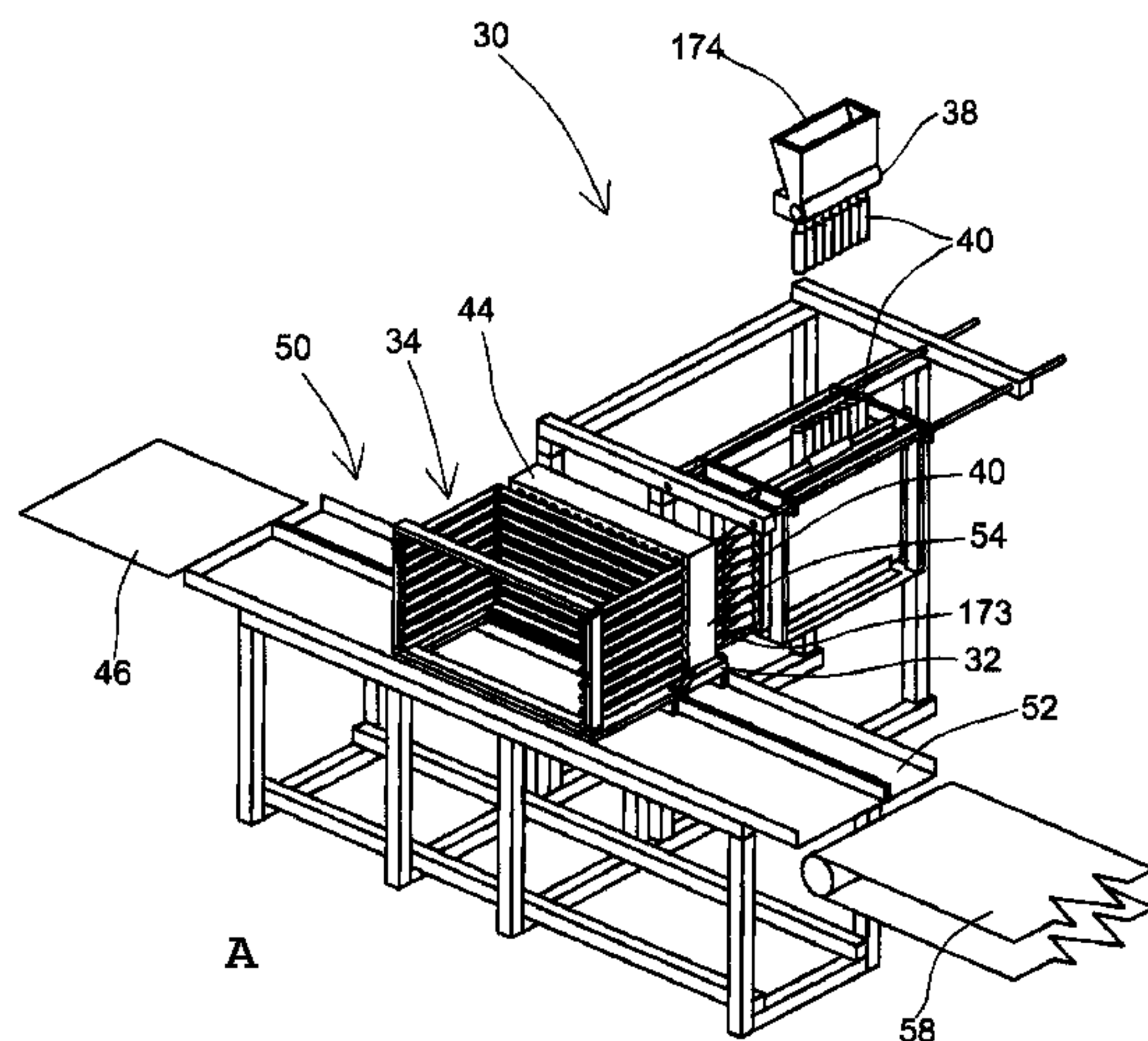
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(54) Titre : METHODE DE MODULATION DE LA CROISSANCE DES PLANTES PAR L'INJECTION D'UNE MOTTE AU
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(54) Title: METHOD TO MODULATE PLANT GROWTH BY INJECTING A PLUG AT LIFT



(57) Abrégé/Abstract:

A method for modulating plant growth is provided whereby seedlings that are grown in containers such as blocks are fertilized at lift. Prior to fertilization, the block, which has numerous plug cavities, is restrained. The seedlings, which are grown in plugs formed in plug cavities, are supported and a bore is drilled into the bottom of the plug. The bore extends to the top of the plug to produce a small port, which serves as a port for expulsion of air during the injection operation. The fertilizer is measured in a metering roller and is then pneumatically injected into the bore in the plug. Upon completion of the injection, the bore is closed to reduce the loss of fertilizer from the plug. The various operations may be automated or performed manually.



ABSTRACT

A method for modulating plant growth is provided whereby seedlings that are grown in containers such as blocks are fertilized at lift. Prior to fertilization, the block, which has numerous plug cavities, is restrained. The seedlings, which are grown in plugs formed in plug cavities, are supported and a bore is drilled into the bottom of the plug. The bore extends to the top of the plug to produce a small port, which serves as a port for expulsion of air during the injection operation. The fertilizer is measured in a metering roller and is then pneumatically injected into the bore in the plug. Upon completion of the injection, the bore is closed to reduce the loss of fertilizer from the plug. The various operations may be automated or performed manually.

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METHOD TO MODULATE PLANT GROWTH BY INJECTING A PLUG AT LIFT

BACKGROUND OF THE INVENTION

Reforestation is often carried out by outplanting seedlings that have been grown in seedling nurseries. The seedlings may be bare root stock or, more commonly, the root is enveloped in growth medium in the form of a plug in a container - this latter is referred to as containerized stock. Outplanting of containerized stock, therefore,
5 involves placing the plug into soil at the reforestation site.

For the purposes of this specification, the term "plug" will be considered to include pellets - for example, Jiffy™ pellets - and any other suitably retained growth medium, for example, growth medium in multiple cavity containers such as styroblocks.
10 A number of plugs are typically retained in a block. For the purposes of this specification, the term block will, therefore, refer to any container that has a plurality of cavities each which holds a plug. Further, the term "fertilizer" will be considered to include both organic and inorganic forms of fertilizer.

15 To produce containerized stock, the seedlings are seeded directly into the plug, which has been prepared in advance, by filling a plug cavity with a growth medium. Typically, the growth medium is inert and is, for example, comprised of peat or a mixture of peat, vermiculite and sand. As the medium is very low in plant nutrients, fertilizer is provided either as a slow-release fertilizer that is included in the mix, or
20 through fertigation.

Commonly, slow-release fertilizers are available as prills. In this context, "prill" is encapsulated fertilizer in the form of a bead. A prill in the context of conifer

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seedlings growth is chemical or organic fertilizer encased in a polymeric coating made of plastic. Alternatively, granular formulations, both organic and inorganic, may be used that slowly release the fertilizer. These slow-release fertilizers may be added to the plug at the time of sowing with the objective of providing a residual load to the seedling once it is lifted and outplanted. However, regardless of the type of slow-release fertilizer used, much of it has been expended by the time the seedling is ready to be lifted.

Once a seedling reaches the prescribed height, caliper and developmental stage, it is lifted. At this time, it may be outplanted directly, as occurs with the "hot lift" seedlings, or it may be placed in cold storage, where it will remain over the winter. At the end of the cold storage period, the seedling is thawed and outplanted directly into the reforestation site.

Establishment of the seedling in the reforestation site is a critical step in the reforestation process. Hence there has been research on methods of increasing the rate of early growth. Frequently, seedling growth following outplanting is limited by a lack of adequate nutrients.

Research to increase the availability of nutrients to the seedling following outplanting has been extensive and has focussed on such techniques as co-cultivating mycorrhizal fungi with the seedling roots in the nursery, placing fertilizer "tea bags" in a hole next to the hole that the plug is planted into at the reforestation site (US Patents Nos. 5,022,182 and 5,317,834), and studying root growth to determine ways to increase the seedling's access to the limited soil nutrients. Limited fertilizer spray programs have also been implemented, but unfortunately, these often result in the brush and weeds outgrowing the seedlings. When this occurs, the brush and weeds have to be controlled, adding further expense to the cost of reforestation.

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Despite the concern about the availability of nutrients to the seedling following outplanting, fertilization at lift, rather than at or following outplanting, does not appear to have been actively pursued. Hence the prior art for such an approach appears to be limited to field crop fertilizers, crop seeders and the lifting and packaging equipment currently employed in seedling nurseries.

There are many patents that disclose devices and methods for injecting materials, including fertilizer into soil. These have been developed for field crops, and not for containerized crops, such as conifer seedlings. For example, US Patent No. 5,394,812 discloses a device and method to inject polymeric materials into soil. The invention is based on a fluid delivery system, with pumps and monitors to control the flow rate. The monitor is in the form of a float valve. The fluid with the polymer therein is delivered to a series of apertures by means of a high-pressure pulse.

US Patent No. 4,907,516 discloses a device and method for pulsed injection of liquid fertilizer into the soil. A solenoid control valve operates intermittently to interrupt the flow of liquid in order to provide liquid fertilizer to the nozzle in a series of short pulses. Penetration of the fertilizer into the soil is dependent upon the force of the jet of liquid through the nozzle.

Seeders for various purposes are known. US Patent No. 6,237,514 discloses an apparatus and method for disbursing agriculture seeds and other particulate materials into soil. A hopper supplies seeds to pockets that are located on sprocket wheels. The seeds are retained in the pocket by a housing that abuts the sprocket wheels. The number of seeds that are retained in each pocket is dependent upon the seed size and the pocket size. Rotation of the sprocket wheels to an open position in the housing results in release of the seeds. The seeds drop without assistance and land on the soil. Seed bed preparation therefore is carried out separately prior to seeding.

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US Patent No. 6,273,648 discloses apparatus providing even distribution of air-entrained particulate material to headers and ultimately to delivery nozzles. Specifically, the patent discloses a conveyor tube and distribution header for use with pneumatic seeders. Turbulence is used within the conveyer tube to propel the seeds
5 toward the distribution head. The distribution head receives the seeds through a flow inlet and then divides the flow into a number of outlet ports.

Another apparatus for dispensing granular or particulate materials is disclosed in US Patent No. 5,189,965. The apparatus is designed to uniformly discharge a
10 predetermined quantity of granular material at a predetermined rate of application. A hopper is used to feed a metering system that has a number of rollers with pockets to receive the granular material. As the rollers turn, the granular materials are released into segregated metering channels and are pneumatically propelled through a delivery system. Hence, a continuous stream of granular or particulate materials is dispensed
15 onto the soil.

The nursery industry employs mechanized planters for emblings (somatic embryos) and seeds. Essentially, a dibbler is used to create a depression in the seed bed and seeds or emblyings are dropped into the depression. The seed bed may be
20 a transplant bed. Alternatively, the seeds may be sown directly into the plugs. The plugs are arranged in a block such as a styroblock.

Typical styroblocks are each comprised of a styrofoam-type polymer in the form of a block with plug cavities. The plug cavities are generally slightly conical and are
25 wider at the top of the block, narrowing to a small hole at the bottom of the block. The number of plug cavities is variable, as are the size and volume of the plug cavities; all are dependent upon the stock type that is being grown or the desired specifications of the final product.

The process of lifting the seedlings from the blocks in preparation for cold storage or planting is generally mechanized, although the operation is still done manually at some nurseries. Usually, the block is grasped in a holding device, a series of pins are aligned with the plugs in a row-by-row manner and the pins are pushed into the plugs pneumatically, resulting in extraction of the seedlings in their plugs. The seedlings then fall onto a moving culling bed, where they are manually checked for size and morphology, grouped into sets of seedlings and wrapped as bundles in a plastic-type film, such as Saran™.

To Applicant's knowledge, fertilization at lift has not previously been integrated into the lifting process. This, in part, reflects the difficulties in developing machinery and methodology that can be integrated into the nursery operations, and that does not damage the seedlings.

At lift, the plugs are small, soft and wet. Furthermore, they are close together, especially in the size 410 blocks (112 plugs of 80 mL), which are the most common block size used. The plugs are easily dislodged from the blocks, as the blocks are designed for easy removal of the seedlings at lift. The styroblocks must be treated with care as they are not very durable or rigid.

The preferred fertilizer for fertilizing conifer seedlings at lift is a slow-release prill or a granular type of fertilizer. The prills are fragile, as the outer coating is usually a thin, plastic polymer. The plastic coating is also hygroscopic and consequently, becomes soft and sticky in high-humidity environments. Similarly, granular fertilizer is hygroscopic and will become soft and sticky in high-humidity environments. Additionally, both granular fertilizer and prills tend to adhere to surfaces when force is applied. This makes mechanical insertion difficult as they will tend to clog the injection tubes.

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The seedlings are also fragile. The aerial tissue is frequently tall, with many needles, but little branching. The root system is often quiescent at the time of lift, and therefore more susceptible to damage.

5 Any mechanized method of application has to accommodate the foregoing constraints.

SUMMARY OF THE INVENTION

10 An aspect of the present invention is a method to modulate plant growth by delivering various selected plant growth modulators (e.g., fertilizer, pesticide, etc.) to a plug at lift. Lift may occur prior to transplanting, as occurs in a transplant nursery, or prior to cold storage, or prior to outplanting. In each case, injection of plant growth modulators into the interior of the plug from the plug's top surface, as contrasted with
15 deposit of such material onto the surface of the plug, could result in perturbation of the seedling. Examination of seedling morphology indicates that there are a large number of crown roots at the top of the plug. In addition, the location of the stem is variable in the plug and the seedling has substantial aerial tissue. These factors may make it difficult to inject fertilizer into the top of the plug, as damage to any part of the plant
20 including the root system, stem or aerial tissue could reduce outplanting success, measured as survival and growth in the first few years following outplanting. Consequently, injection is preferably into the bottom of the plug. In a preferred embodiment, the present invention provides a method for injection of the plant growth modulator into the bottom of the plug, preferably by pneumatically injecting the plant
25 growth modulator into the plug.

For injection into the bottom of the plug, the blocks are preferentially placed on their sides. This promotes retention of a specific dose of fertilizer; if the blocks are upright and the plugs are injected from below, the fertilizer tends to fall out of the plug--even when all the operations are performed with the seedlings on their side there is
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loss of fertilizer. Further, more air pressure and a higher air flow would be required to inject from below as compared with injecting from the side. As a consequence, the seedlings should be supported, as they may bend and be damaged if left unsupported.

5 In order to successfully inject plant growth modulator into the plug, it is preferable to pre-form a bore and a port in the plug. The bore is preferably formed by drilling with a specially formed cavity tool through the bottom of the plug. As the cavity tool reaches the end of its stroke, a distal tip of the cavity tool penetrates a top end of the plug and produces the port. The port allows air to be expelled from the bore. By
10 having a shoulder on the cavity tool between a wide cylindrical body and a narrow distal tip, a mating shoulder is created within the bore. The narrowing of the bore afforded by the shoulder impedes movement of the plant growth modulator from the bore into the port. Further, the smaller diameter of the narrow distal tip and its flexibility reduces the risk of damage by the cavity tool to the seedling in the plug.

15 In order to optimize the injection procedure, the amount (dose) of plant growth modulator injected into each plug should be controlled. Assuming that a metering system of the sort disclosed in US Patent No. 5,189,965 is used, the correct dose can be applied by selecting the appropriate metering roller, which forms part of the
20 metering roller system. Each metering roller has pockets sized to deliver a specific amount of plant growth modulator, and different rollers have different pocket sizes. Once the dose has been determined, the appropriate metering roller is used to deliver plant growth modulator to the individual injectors, which deliver the dose to the plug. The delivery is preferably effected using a pneumatic injection system.

25 Once the plug has been injected, it is preferable to close the bore at the bottom of the plug. Closure can be effected with a bore closer or a paste injector. Closing the bore facilitates retention of the plant growth modulator in the bore.

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In a preferred aspect of the invention, drilling with a cavity tool precedes injection of plant growth modulator into the plug.

5 In a preferred aspect of the invention, drilling occurs in at least one self-contained set of plugs, while at the same time injection is occurring in at least one adjacent self-contained set of plugs, and then the sets are laterally displaced so that the drilled set is positioned for injection, the injected set removed, and a fresh set is positioned in place for drilling, thereby minimizing the time required to drill and inject a series of such plug sets. The "set" of plugs may conveniently be a row of plugs in
10 a block, or in a more expensive facility, could be an entire block of plugs, provided that the plugs may be maintained in satisfactory alignment for the drilling and injection operations.

15 In a preferred aspect of the invention, seedlings are held in a seedling holder to reduce damage to the seedlings during nursery operations. Preferably, the seedling holder is comprised of a series of guides spaced to accept a row of seedlings, that slide between the row and support the aerial tissue of the seedlings.

20 In another aspect of the invention, the styroblock that holds a set of plugs to be drilled and injected is retained in a block restraint while the bore is drilled in the plug and while the plant growth modulator is thereafter delivered into the bore. Preferably a pre-selected dose of the plant growth modulator is delivered to the injector by a metering roller, and the plant growth modulator is then injected into the bore.

25 In another aspect of the invention, all the seedlings in a block are supported by the seedling holder, which is comprised of a series of guides and dividers. Preferably the dividers are biased from the guides in an open position to allow the seedling to slide into place, closing onto the guides in the closed position to hold the seedlings. A bore is then drilled in the plugs.

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In another aspect of the invention, all the seedlings in a block are supported by the guides of the seedlings holder, and more preferably the seedlings are held by the dividers of the seedling holder. Preferably, a bore is then drilled in the plugs.

5 In another aspect of the invention, all the seedlings in a container are supported and held by the seedling holder, a bore is drilled in the plug, and the plant growth modulator is injected into the bore.

10 In another aspect of the invention, all the seedlings in a container are supported and held by the seedling holder, a bore is drilled in the plug, a pre-selected dose of the plant growth modulator is delivered to the injector by a metering roller and the plant growth modulator is injected into the bore.

15 In another aspect of the invention, the block is retained in a block restraint, all the seedlings in a block are supported and held by the seedling holder, a bore is drilled in the plug and plant growth modulator is injected into the bore. Preferably, a pre-selected dose of the plant growth modulator is delivered to the injector by a metering roller.

20 In another aspect of the invention, all the seedlings in a container are supported and held by the seedling holder, a bore is drilled in the plug, a plant growth modulator is injected into the bore, and the bore is closed.

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5 In another aspect of the invention, the block is retained in a block restraint, all the seedlings in a container are supported and held by the seedling holder, a bore is drilled in the plug, a pre-selected dose of the plant growth modulator is delivered to the injector by a metering roller, the plant growth modulator is injected into the bore, and the bore is closed.

10 In a preferred aspect of the invention, the operations of drilling, injecting and closing occur concomitantly and preferably concurrently, each in adjacent blocks or in adjacent rows of a block. Accordingly, it is preferable to align and then restrain the block during drilling. An indexing bar is employed to align the various tools with the plugs, and a clamp holds both a block restraint and a seedling holder in place.

15 In the preferred aspect of the invention, the operations are automated, and may, for example, be controlled by a micro-controller.

20 In one aspect of the invention, the plant growth modulator that is injected is a suitable selected granular fertilizer.

In another aspect of the invention, the plant growth modulator is suitable selected fertilizer prills.

25 In yet another aspect of the plant growth modulator is suitable selected encapsulated biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof.

30 In another aspect of the invention, the plant growth modulator is a suitable selected pesticide.

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In yet another aspect of the invention, the plant growth modulator is a suitable selected growth adjuvant.

5 In yet another aspect of the invention, the plant growth modulator is hygroscopic.

In another aspect of the invention, the plant growth modulator is a seed.

10 Note that different types of plant growth modulator may be combined in a single injection, assuming physical, chemical and biological compatibility between the modulators injected.

15 The present invention has been developed concurrently with the development of apparatus suitable for its implementation. Such apparatus, and the use of the apparatus in conjunction with the method, are preferably characterized by the following features:

20 In one aspect of the preferred apparatus/method implementation, a plug is prepared for subsequent injection of plant growth modulator into the plug by drilling a bore. The bore is created in the plug by a cavity tool. Penetration and exit of the distal end of the cavity tool through the top of the plug results in the formation of a port for release of air during injection of the plant growth modulator into the bore. The bores are preferably drilled in a row of plugs or other selected set of plugs simultaneously using a corresponding set of aligned drills.

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It is preferable to drill a series of plugs using a cavity tool system comprising a series of cavity tools that are positioned along a head and spaced in order to align with the plugs of the container during drilling of the bores.

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Preferably, predetermined doses of plant growth modulator are delivered using a metering roller system, comprising a metering roller and a perforated plate. The metering roller has a series of pockets, sized to accept a specific and predetermined amount of plant growth modulator. The metering roller preferably subtends a hopper.

5 Rotation of the metering roller from a first position, wherein the pockets accept plant growth modulator from the hopper, to a second position, wherein the pockets are aligned with perforations in the perforation plate results in plant growth modulator being delivered in specific and predetermined doses to individual injectors.

10 Each injector is preferably comprised of a pneumatic injection tube, an air delivery tube, a collection chamber and a nozzle. The collection chamber is between the air delivery tube and the nozzle. Plant growth modulator that collects in the collection chamber is air-entrained by injecting air through the air delivery tube and into the pneumatic injection tube in pulses of a predetermined duration and intensity.

15 The air-entrained material is then forced into the plug.

A row of plugs or other selected set of plugs may be injected at the same time using the foregoing or similar injection system. For this purpose, the injection system comprises an aligned series of injectors that are positioned on a head in order to

20 maintain alignment of the injectors with the plugs in the styroblock or other suitable container during injection of plant growth modulator into the bores. Preferably the selection of the set of plugs to be injected is at least a complete row and is matched with the set of plugs to be drilled, so that drilling and injection operations can occur side by side simultaneously; after each such combined drilling and injection step, the

25 block is moved laterally to bring the freshly drilled set into alignment with the injection apparatus while an undrilled set of plugs is brought into alignment with the drilling apparatus, and the procedure is repeated *seriatim*.

After the plugs have been injected, it is preferable to close the bore. Each bore

30 is closed using a bore closer. Preferably, a set of bores are closed simultaneously

using a bore closing system. The bore closing system comprises a series of bore closers that are positioned on a bore closer head and spaced in order to align with the plugs of the container during closing of the bores. Preferably the set of bores to be closed at a given time by the bore closing system is matched to the set of plugs to be drilled and the set of plugs to be injected, so that drilling, injecting, and closing operations may be performed simultaneously on adjacent sets of plugs, and consecutively seriatim as the block is laterally displaced following each such combined operation.

In another aspect of the invention, injection is preferably carried out hydraulically using a hydraulic injector, comprising a pneumatic injection tube, a collection chamber, a nozzle and a hydraulic tube which has, at a distal end, a hydraulic ram. Actuation of the hydraulic ram forces air through the pneumatic injection tube, air-entraining the plant growth modulator in the collection chamber, and releasing it through the nozzle, which is directed into the bore in the plug.

Injection with the hydraulic injector is preferably controlled by, for example, a microprocessor, such that a timed sequence of controlled pulses of air are delivered to the pneumatic injection tube. Each pulse of air causes delivery into each bore in a selected set of one dose of plant growth modulator. After each pulse, the collection chamber of each injector is reloaded with plant growth modulator. The hydraulic injection system preferably comprises a series of injectors that are positioned on a head spaced in order to align with the plugs of the container during injection of the bores.

In yet another aspect of the invention, plant growth modulator is injected using a fluid injector. The fluid injector comprises a fluid delivery tube, a collection chamber, a fluid injection tube and a nozzle. Fluid is injected into the injection tube from the fluid delivery tube, thereby fluid-entraining the plant growth modulator in the collection chamber, and releasing it through the nozzle, which is directed into the bore in the

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plug. Preferably, a series of plugs are injected using a fluid injection system, which comprises a series of injectors that are positioned on a head spaced in order to align the injectors with the plugs of the container during injection of the bores.

5 In another aspect of the invention, plant growth modulator is injected by means of a sequence of fluid pulses applied to consecutive rows or other selected sets of plugs. Each pulse of fluid results in delivery via each injector in the set of one dose of plant growth modulator. After each pulse, plant growth modulator is reloaded into the collection chamber of each injector in the set.

10 SUMMARY OF THE DRAWINGS

Figures 1A and 1B. An isometric view of a fertilizer injector, suitable for implementing aspects of methods according to the invention. Figure 1A shows a left-hand view and
15 Figure 1B shows a detail right-hand view of the receiving tray, block restraint and seedling holder.

Figure 2. A plan view of the cavity tool system, injecting system and bore closing system of the fertilizer injector shown in Figures 1A and 1B.

20 Figure 3. An isometric view of the seedling holder shown as part of the injector of Figures 1A and 1B.

Figure 4. An isometric view of a part of the seedling holder in Figure 3.

25 Figures 5A, B and C. A longitudinal mid-section view through a plug and plug cavity in a block. Figure 5A shows the plug prior to preparation of the bore. Figure 5B shows the plug during preparation of the bore. Correct placement of a cavity tool is shown according to an aspect of the invention. Figure 5C shows the plug after preparation
30 of the bore.

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Figure 6. An isometric view of a cavity tool system suitable for implementing aspects of methods of the invention.

Figure 7. An exploded view of the cavity tool system shown in Figure 6.

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Figure 8. A side view of a cavity tool suitable for implementing aspects of methods according to the invention.

Figure 9. An isometric view of an injection slide suitable for implementing aspects of the methods according to the invention.

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Figure 10. An isometric view of a metering roller system, with the injection tube of the injection system exploded therefrom, suitable for implementing aspects of methods according to the invention.

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Figure 11. An exploded view of the metering roller system shown in Figure 10.

Figure 12. An isometric view of an injection system suitable for implementing aspects of methods according to the invention.

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Figure 13. An isometric view of a bore closer system suitable for implementing aspects of methods according to the invention.

Figure 14. An exploded view of a bore closer system shown in Figure 13.

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Figure 15. An exploded longitudinal section of a second embodiment suitable for implementing aspects of methods according to the invention, showing a paste extruder.

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Figure 16. An isometric view of a second embodiment suitable for implementing aspects of the methods according to the invention showing a paste extruder head.

Figure 17. An exploded view of the paste extruder head shown in Figure 16.

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Figure 18. A plan view of an indexing bar and a dog, mounted to the receiving tray suitable for implementing aspects of the methods according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED METHODS

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A fertilizer injector, generally indicated as 30 and shown in Figure 1A can be integrated into standard lift operations in the nursery and is used for fertilizing plugs with prills or granular material at lift. The fertilizer injector 30 is comprised of a block restraint 32, a seedling holder 34, a cavity tool system 36, a metering roller system 38, an injection system 40, and a bore closing system 42. The various systems are sub-combinations of the entire injection apparatus. Prills are the preferred form of slow release fertilizer, but they are difficult to inject because of the fragile outer coating and their hygroscopic nature. Hence, the fertilizer injector 30 is designed to accommodate these features of the prills.

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There are a number of operations that are performed during the injection process. First, blocks 44 that contain seedlings 56 are restrained in the block restraint 32. This assists in aligning the plugs 90 with the cavity tools 84, the injectors 178 and the bore closers 206, in addition to restraining the block 44. The seedling holder 34 is then positioned around the seedlings 56. This serves to support the seedlings 56 and reduce twisting and bending of the aerial tissue. Once the block 44 is restrained and the seedlings 56 are held, the cavity tool system 36 is aligned with a row of plugs 90. The cavity tool system 36 prepares the plug 90 for injection by drilling a bore 86 through the length of the plug 90. Once the first row of plugs 90 have been drilled, the next row is drilled while the first row is being injected. The injection is carried out with

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the injection system 40. A predetermined dose of fertilizer is fed into the injection system 40 by the metering roller system 38 and the fertilizer is then injected into the bore 86 in the plug 90. The plugs 90 in a given row are injected simultaneously. The process continues in a row by row manner until all the plugs 90 have bores 86 drilled in them and all the plugs 90 have been injected. Once the injection has been completed, the bores 86 are closed with a bore closing system 42. The bore closing system 42 operates in a row by row manner, closing the bores in a row of plugs 90 and then moving to the next row of plugs 90. Once the closing operation has been completed, the block 44 is released from the block restraint 32, the seedlings 56 are released from the seedling holder 34 and the block 44 is moved to the lifting conveyor 58.

In a preferred aspect of the invention, drilling occurs in at least one self-contained set of plugs 90, while at the same time, injection is occurring in at least one adjacent self-contained set of plugs 90, and closing is occurring in at least one self-contained set of plugs 90 adjacent to self-contained set of plugs 90 being injected. The sets are then laterally displaced so that the drilled set is ready for injection, the injected set is ready for closing and a fresh set is positioned in place for drilling. The set of plugs 90 may be a row of plugs 90 or may be an entire block 44 of plugs 90, provided that the plugs 90 may be maintained in satisfactory alignment for the drilling, injecting and closing operations. The details of the operations and the apparatus follow.

Blocks 44 or other seedling containers are preferably placed on their side and are moved to the seedling holder 34 by a loading conveyor 46. Once at the seedling holder 34, the block 44 is clamped to the seedling holder 34 by a clamp 48.

The block restraint 32 is comprised of a receiving tray 50 with a channel 52 that is wide enough to accommodate the block 44 on its side. Both the receiving tray 50 and the channel 52 extend longitudinally between the loading conveyor 46 and a lifting

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conveyor 58. A stop 54 to receive the block 44 is preferably an L-shaped member and is mounted on the block restraint 32.

The seedling holder 34 is comprised of a series of guides 62 and dividers 64 mounted on two open boxes; a bottom box 68, and an end box 70. The bottom box 68 is mounted perpendicular to the end box 70 and holds the clamp 48 to clamp the seedling holder 34 and block restraint 32 in place on the receiving tray 50. As the block 44 moves into the seedling holder 34, the guides 62 separate the seedlings 56 into rows. Once all the seedlings 56 in the block 44 are in the seedling holder 34, and the block 44 is in the block restraint 32, both are locked in position with the clamp 48. The dividers 64 are then closed to hold the seedlings 56. This geometry facilitates maintenance of the desired alignment of the block 44 and the seedlings 56 with each other and, therefore, tends to avoid twisting and bending of the seedlings 56 by the seedling holder 34.

Two opposing side members 72, 74 of the end box 70 support the series of guides 62 and dividers 64. The guides 62 are preferably made of metal and are trapezoid-shaped plates that are preferably mounted horizontally to the side members 72, 74. The acute angle of the trapezoid is located on a loading end 78 of the seedling holder 34 such that it is proximal to the block 44. An acute angle is preferred over a right angle, as it assists in coaxing each seedling 56 onto the guide starting with the stem, which is sturdy and has few needles and ending with the fragile aerial growth.

A series of dividers 64, preferably two per guide 62 are mounted on hinges 76 that are mounted on the side members 72, 74 and extend between the side members 72, 74. The dividers extend between the side members 72, 74. The dividers 64 provide a space 82 such that a row of seedlings 56 can be moved horizontally through the space 82 when the dividers 64 are in the open position. When the dividers 64 are closed, the seedlings 56 are gently restrained. The dividers 64 are preferably made

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of a pliable material such as webbing or rubber, in order to reduce the potential for damage to the seedlings 56.

Once the seedlings 56 are supported in the seedling holder 34, a cavity tool 84 is employed to drill a bore 86 and a port 88 into the plug 90. As shown in Figure 5B, the cavity tool 84 enters the plug 90 through a small hole 92 that is in the bottom of each plug cavity 94, then enters the plug 90 at a bottom end 96 and progresses through the plug 90, creating the port 88 for air release at a top end 98 of the plug 90.

Proper alignment and operation of the cavity tools 84 is provided by the cavity tool system 36. Preferably, the cavity tool system 36 is comprised of a head (generally indicated by number 100) that retains a series of cavity tools 84 that are coupled to a drive shaft 106 (Figures 6 and 7). As shown in Figure 6, the cavity tools 84 are aligned along the head 100 such that they will be in alignment with the plugs 90 in at least one row. Preferably, the head 100 is sufficiently large enough to hold a gang of cavity tools 84 corresponding in number and location to the plugs 90 in a 410 block 44, the designation "410" being a size designation used in the industry. It is proposed that different heads 100 will be available for different block sizes and configurations.

The head 100 is comprised of two opposing sides 108, 110, a base 112, a top 114, a mount 116, a dust cap 154 and a cavity tool holder 118. The sides 108, 110, base 112, top 114 and dust cap 154 are attached to one another to form a box 120. The cavity tool holder 118 is housed in the box 120 and is attached to the sides 108, 110 of the box 120. Apertures 122 in the cavity tool holder 118 are located so as to be in register with the plugs 90 of the block 44. Similarly, the top 114 of the head 100 has a series of openings 124 that are in register with the plugs 90 of the block 44. The cavity tools 84 are positioned such that one tool 84 is aligned with one opening 124 and a corresponding aperture 122. This aligns one cavity tool 84 with one plug 90. The dust cap 154 impedes entry of dust into the head 100.

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The cavity tools 84 are approximately torpedo-shaped, but formed with an annular shoulder 134, for the purpose previously stated (see Figure 8). Further, a distal tip 130 of the cavity tool 84 is conical. The shape of the cavity tool 84 has been shown to reduce damage to the seedling roots during drilling as the roots are pushed
5 aside as the cavity tool 84 advances. A long wide, cylindrical body 126 extends between a proximal end 128 and a distal tip 130, which is narrow and terminates in a point 132. A shoulder 134 between the cylindrical body 126 and the distal tip 130 is preferably at 20 degrees relative to a longitudinal axis 136. The distal tip 130 is long enough to extend out through the top end 98 of the plug 90. The cavity tool 84 is
10 preferably aluminum or a metal with similar malleability or a flexible plastic polymer, as harder materials may damage the aerial tissue or roots.

Rotatably mounted proximally on the cavity tool 84 and located between the top 114 of the head 100 and the cavity tool holder 118 is an inner bearing 138, a spacer
15 140 and an outer bearing 142 (see Figure 6). The bearings 138, 142 rotatably mount the cavity tool 84 in the cavity tool holder 118. The proximal end 128 of the cavity tool 84 is preferably mated to a first mitre gear 144 in order to drive the cavity tool. The first mitre gear 144 engages a second mitre gear 146 with a peripheral rotary engagement of approximately 90 degrees. The second mitre gear 146 is mounted
20 coaxially on the drive shaft 106 and is driven by the shaft 106. A guide 150 on either side of the second mitre gear 146 separates it from at least one spanner 152. The drive shaft 106 is rotatably mounted on the spanners 152, which bridge the cavity tool 84 holder and the top 114 of the head 100.

25 The cavity tools 84 are able to rotate freely about a longitudinal axis 136 and are driven by means of the drive shaft 106, which is coupled to and driven by the output shaft of a gear box (not shown). The gear box, in turn, is coupled to and driven by a motor (not shown). The rate of rotation and penetration of the cavity tools 84 is controlled to facilitate displacement of the seedling roots so that the roots are pushed
30 aside rather than being damaged. The preferred rate of rotation in a prototype

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apparatus was found to range from about 80 to about 400 rpm. Penetration by the cavity tools 84 is controlled such that the tools 84 move distally longitudinally far enough to exit through the top end 98 of the plugs 90 in order to create the ports 88. The cavity tools 84 are then retracted and moved into alignment with the next row or
5 rows of plugs 90.

Placement of the cavity tools 84 is controlled by an injection slide 158. The head 100 of the cavity tool system 36 is affixed to a plate 156 by the mount 116 and the plate 156 is vertically mounted on the injection slide 158. The injection slide 158
10 is comprised of a foot 160, four risers 162 and a frame (generally indicated by number 164)(see Figure 9). A support rod 166 extends between a front member 168 and a back member 170 of the frame 164. The plate 156 is coupled to a hanger 172, which hangs from the support rod 166. Movement of the head 100 towards and away from the block 44 is accomplished by sliding the hanger 172 along the support rod 166.
15 This is preferably controlled by a press which is preferably hydraulically actuated. Correct placement of the cavity tool system 36 is promoted by a positioning dowel 173 which extends outwardly from the plate 156 and is received by an aperture 175 in the block restraint 32.

Correct operation of the cavity tool system 36 results in a plug 90 with a wide bore 86, which will receive the fertilizer, and a narrow port 88 for air release from the plug 90 (see Figure 5C). Such a plug 90 is ready for injection using injectors 178 on the injection system. The block 44 remains clamped by the block restraint 32, and the seedling holder 34 continues to support the seedlings 56 during the injection
20 operation. The injection system 40 is mounted beside the cavity tool system 36 such that the series of cavity tools 84 are aligned with one row of plugs 90 and the injection system 40 is aligned with the adjacent row of plugs 90(Figure 1A).
25

Fertilizer is delivered from a hopper 174 through an orifice 180 to the metering roller system 38 prior to entry into the injection system 40 (see Figure 10). The hopper
30

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is affixed to the injection slide 158 by a support 176. The metering roller system 38 is comprised of a metering roller 182, at least one bolt 184 and a perforated cover 188 (see Figure 11). The perforated cover 188 is affixed to the hopper 174 and the metering roller 182 is rotationally mounted thereon. Preferably, the perforated cover 188 is provided with a flap 189 that extends along its length.

The metering roller 182 has pockets 190 sized to hold the volume of fertilizer needed in a particular dose. A number of metering rollers 182 are, therefore, available in order to provide a range of doses. For example, a series of 6 rollers deliver 0.5 g, 1.0 g, 1.5 g, 2.0 g, 2.5 g and 3.0 g of a given standard of fertilizer. The metering roller is preferably comprised of a high density plastic polymer. The metering roller 182 rotates, by means of a handle 186 and delivers the doses to a series of inlets 192 of a series of pneumatic injection tubes 194 through perforations 196 of the perforated cover 188 and then continues its rotation to position the pockets 190 below the hopper 174 in order to refill. In this position, air flow from the pneumatic injection tubes 194 into the hopper 174 is impeded. The reduced air flow assists in removing any residual fertilizer from the pockets 190 and assists in removing residual fertilizer from the pneumatic injection tubes 194 prior to refilling.

Each injector 178 is comprised of a pneumatic injection tube 194, a collection chamber 198, a nozzle 200 and an air delivery tube 202. In one embodiment, the collection chamber 198 is simply a bend in the tube, that projects below both the inlet 192 and the nozzle 200 (see Figure 12). The air delivery tube 202 is located between the inlet 192 and the collection chamber 198. It is in pneumatic communication with the pneumatic injection tube 194. Pulses of air enter into the pneumatic injection tube 194 under the control of a pneumatic pump (not shown). The velocity and volume of air in a given pulse is controlled by a controller (not shown), for example, a microprocessor, such that a timed sequence of controlled pulses of air are delivered to the pneumatic injection tube 194. The air pressure is preferably 15 ± 2 psi and the duration of the pulse is preferably 0.6 ± 0.5 second. Each pulse of air propels the

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fertilizer, which has been delivered to the collection chamber 198 by the metering roller system 38, into the nozzle 200, which is sized to mate with the bore 86. The air-entrained fertilizer then enters each bore 86 in a selected set of plugs 90 where it is retained. Excess air escapes through the port 88 in the plug 90. The bore 86 has a shoulder 204 formed by the shoulder 134 of the cavity tool 84 (see Figures 3B and 6). This assists in retaining the fertilizer in the bore 86. After each pulse, the collection chamber 198 of each injector 178 is reloaded with fertilizer.

The injection system 40 is mounted on the same plate 156 that the head 100 of the cavity tool system 36 is mounted on. Hence, movement into and out of the block 44 is again controlled by sliding the hanger 172 along the support rod 166 of the injection slide 158.

The final step involves closing the bore 86. A bore closer 206 engages the bottom end 96 of the plug 90 and exerts pressure on the bottom end 96 of the plug 90. In one embodiment (see Figure 13), a paddle 208 is mounted on a distal end 210 of the bore closer 206 and the bore closer 206 is rotated, while pressure is exerted on the bottom end 96 of the plug 90. In another embodiment the bore closer 206 has a concave end (not shown) that accepts the bottom end 96 of the plug 90.

Proper alignment and operation of the bore closers 206 is provided by the bore closing system 42. Preferably, the bore closing system 42 is comprised of a head 212 that retains a series of bore closers 206 that are coupled to a drive shaft 216 (see Figure 14). The bore closers 206 are aligned along the head 212 such that they will be in alignment with the plugs 90 in at least one row. Preferably, the head 212 is sufficiently large enough to hold a gang of bore closers 206 corresponding in number and location with the plugs 90 in a 410 block 44. It is proposed that different heads 212 will be available for different block sizes.

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The head 212 is comprised of two opposing sides 218, 220, a top 222, a base 224, a mount 226, a dust cap 236 and a bore closer holder 228. The sides 218, 220, top 222, base 224 and dust cap 236 are attached to one another to form a box 230. The bore closer holder 228 is housed in the box 230 and is attached to the sides 218, 220 of the box 230. Apertures 232 in the bore closer holder 228 are located so as to be in register with the plugs 90 of the block 44. Similarly, the top 224 has a series of openings 234 that are in register with the plugs 90 of the block 44. The bore closers 206 are positioned such that one closer 206 is aligned with one opening 234 and a corresponding aperture 232. This aligns one cavity tool 84 with one plug 90.

The mount 226 attaches the bore closing system 42 to the same plate 156 to which the head 100 of the cavity tool system 36 is attached. Hence movement into and out of the block 44 is again controlled by sliding the hanger 172 along the support rod 166 of the injection slide 158. The dust cap 236 impedes entry of dust into the head 212.

Rotatably mounted proximally on the bore closer 206 is an inner bearing 238, a spacer 240 and an outer bearing 242. The bearings 238, 242 rotatably mount the bore closer 206 in the bore closer holder 228. A proximal end 244 of the bore closer 206 is mated to a first mitre gear 246 in order to drive the bore closer 206. A second mitre gear 248 engages the first mitre gear 246 with a peripheral rotary engagement of approximately 90 degrees. The second mitre gear 248 is mounted coaxially on the drive shaft 216 and is driven by the shaft. A guide 252 on either side of the second mitre gear spaces it from spanners 254. The drive shaft 216 is rotatably mounted on the spanners 254, which bridge the bore closer 206 and the top 224 of the head 212. The bore closer 206 preferably rotates at 10-400 rpm.

In a second embodiment there is provided a paste extruder 256 as a means for closing the bore 86 (see Figure 15). A suitable paste is biodegradable and is sufficiently viscose to remain in the bore 86 after injection. The paste extruder 256 is

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preferably air-actuated and has a plunger 258 housed within a chamber 260. The plunger is depressed when air is forced through a pneumatic tube 261. The chamber 260 has an aperture 262 distal to the plunger 258. Actuation of the plunger 258 forces a predetermined amount of paste from the chamber 260, through the aperture 262 and into the bore 86 of the plug 90. The aperture 262 is sized to fit in the small hole 92 in the bottom of the plug cavity 94 and is preferably also sized to enter into the bore 86. The depth of the extrusion is controlled by the force exerted on the plunger 258, the viscosity of the paste and depth of the paste extruder 256 in the bore 86.

A series of paste extruders 256 are mounted on a head 264 that is similar to that described above. The paste extruders 256 are aligned along the head 264 such that they will be in alignment with the plugs 90 in at least one row. Preferably, the head 264 is sufficiently large enough to hold a gang of paste extruders 256 corresponding in number and location with the plugs 90 in a 410 block 44. It is proposed that different heads 264 will be available for different block sizes.

The head for the paste extruders 256 is comprised of two opposing sides 266, 268, a base 270, a top 272, a mount 274, a dust cap 300 and a paste extruder holder 276. The sides 266, 268, dust cap 300, base 270 and top 272 are attached to one another to form a box 278. The paste extruder holder 276 is housed in the box 278 and is attached to the sides of the box 278. Apertures 280 in the paste extruder holder 276 are located so as to be in register with the plugs 90 of the block 44. Similarly, the top 272 has a series of openings 282 that are in register with the plugs 90 of the block 44. Each paste extruder 256 is positioned in the opening 282 and the corresponding aperture 280 in order to be aligned with the plug 90.

During the injection process, it is necessary to reposition the block restraint 32 and the seedling holder 34 to align the fertilizer injector 30 with rows of plugs 90 that have not been injected. Contact points between the receiving tray 50 and both the block restraint 32 and seedling holder 34 are preferably coated with a material

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such as a high density plastic polymer to reduce friction. The block 44 may be repositioned as needed by manually releasing and moving the block restraint 32 and seedling holder 34 along an indexing bar 294. Different indexing bars 294 corresponding to different block sizes can be used as needed. The indexing bar 294 has a series of stops 296 that are spaced for alignment with the plugs 90 in a block 44 (Figure 18). The indexing bar 294 is affixed to the seedling holder 34 and is positioned to accept a dog 298 mounted on the receiving tray 50. Engagement of a stop 296 with the dog 298 facilitates alignment of the various tools and injectors with the plugs 90.

Once aligned, the cavity tool system 36, the injection system 40 and the bore closing system 42 can be moved into and away from the block 44 along the injection slide 158. The movement is controlled by a press (not shown) which is preferably hydraulically actuated.

Once the block 44 of plugs 90 has been fertilized and the bore 86 closed, the seedling holder 34 is disengaged, the block restraint 32 is disengaged and the block 44 is moved onto the lifting conveyor 58.

The foregoing description of injecting fertilizer into plugs at lift describes the preferred methods and is not meant to be limiting. As would be apparent to one skilled in the art, there can be, for example, variation in the degree of mechanization, the mode of restraining and supporting the blocks and seedlings and the type of container that is restrained. Fertilizer may be delivered into the bore in the plug in a variety of ways, including in a fluid. Further, while the foregoing description is premised by way of example upon injection of fertilizer, a variety of different materials can be injected. For example, encapsulated biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof, pesticides, including herbicides, insecticides, and herbivore deterrents, hygroscopic materials, seed and growth adjuvants could be injected. Finally, a variety of materials may be injected into a plug that does not contain a seedling. For example, the method can be used to seed

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plugs. Similarly, it can deliver material into a plug in which a plant, rather than a seedling is growing.

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WHAT IS CLAIMED IS:

- 1. A method of modulating growth of a plant grown in a plug contained in a block using a selected plant growth modulator, comprising restraining the block, supporting a set of plants, drilling a bore a sufficient distance through the plug to provide a distal port for release of air through the port, metering a selected dose of the selected plant growth modulator, and injecting the selected dose of the selected plant growth modulator into the bore.**
- 2. The method of claim 1 further comprising closing the bore after injecting the selected dose of the selected plant growth modulator.**
- 3. The method of claim 1 wherein selected steps in the sequence of steps of the method are synchronized and automated under the control of a timer, micro-controller, or other selected means.**
- 4. A method of modulating growth of a set of plants grown in a set of plugs contained in a block using a selected plant growth modulator, comprising restraining the block, supporting the set of plants, drilling a bore in each plug of a set of plugs to provide a set of bores, each bore being drilled a sufficient distance through the plug to provide a distal port for release of air through the port, metering a set of a selected dose of the selected plant growth modulator, and injecting the set of the selected dose of the selected plant growth modulator into the set of bores.**
- 5. The method of claim 4 further comprising drilling one set of plugs, displacing the set of plugs that has been drilled and injecting the set of plugs that has been displaced concurrently with the drilling of a fresh, adjacent set of plugs.**

6. The method of claim 1 wherein the selected plant growth modulator is incorporated into particulate material.
7. The method of claim 6 wherein fertilizer is incorporated into the particulate material.
8. The method of claim 7, wherein the particulate material is a prill.
9. The method of claim 6 wherein biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof is incorporated into the particulate material.
10. The method of claim 6 wherein pesticide is incorporated into the particulate material.
11. The method of claim 6 wherein a growth adjuvant is incorporated into the particulate material.
12. The method of claim 1 wherein the selected plant growth modulator is a seed.
13. The method of claim 6 wherein hygroscopic material is incorporated into the particulate material.
14. The method of claim 1 further characterized in that drilling of the bore and port is from a bottom end of the plug continuing through a top end of the plug.
15. The method of claim 14 further comprising forming a narrow port and a wide bore, with a shoulder between.

16. The method of claim 4 wherein the selected plant growth modulator is incorporated into particulate material.
17. The method of claim 16 wherein fertilizer is incorporated into the particulate material.
18. The method of claim 17, wherein the particulate material is a prill.
19. The method of claim 16 wherein biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof is incorporated into the particulate material.
20. The method of claim 16 wherein pesticide is incorporated into the particulate material.
21. The method of claim 16 wherein a growth adjuvant is incorporated into the particulate material.
22. The method of claim 20 wherein the selected plant growth modulator is a seed.
23. The method of claim 16 wherein hygroscopic material is incorporated into the particulate material.
24. The method of claim 4 further characterized in that drilling of the bore and port is from a bottom end of the plug continuing through a top end of the plug.
25. The method of claim 24 further comprising forming a narrow port and a wide bore, with a shoulder between.

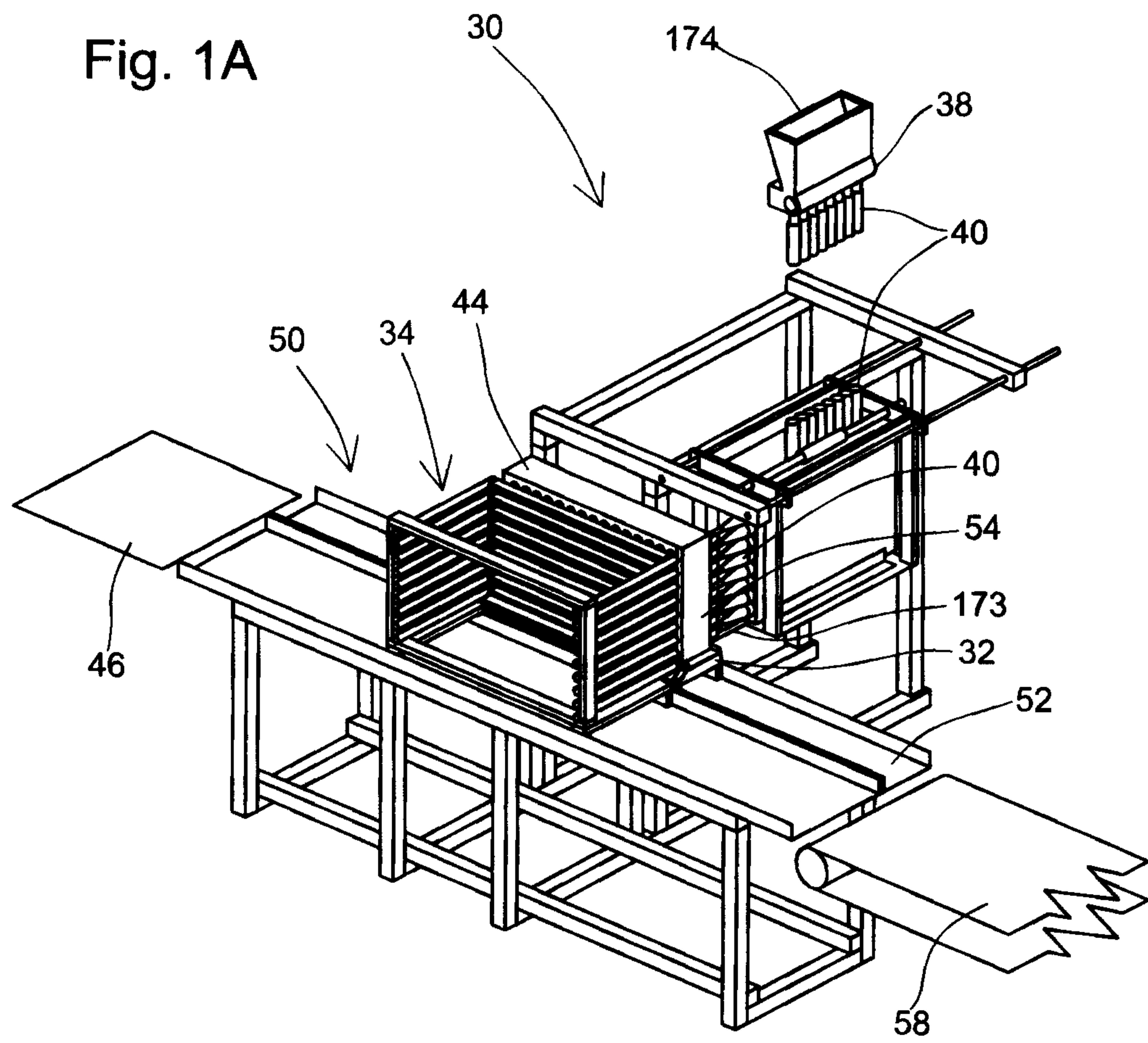
26. The method of claim 5, wherein the selected set of plugs is a matrix of equally spaced plugs.
27. The method of claim 5, wherein the selected set of plugs is a linear array of equally spaced plugs.
28. A method of modulating growth of a plant grown in a plug contained in a block using a selected plant growth modulator, comprising restraining the block, preparing a bore extending a sufficient distance through the plug to provide a distal port for the release of air through the port, and delivering the selected plant growth modulator into the bore.
29. The method of claim 28 further comprising closing the bore after delivering the selected dose of the selected plant growth modulator.
30. The method of claim 28 wherein selected steps in the sequence of steps of the method are synchronized and automated under the control of a timer, micro-controller, or other selected means.
31. A method of modulating growth of a set of plants grown in a set of plugs contained in a block using a selected plant growth modulator, comprising restraining the block, preparing a bore in each plug of a set of plugs to provide a set of bores, each bore extending a sufficient distance through the plug to provide a distal port for the release of air through the port, and delivering a set of the selected plant growth modulator into a set of bores.
32. The method of claim 31 further comprising preparing a set of bores in one set of plugs, displacing the set of plugs and delivering the selected plant growth modulator to the set of plugs that has been displaced concurrently with the preparation of the set of bores in a fresh, adjacent set of plugs.

33. The method of claim 28 wherein the selected plant growth modulator is incorporated into particulate material.
34. The method of claim 33 wherein fertilizer is incorporated into the particulate material.
35. The method of claim 34, wherein the particulate material is a prill.
36. The method of claim 33 wherein biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof is incorporated into the particulate material.
37. The method of claim 33 wherein pesticide is incorporated into the particulate material.
38. The method of claim 33 wherein a growth adjuvant is incorporated into the particulate material.
39. The method of claim 28 wherein the selected plant growth modulator is a seed.
40. The method of claim 33 wherein hygroscopic material is incorporated into the particulate material.
41. The method of claim 28 further characterized in that the bore and port is prepared by drilling from a bottom end of the plug continuing through a top end of the plug.
42. The method of claim 41 further comprising forming a narrow port and a wide bore, with a shoulder between.

43. The method of claim 31 wherein the selected plant growth modulator is incorporated into particulate material.
44. The method of claim 43 wherein fertilizer is incorporated into the particulate material.
45. The method of claim 44, wherein the particulate material is a prill.
46. The method of claim 43 wherein biological material selected from the group consisting of bacteria, fungi, nematodes, virus, and combinations thereof is incorporated into the particulate material.
47. The method of claim 43 wherein pesticide is incorporated into the particulate material.
48. The method of claim 43 wherein a growth adjuvant is incorporated into the particulate material.
49. The method of claim 31 wherein the selected plant growth modulator is a seed.
50. The method of claim 43 wherein hygroscopic material is incorporated into the particulate material.
51. The method of claim 31 further characterized in that the bore and port are prepared by drilling from a bottom end of the plug continuing through a top end of the plug.
52. The method of claim 51 further comprising forming a narrow port and a wide bore, with a shoulder between.

- 53. The method of claim 31, wherein the selected set of plugs is a matrix of equally spaced plugs.
- 54. The method of claim 31, wherein the selected set of plugs is a linear array of equally spaced plugs.
- 55. The method of claim 28, further comprising supporting a set of plants.
- 56. The method of claim 28, further comprising metering a selected dose of the selected plant growth modulator.
- 57. The method of claim 28, further comprising injecting the selected plant growth regulator into the bore.
- 58. The method of claim 31, further comprising supporting a set of plants.
- 59. The method of claim 31, further comprising metering a set of the selected dose of the selected plant growth modulator.
- 60. The method of claim 31, further comprising injecting a set of the selected plant growth regulator into the set of bores.

Fig. 1A



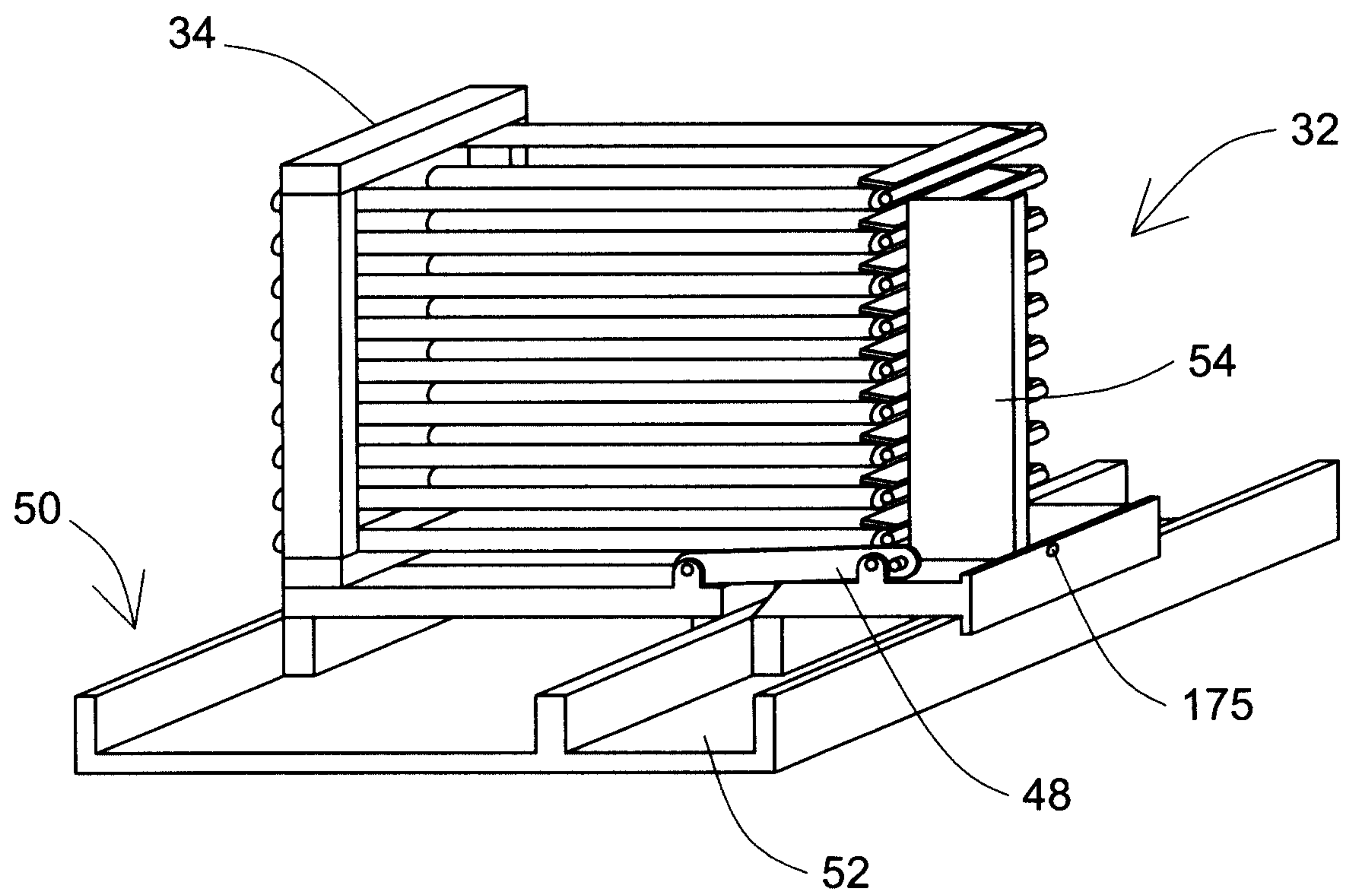


Fig. 1B

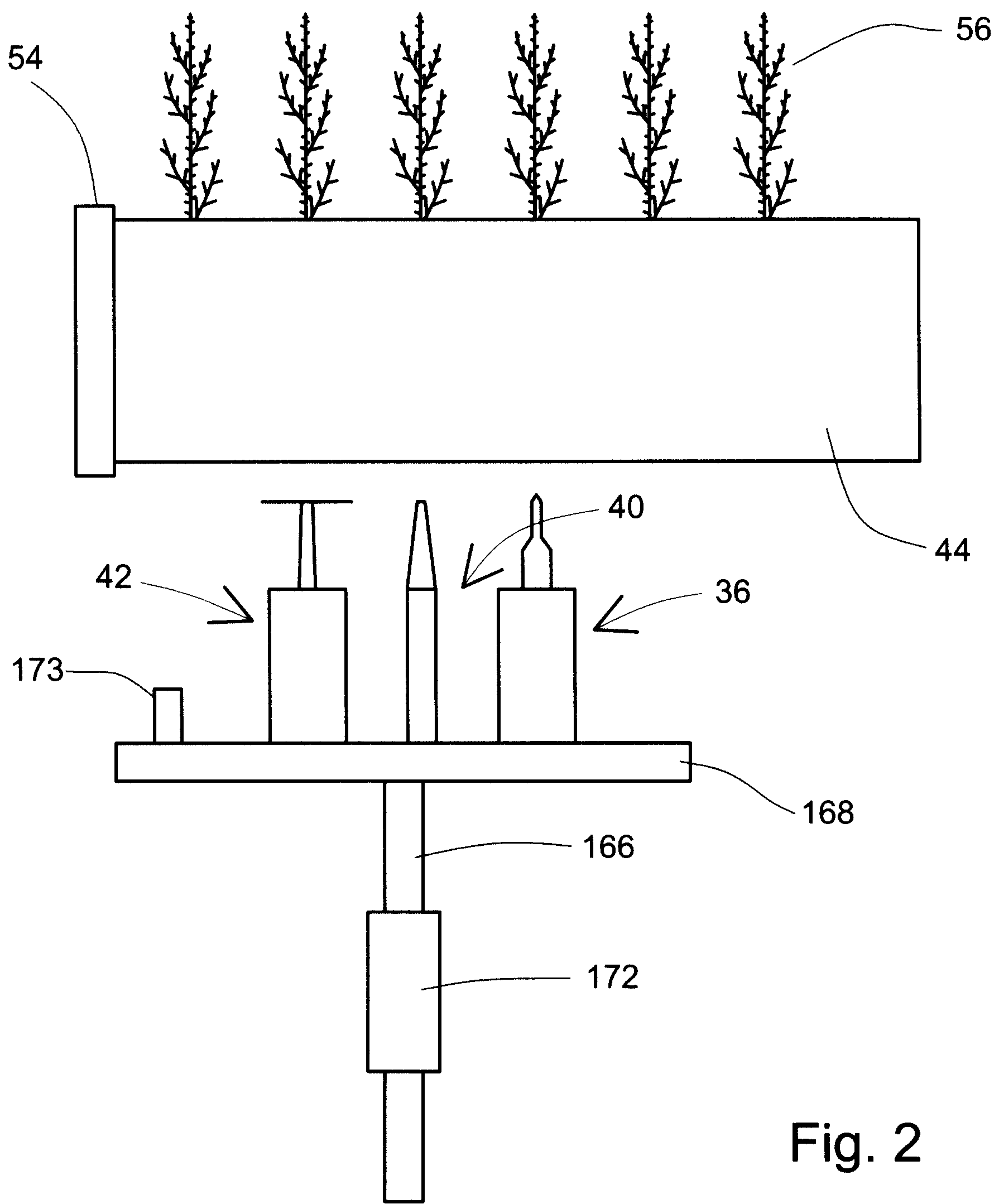


Fig. 2

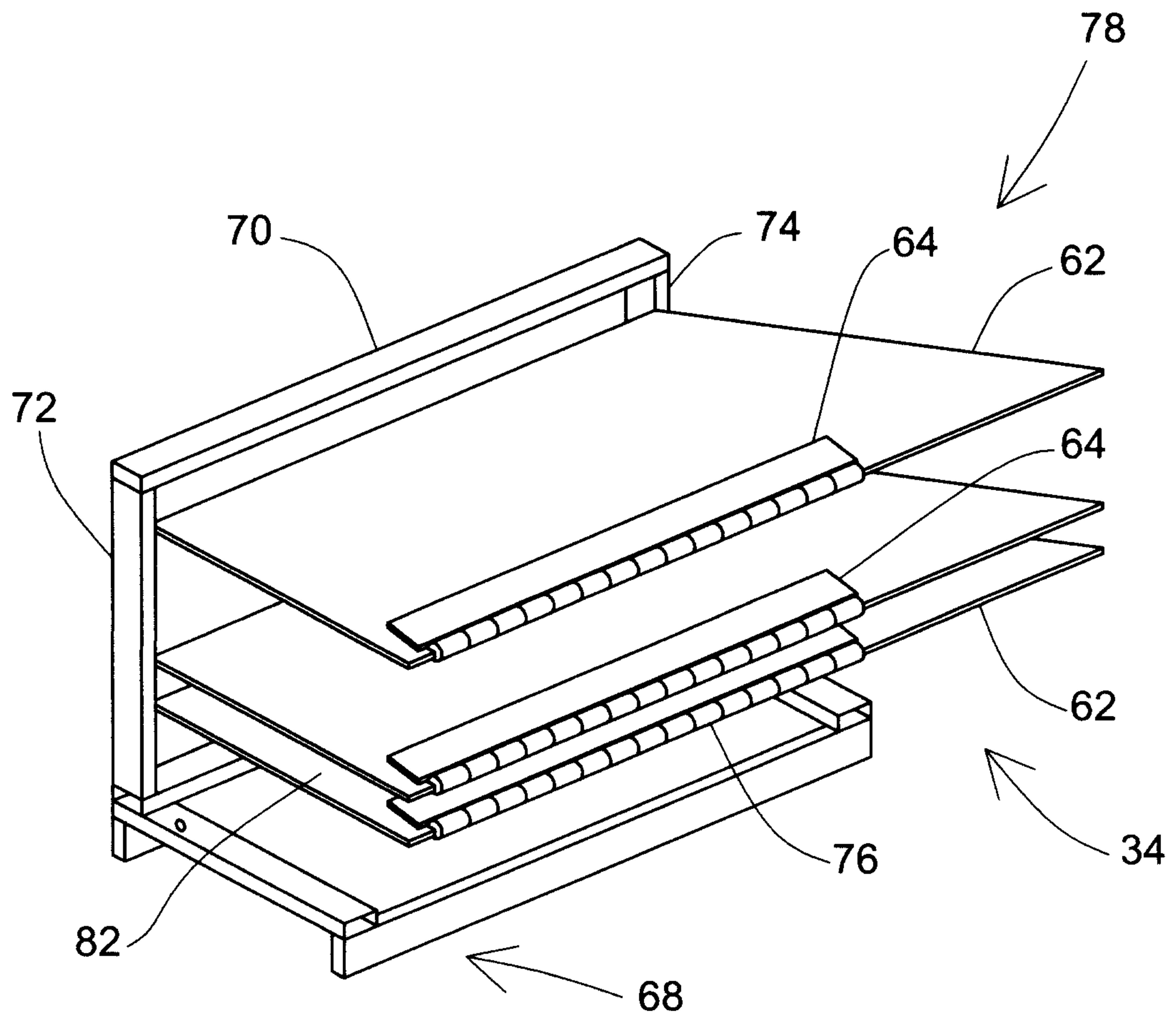


Fig. 3

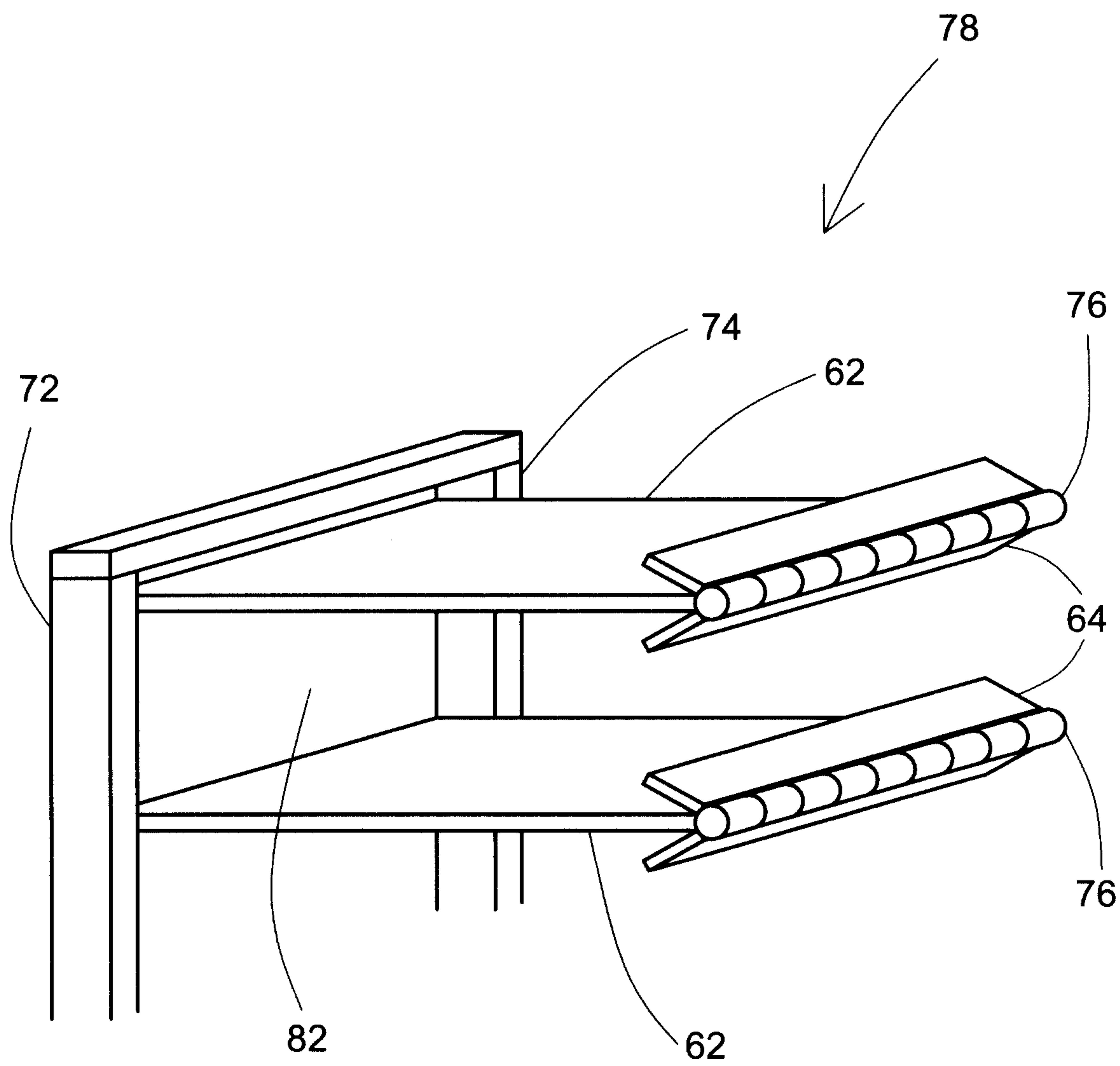


Fig. 4

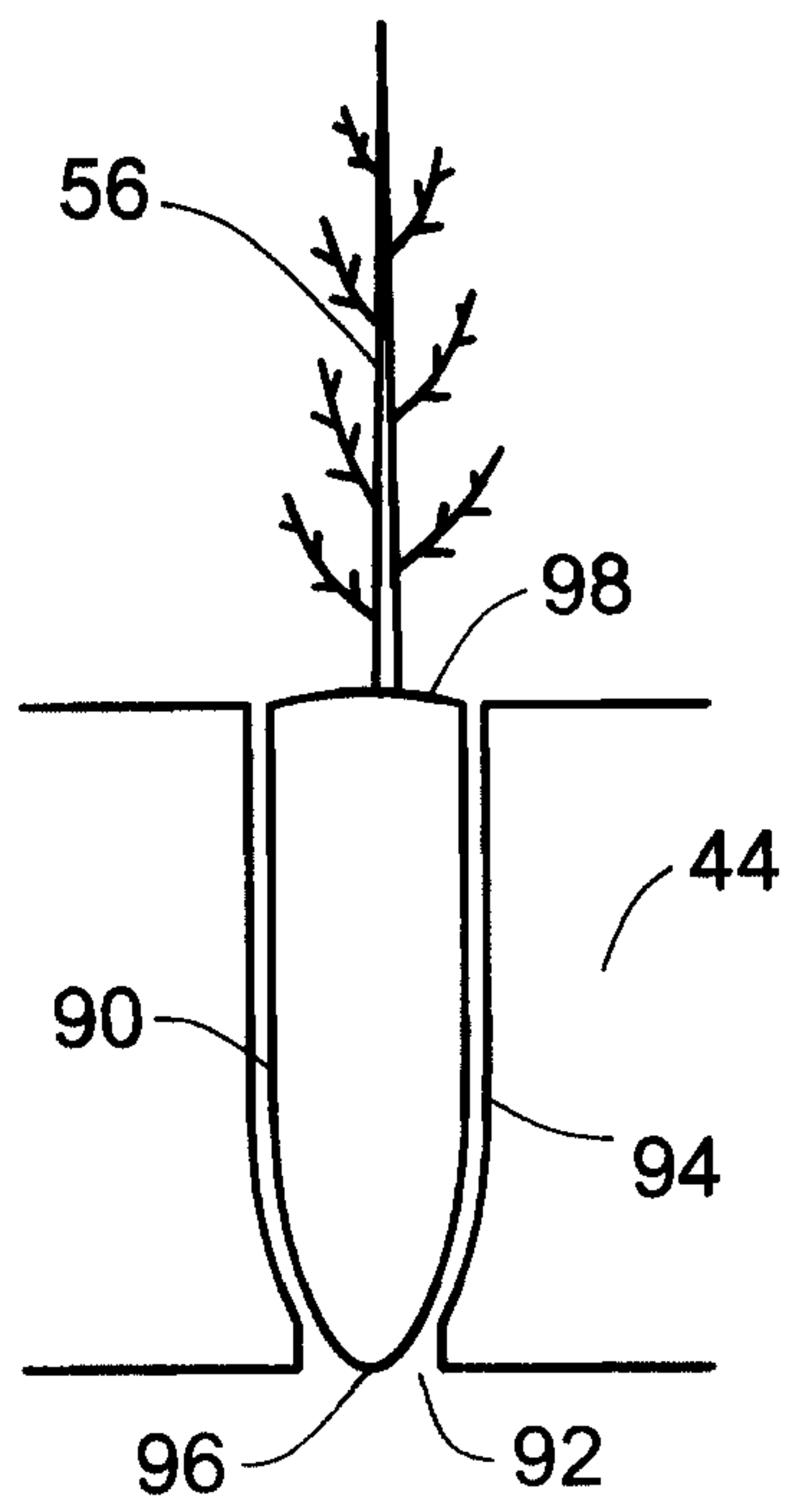


Fig. 5A

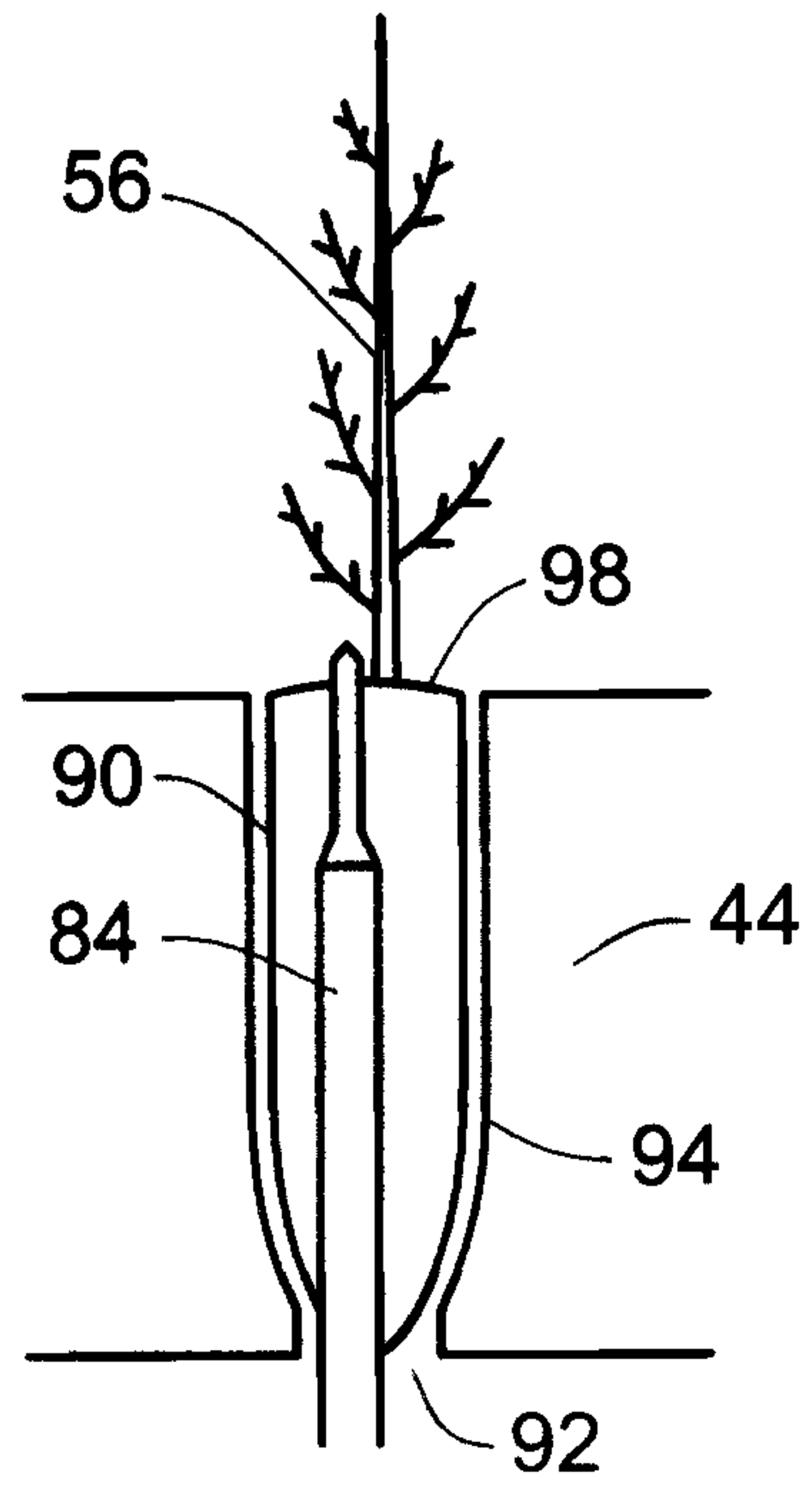


Fig. 5B

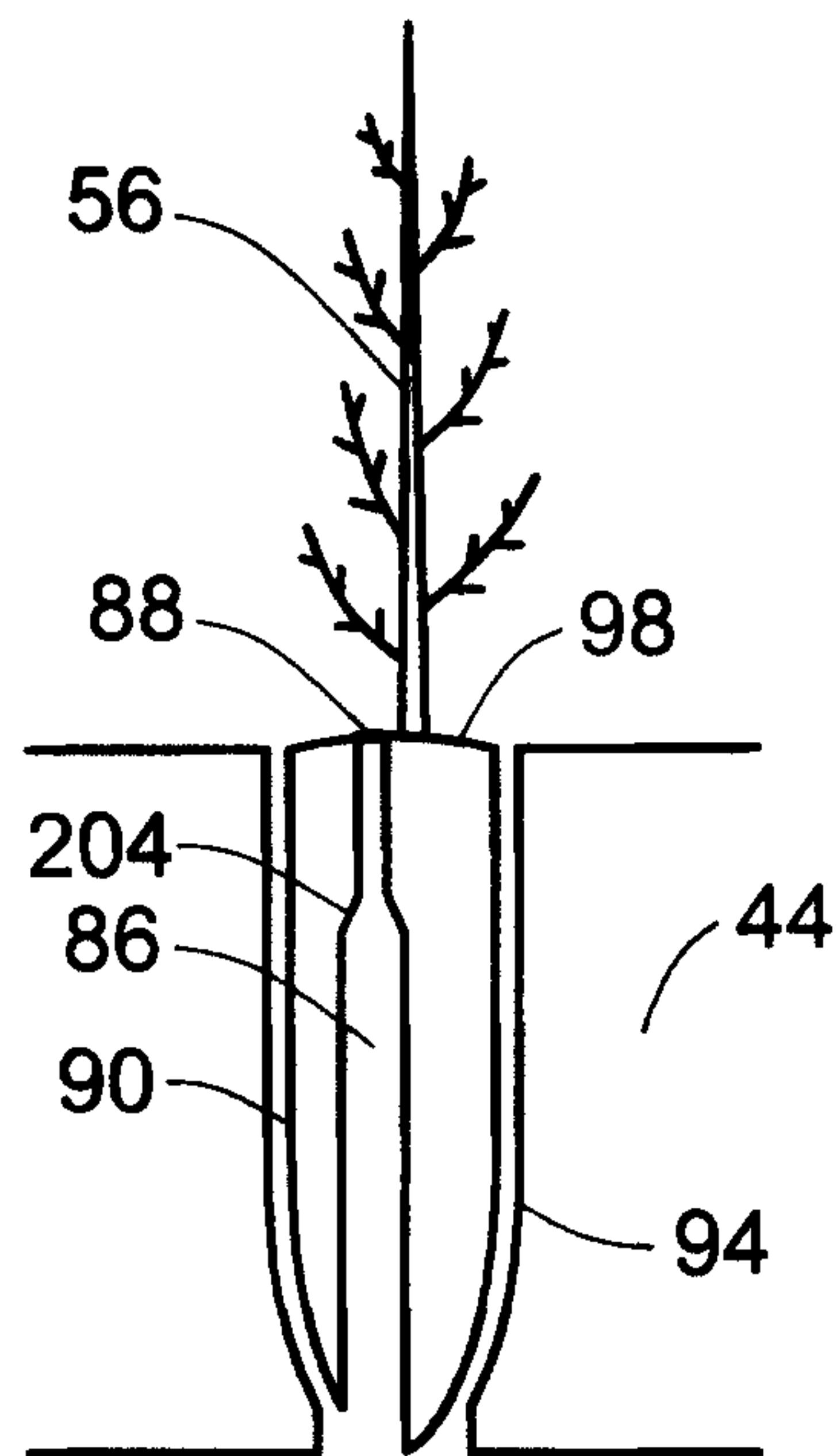


Fig. 5C

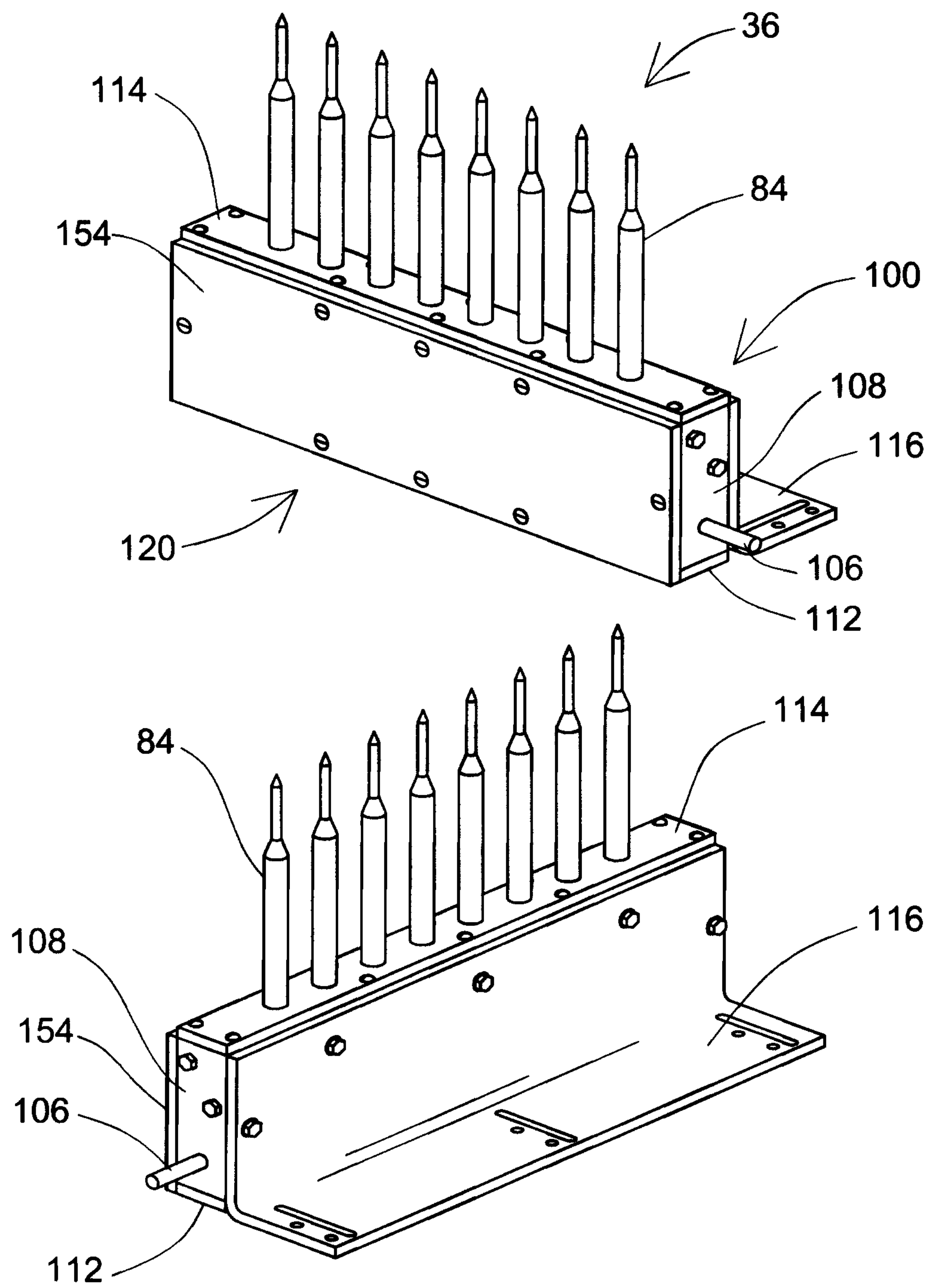


Fig. 6

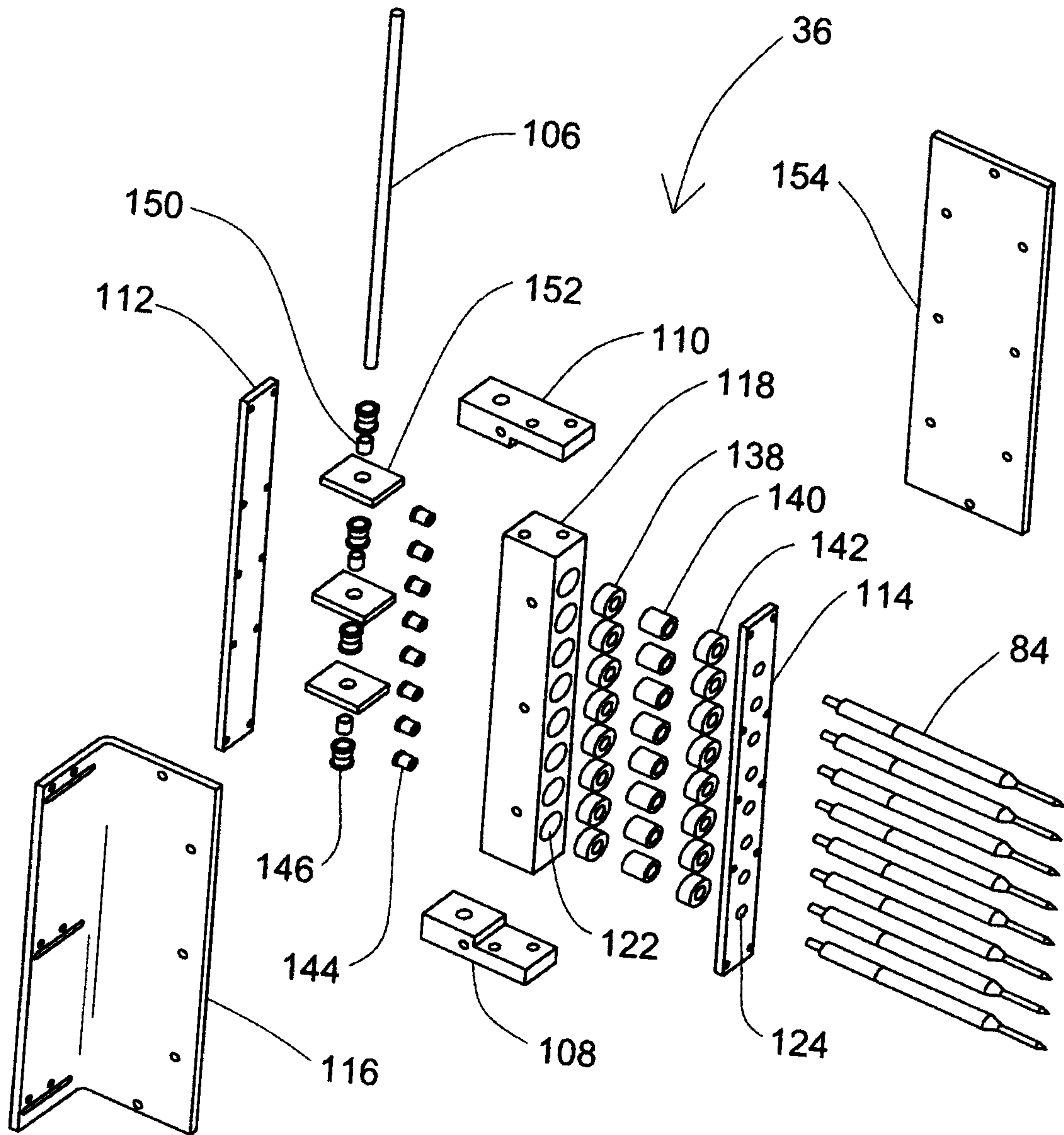


Fig. 7

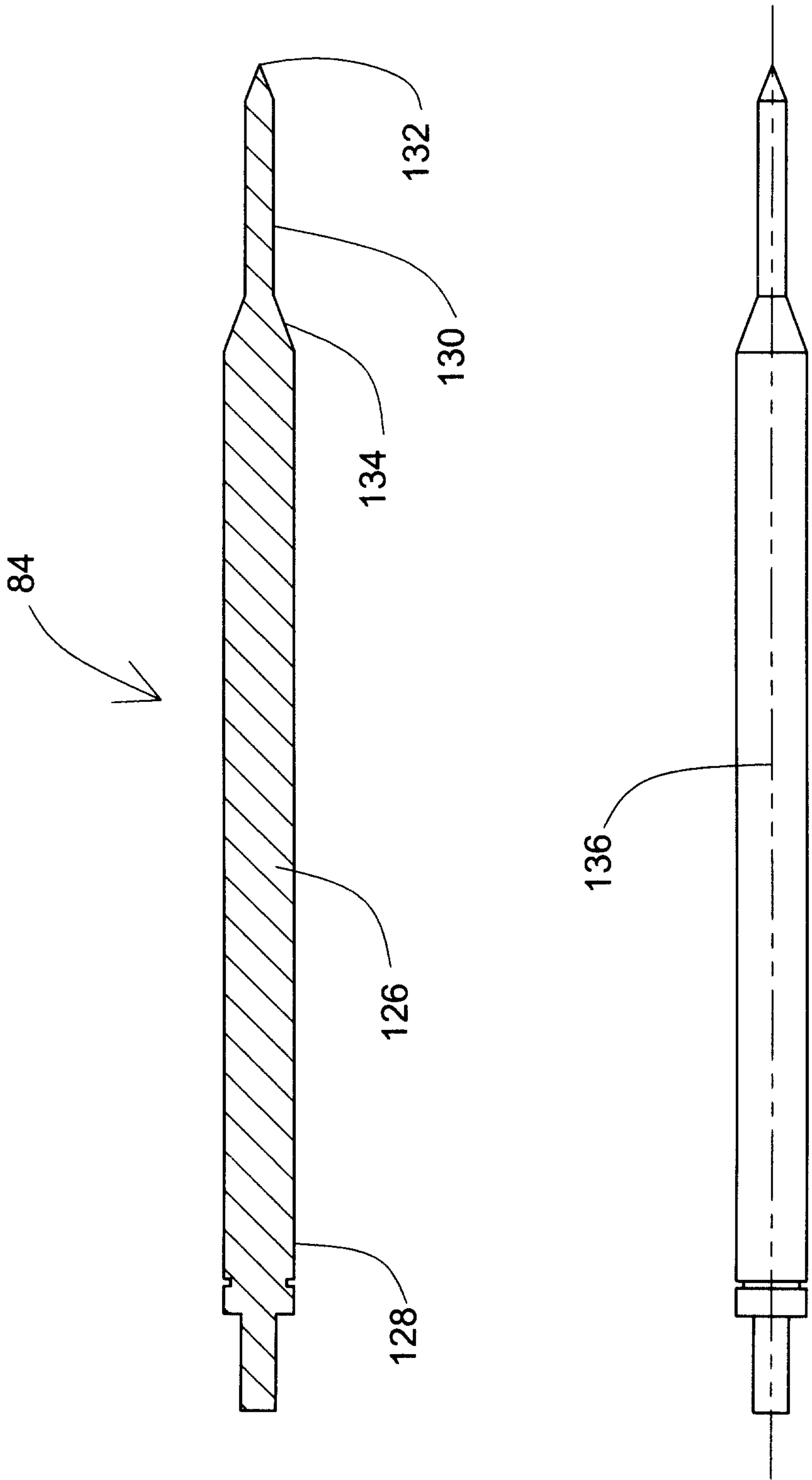


Fig. 8

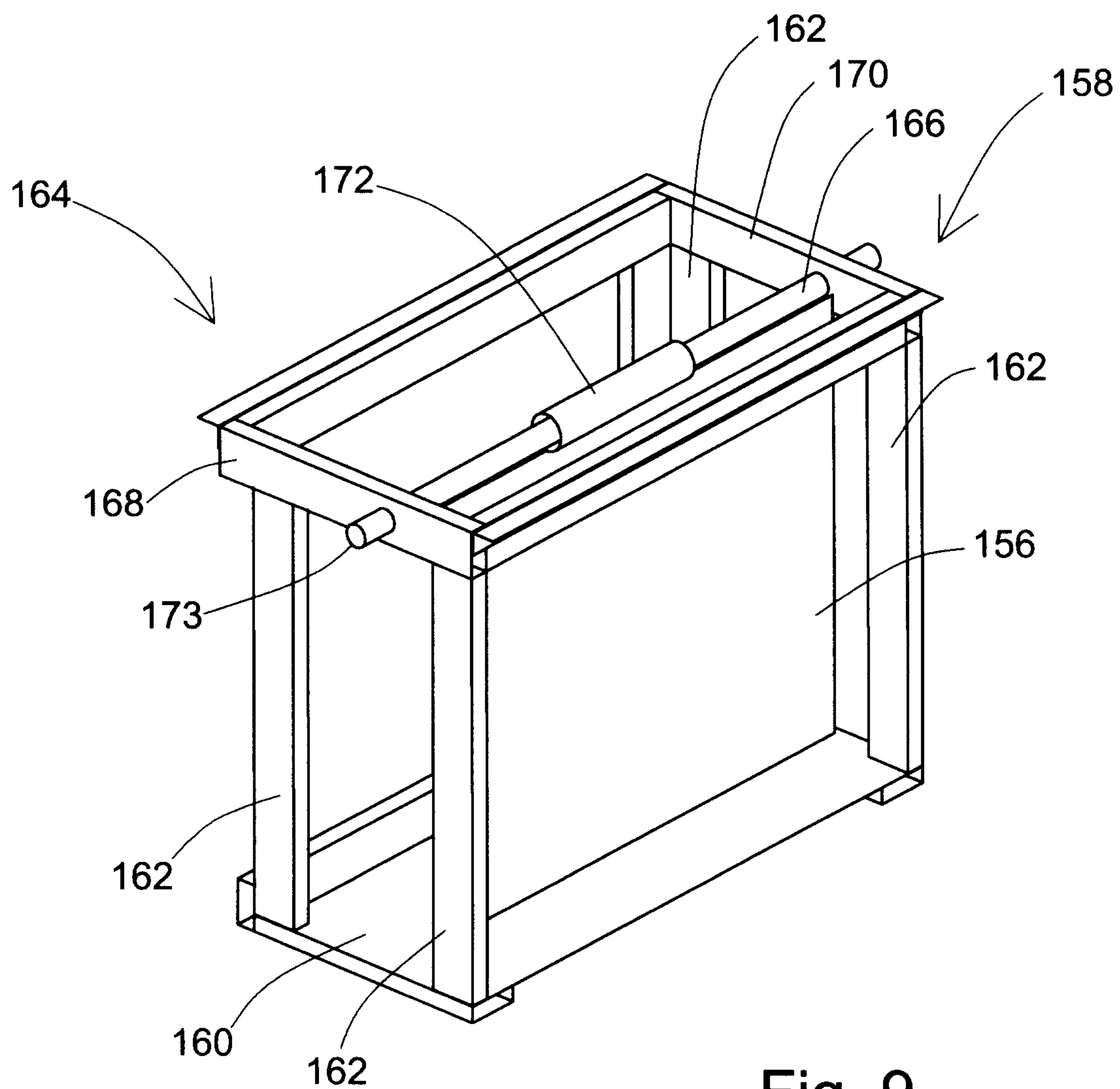


Fig. 9

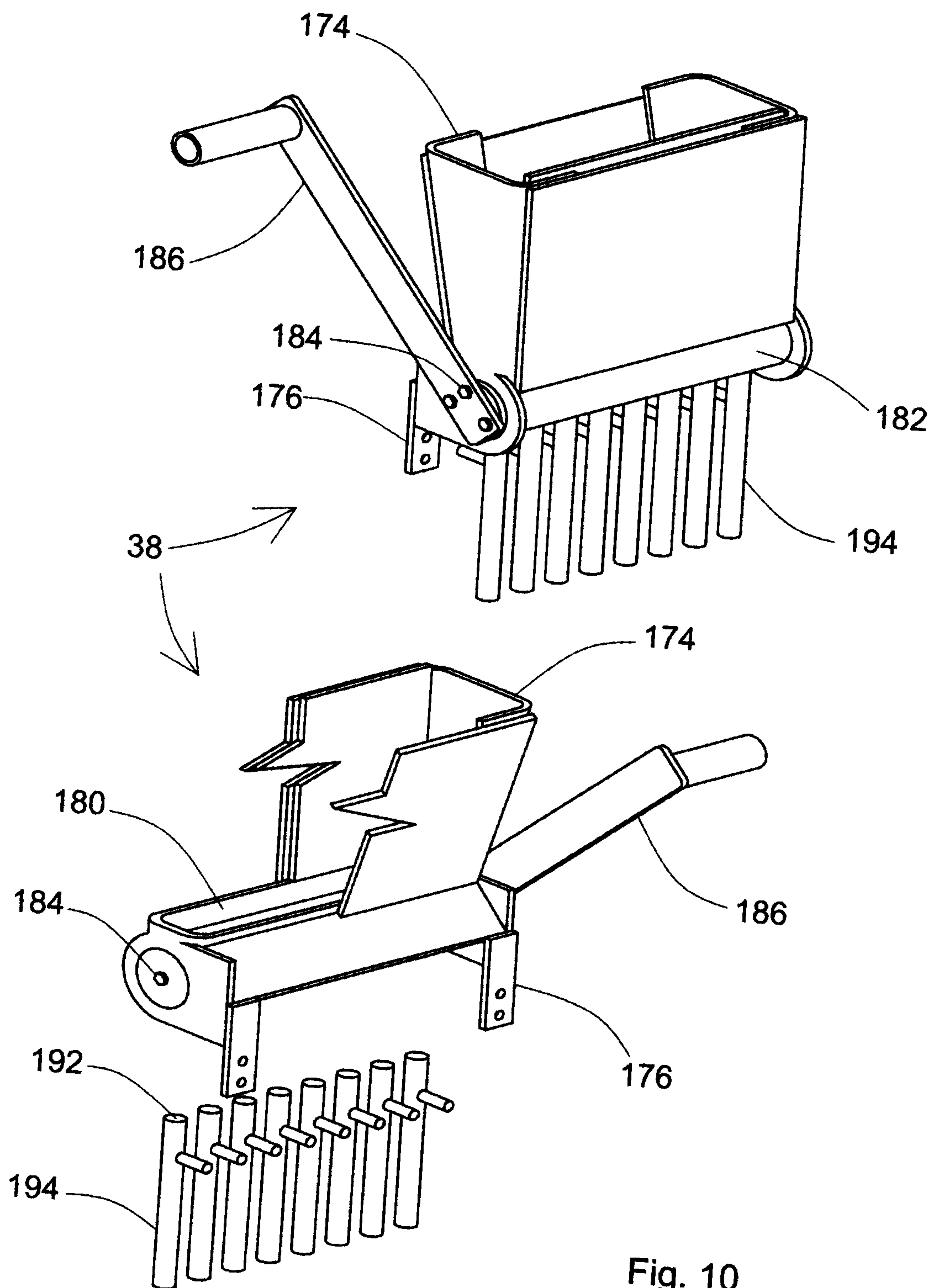


Fig. 10

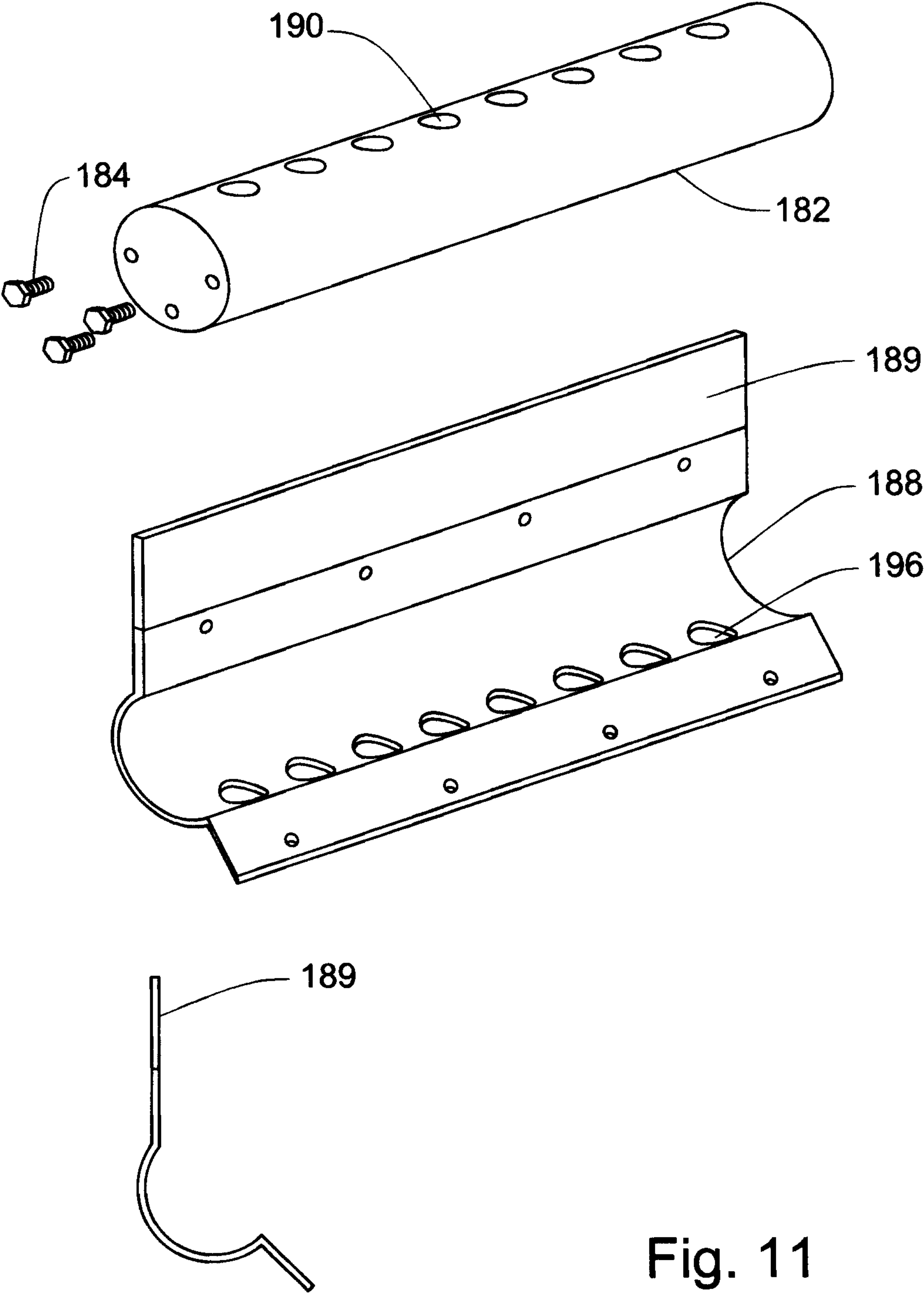


Fig. 11

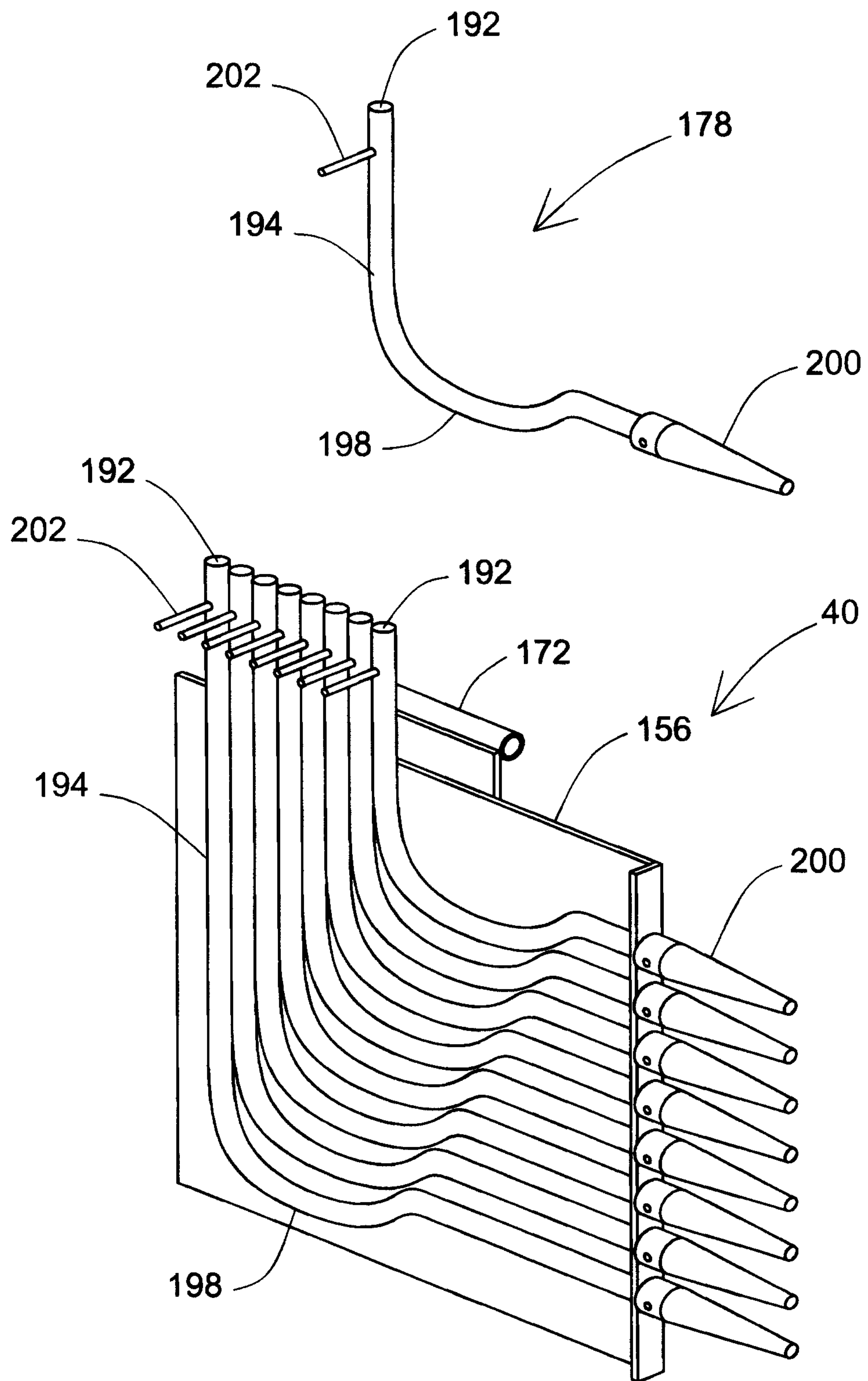


Fig. 12

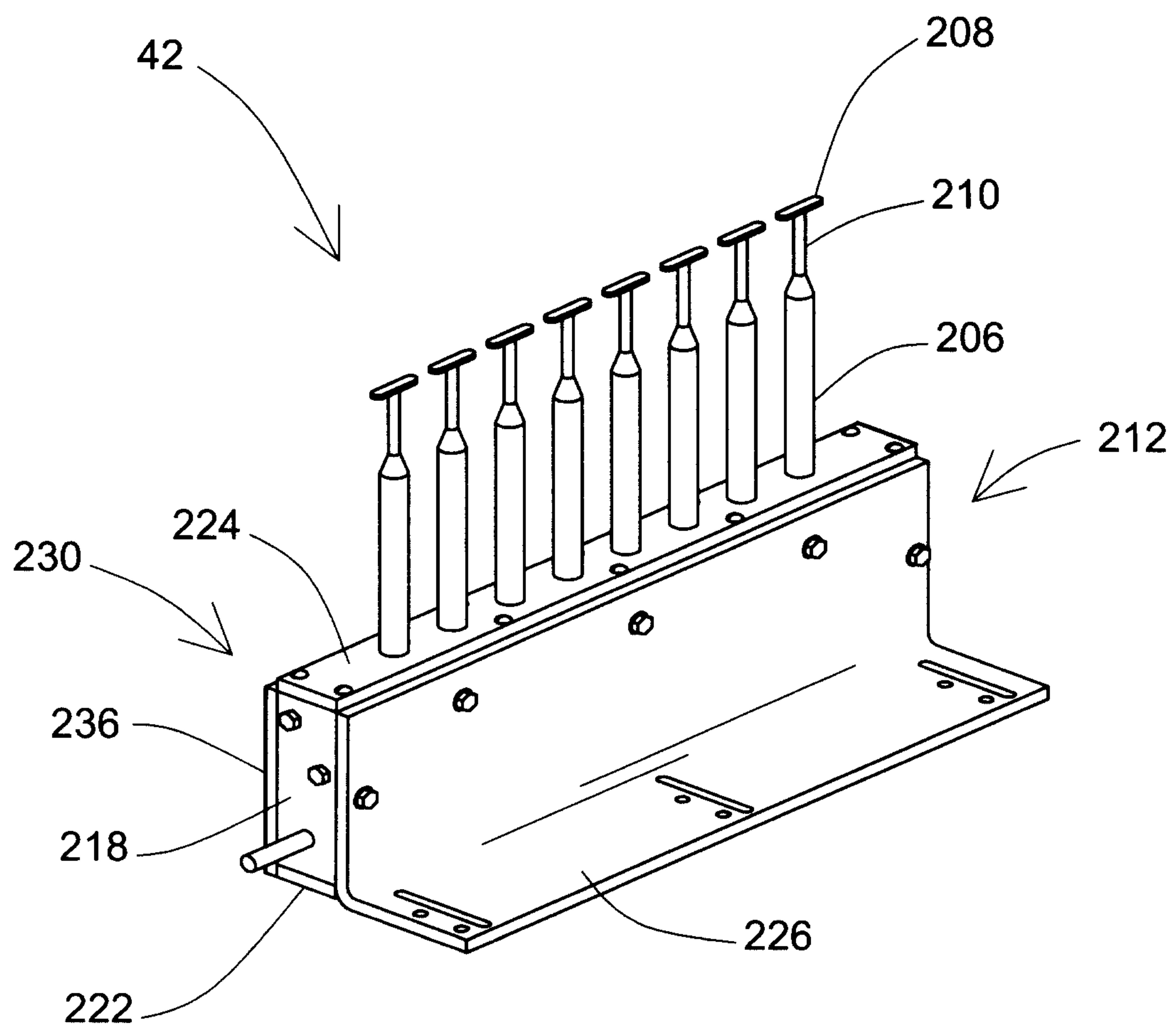


Fig. 13

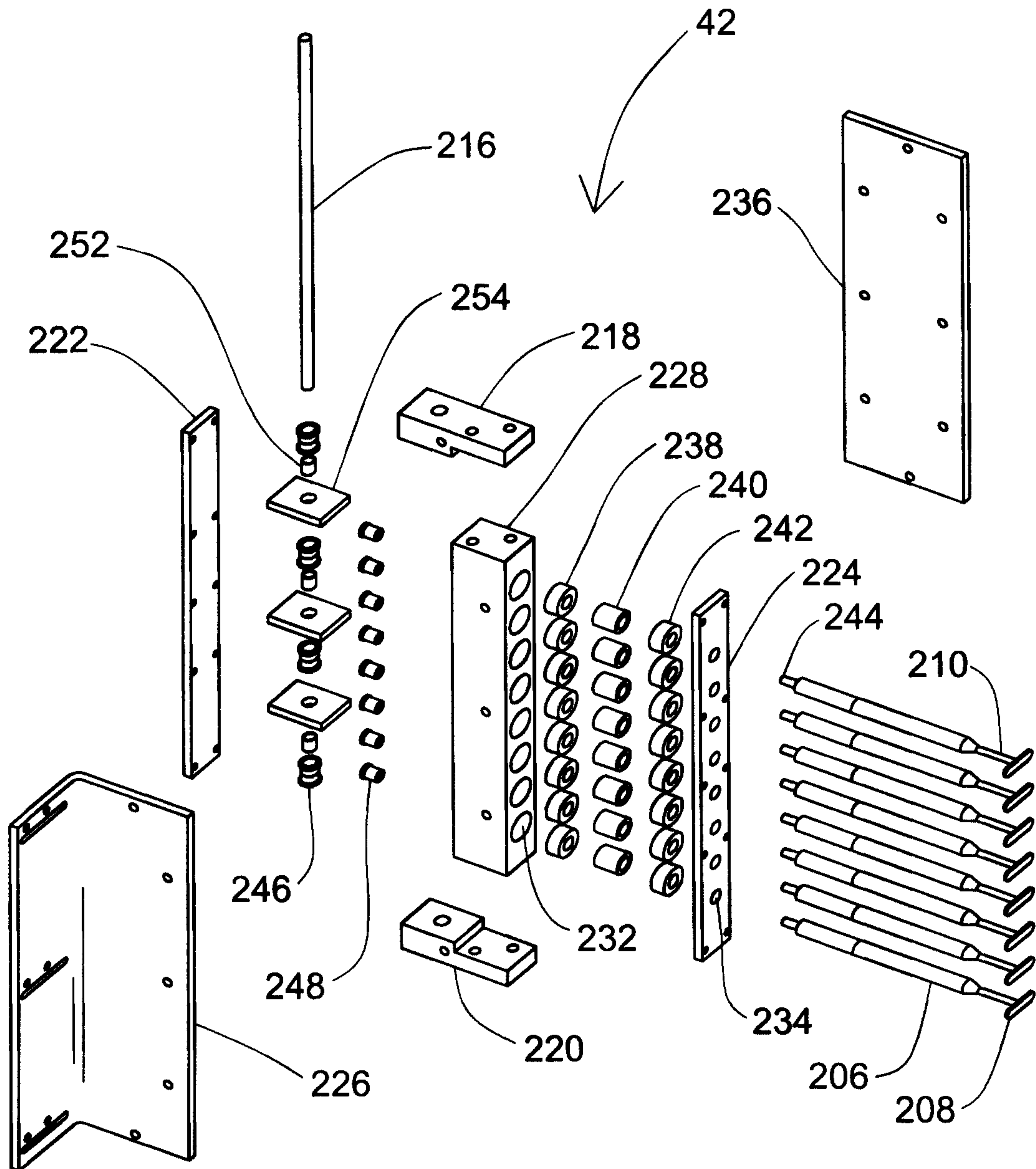


Fig. 14

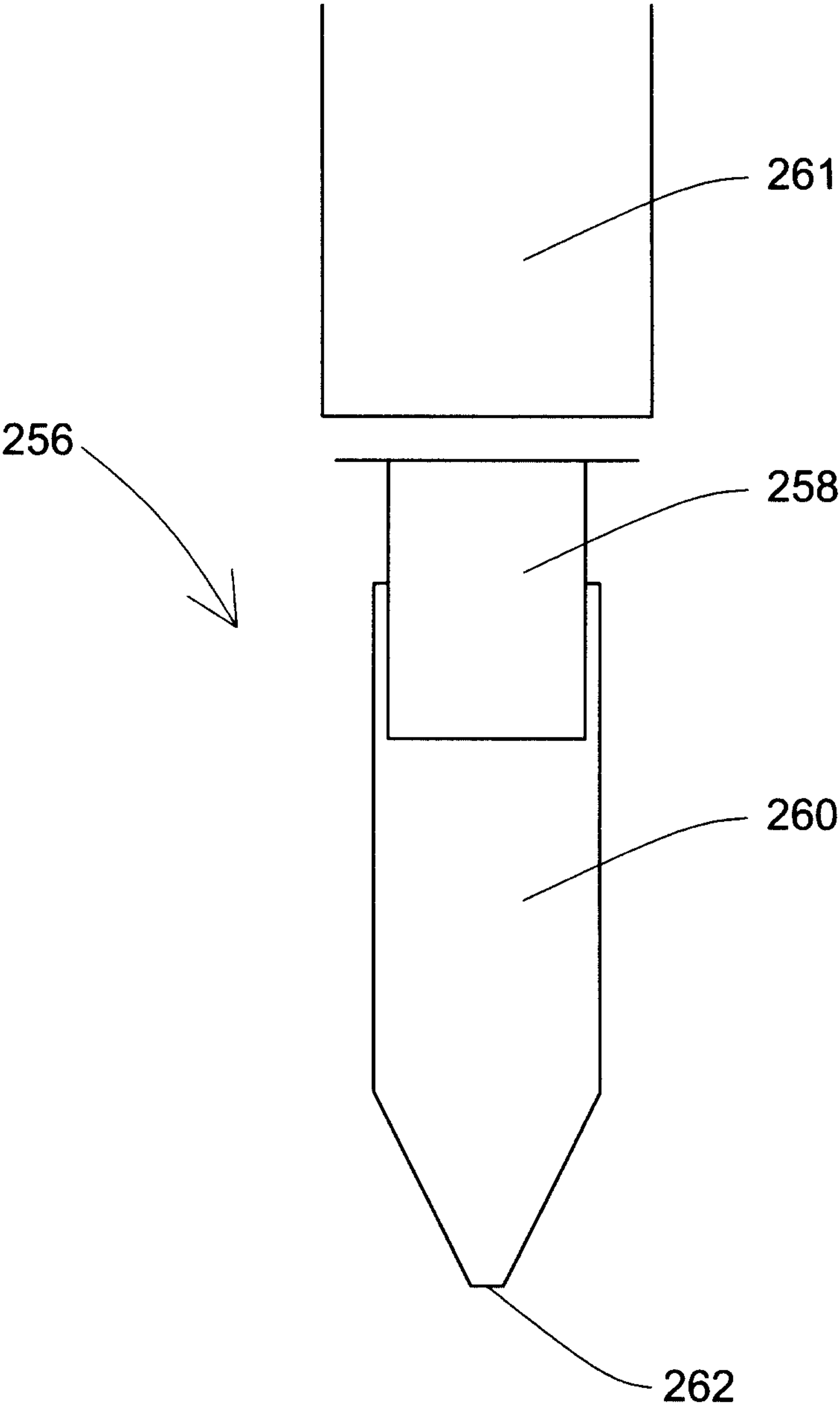


Fig. 15

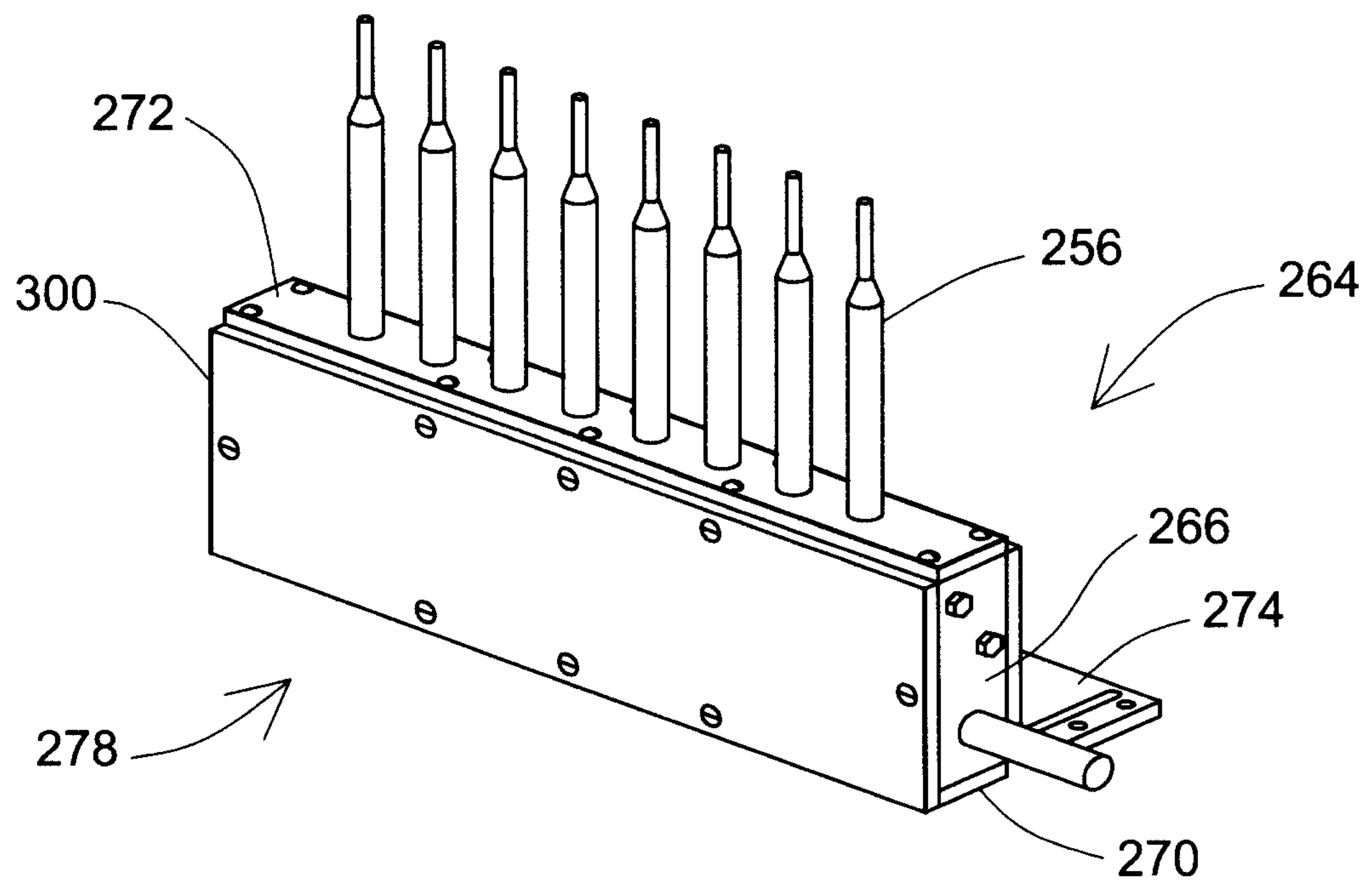


Fig. 16

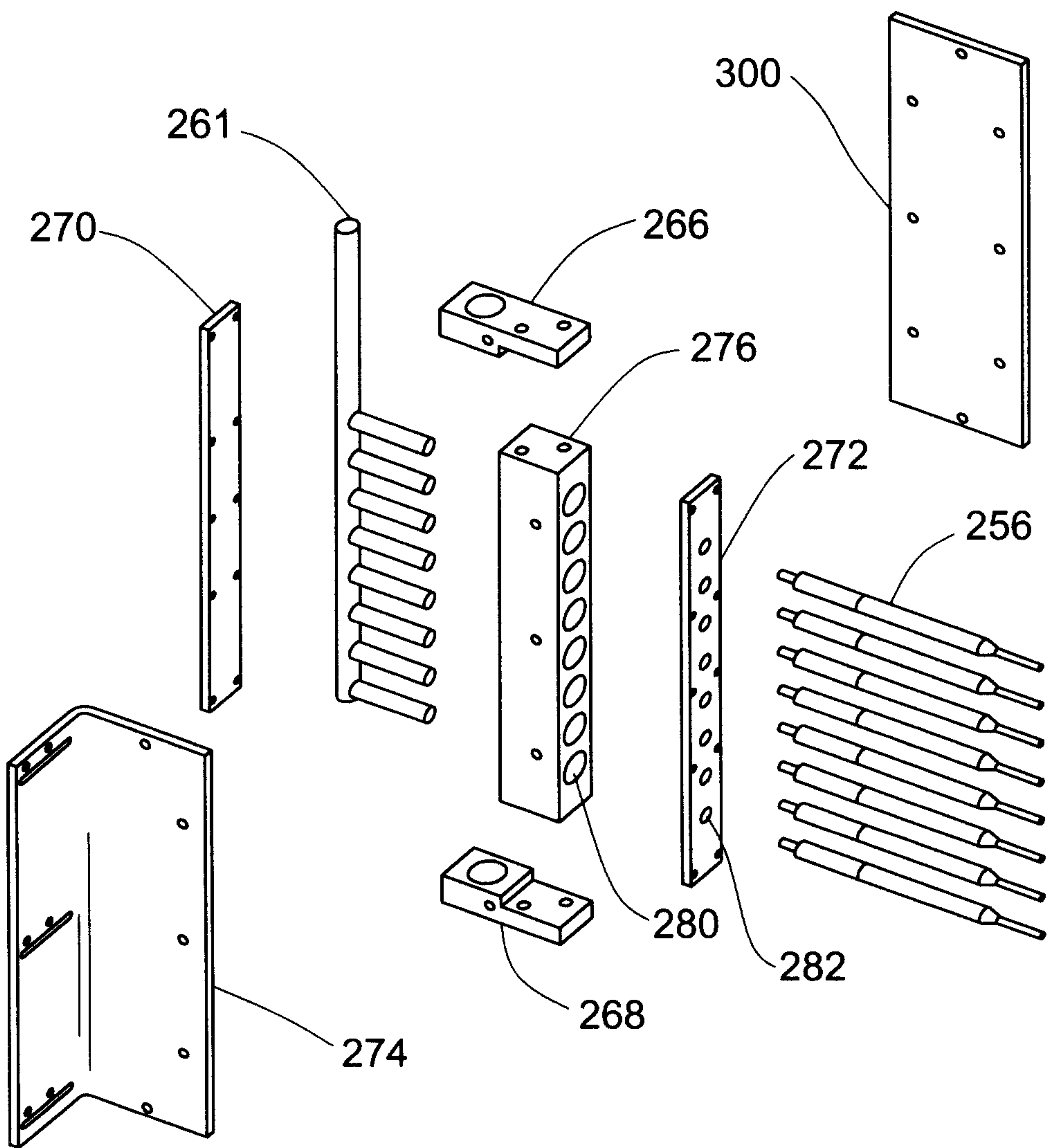


Fig. 17

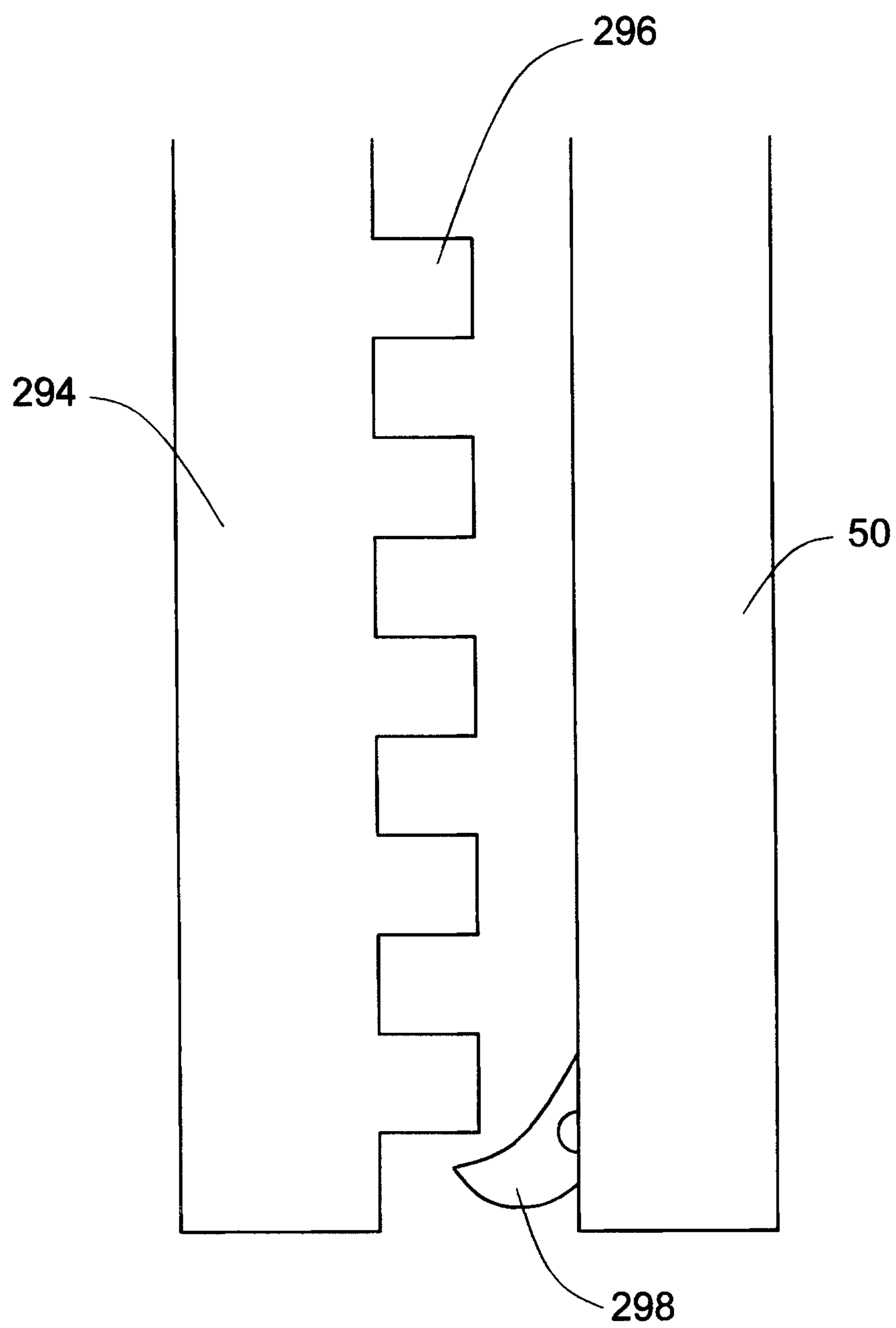


Fig. 18

