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(54) **SOIL SAMPLING SYSTEM WITH SAMPLE CONTAINER RIGIDLY COUPLED TO DRIVE CASING**

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Related U.S. Patent Documents

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U.S. Applications:

(63) Continuation of application No. 07/954,987, filed on Sep. 30, 1992, now abandoned.

(51) **Int. Cl.**^{7} **G01N 1/04**
(52) **U.S. Cl.** **73/864.44**; 73/864.45
(58) **Field of Search** 71/864.44, 864.45; 175/20, 58, 249

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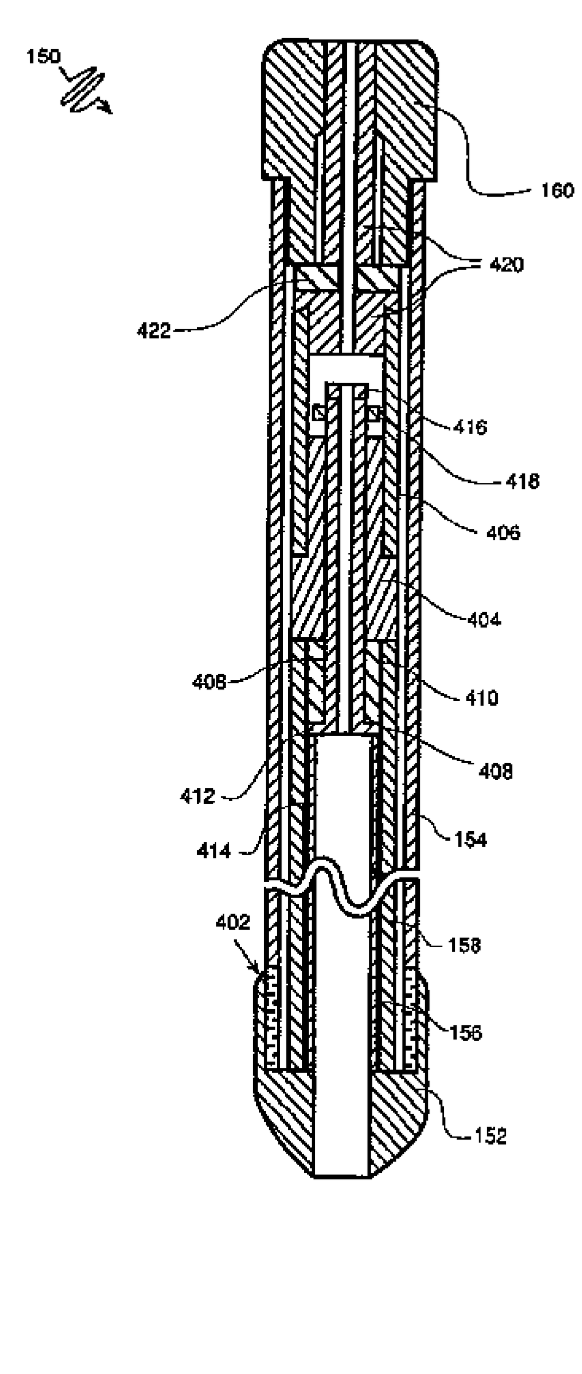
(57) **ABSTRACT**

A soil sampling system includes a rig for driving a drive casing, a sample barrel, and sample liners simultaneously into soil to be sampled. The rig includes mechanisms for driving the casing, barrel, and lining in three modes: hydraulic hammer, continuous pressure, and vibration. The three drive mechanisms can be operated singly or in any combination. After the casing, barrel, and liners are advanced a selected depth into the soil, the barrel and liners are removed. The drive casing remains in the soil. New sample liners are put into the sample barrel, and an inner rod is attached to the sample barrel. The sample barrel is then replaced into the drive casing, and extensions are attached to the drive casing. The drive casing, including extensions, and the sample barrels, along with sample liners and inner rod, are driven further down into the soil. The rig also includes a winch that can be coupled to the inner rod or sample barrel so that the casing and/or barrel (including sample liners) can be retrieved from the drive casing. A clamp system allows the sampler to be hydraulically retracted from the ground when sampling is finished.

26 Claims, 8 Drawing Sheets



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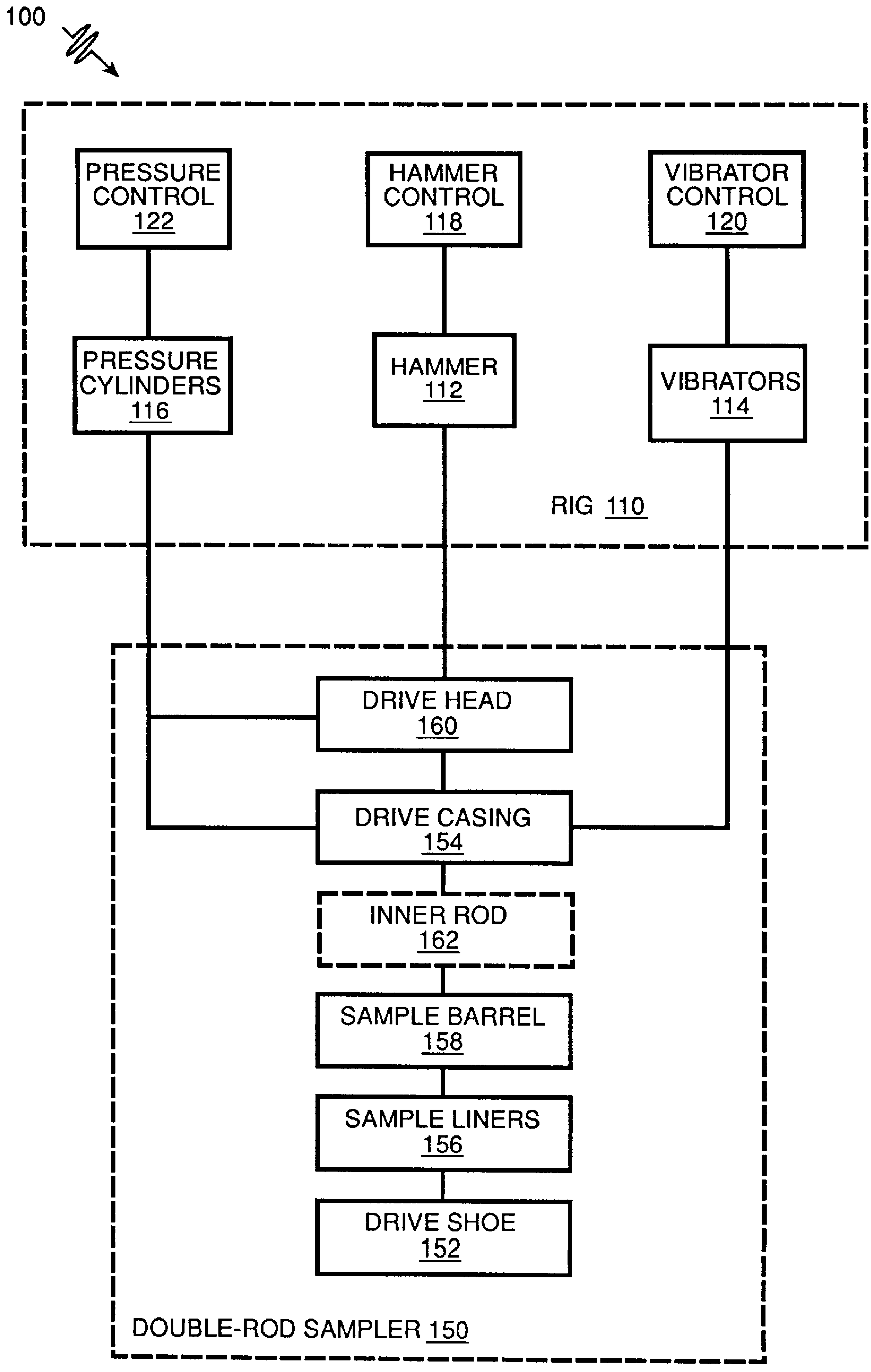
100
PRESSURE CONTROL 122
HAMMER CONTROL 118
VIBRATOR CONTROL 120
PRESSURE CYLINDERS 116
HAMMER 112
VIBRATORS 114
RIG 110
DRIVE HEAD 160
DRIVE CASING 154
INNER ROD 162
SAMPLE BARREL 158
SAMPLE LINERS 156
DRIVE SHOE 152
DOUBLE-ROD SAMPLER 150

Figure 1

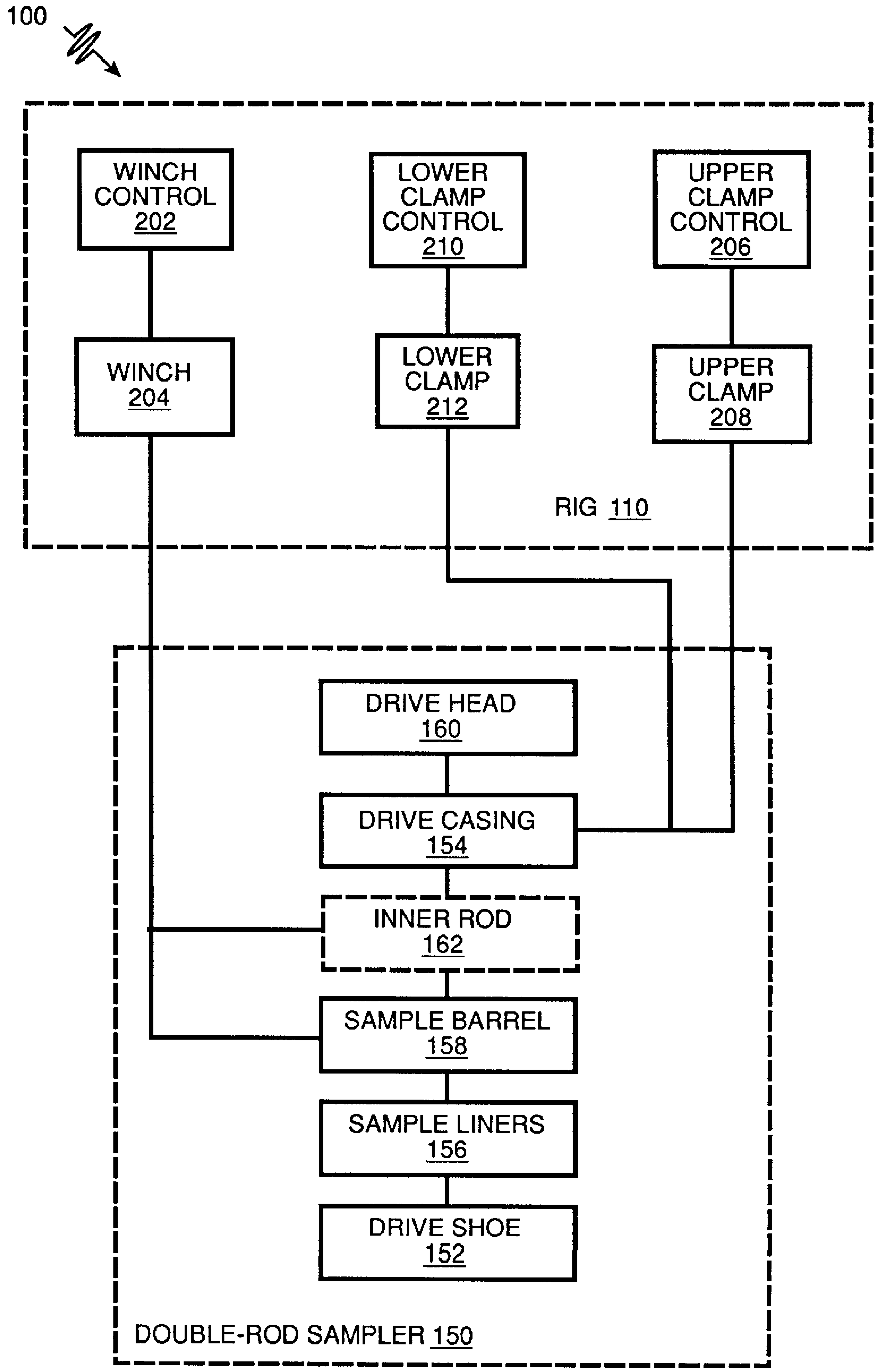
100
WINCH CONTROL 202
LOWER CLAMP CONTROL 210
UPPER CLAMP CONTROL 206
WINCH 204
LOWER CLAMP 212
UPPER CLAMP 208
RIG 110
DRIVE HEAD 160
DRIVE CASING 154
INNER ROD 162
SAMPLE BARREL 158
SAMPLE LINERS 156
DRIVE SHOE 152
DOUBLE-ROD SAMPLER 150

Figure 2

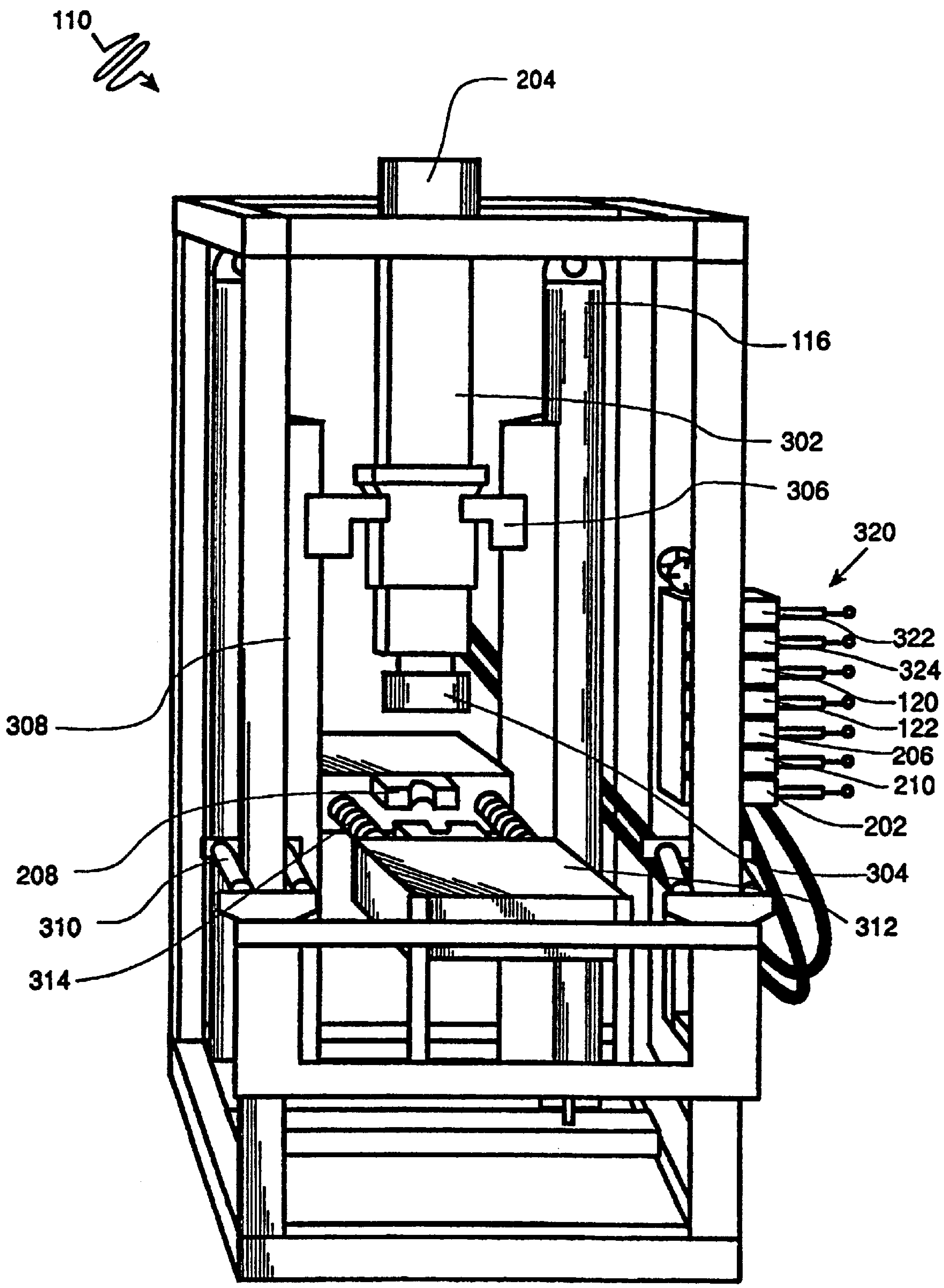
110
204
116
302
306
320
322
324
120
122
206
210
202
304
312
308
208
310
314

Figure 3

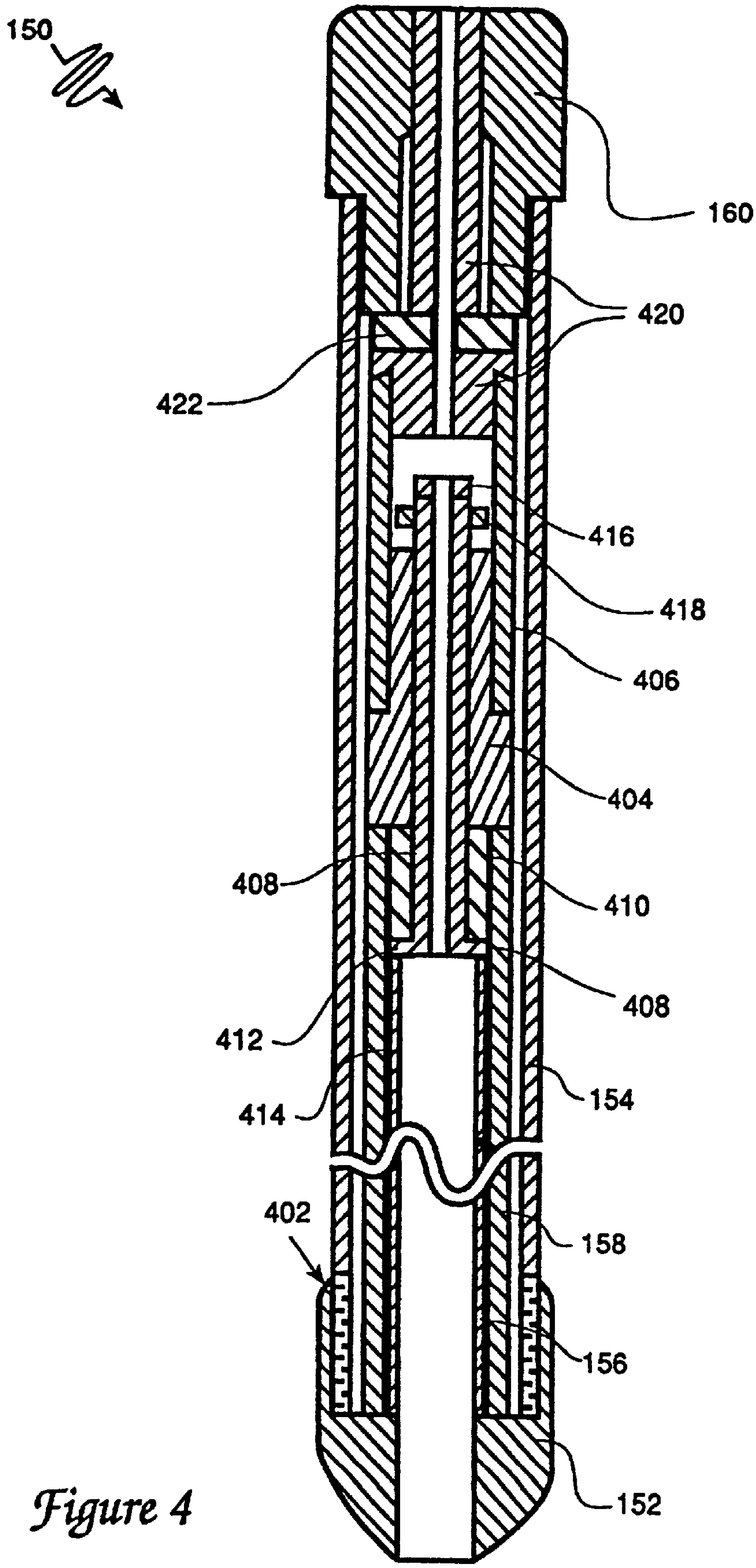
150
160
420
422
416
418
406
404
408
410
408
412
154
414
402
158
156
152

Figure 4

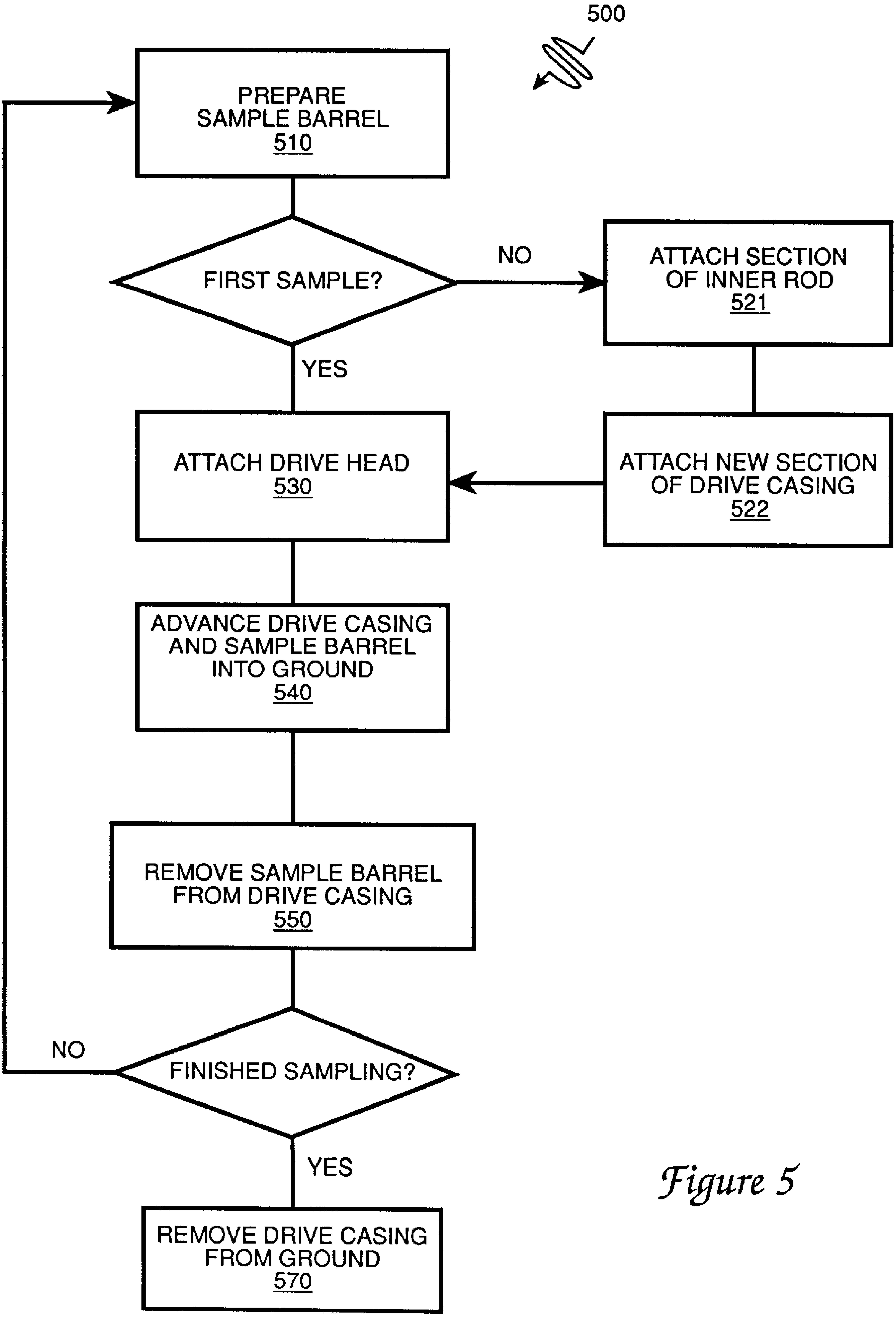
500
PREPARE SAMPLE BARREL 510
FIRST SAMPLE?
NO
ATTACH SECTION OF INNER ROD 521
YES
ATTACH DRIVE HEAD 530
ATTACH NEW SECTION OF DRIVE CASING 522
ADVANCE DRIVE CASING AND SAMPLE BARREL INTO GROUND 540
REMOVE SAMPLE BARREL FROM DRIVE CASING 550
NO
FINISHED SAMPLING?
YES
REMOVE DRIVE CASING FROM GROUND 570

Figure 5

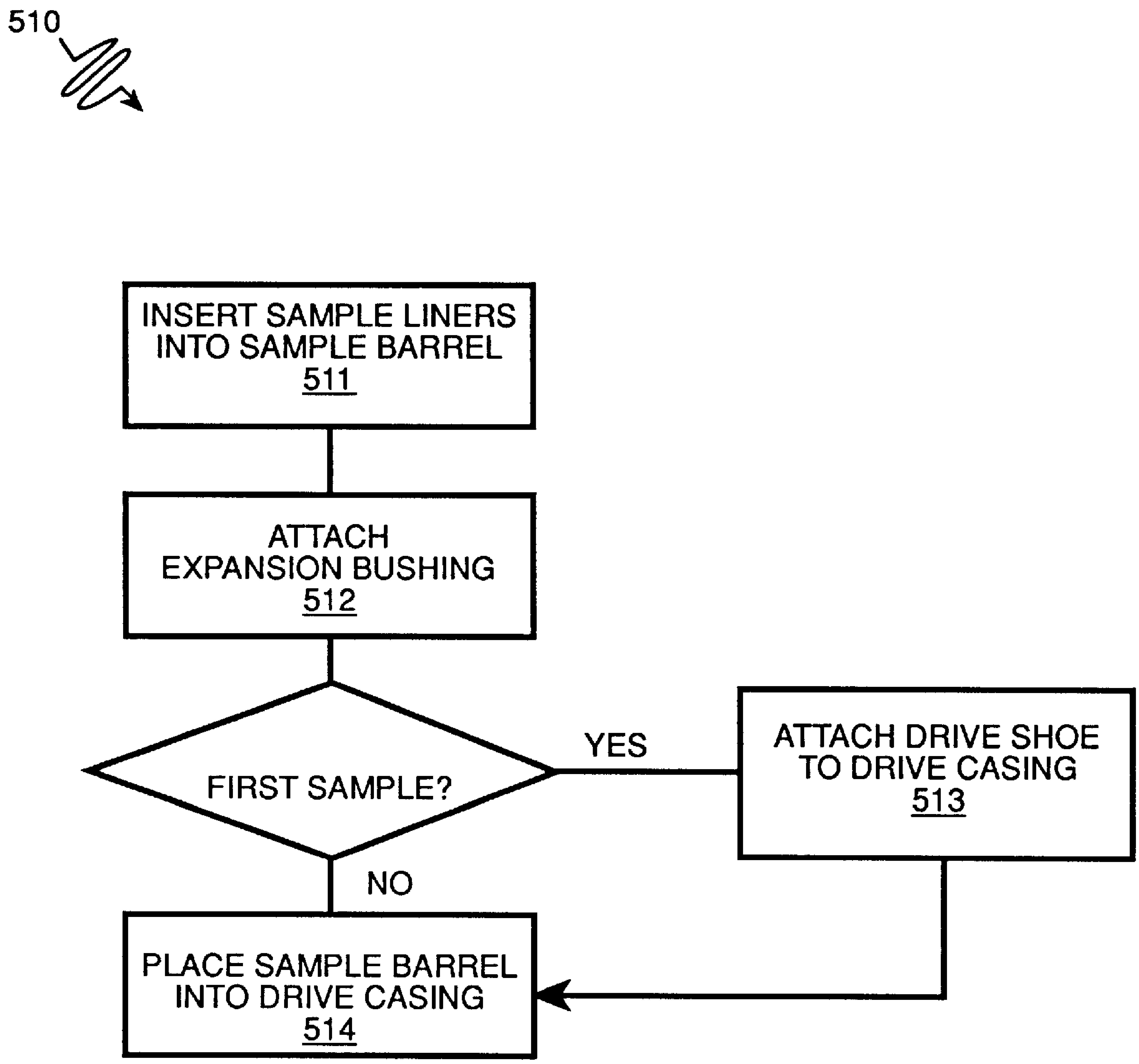
510
INSERT SAMPLE LINERS INTO SAMPLE BARREL 511
ATTACH EXPANSION BUSHING 512
FIRST SAMPLE?
YES
NO
ATTACH DRIVE SHOE TO DRIVE CASING 513
PLACE SAMPLE BARREL INTO DRIVE CASING 514

Figure 6

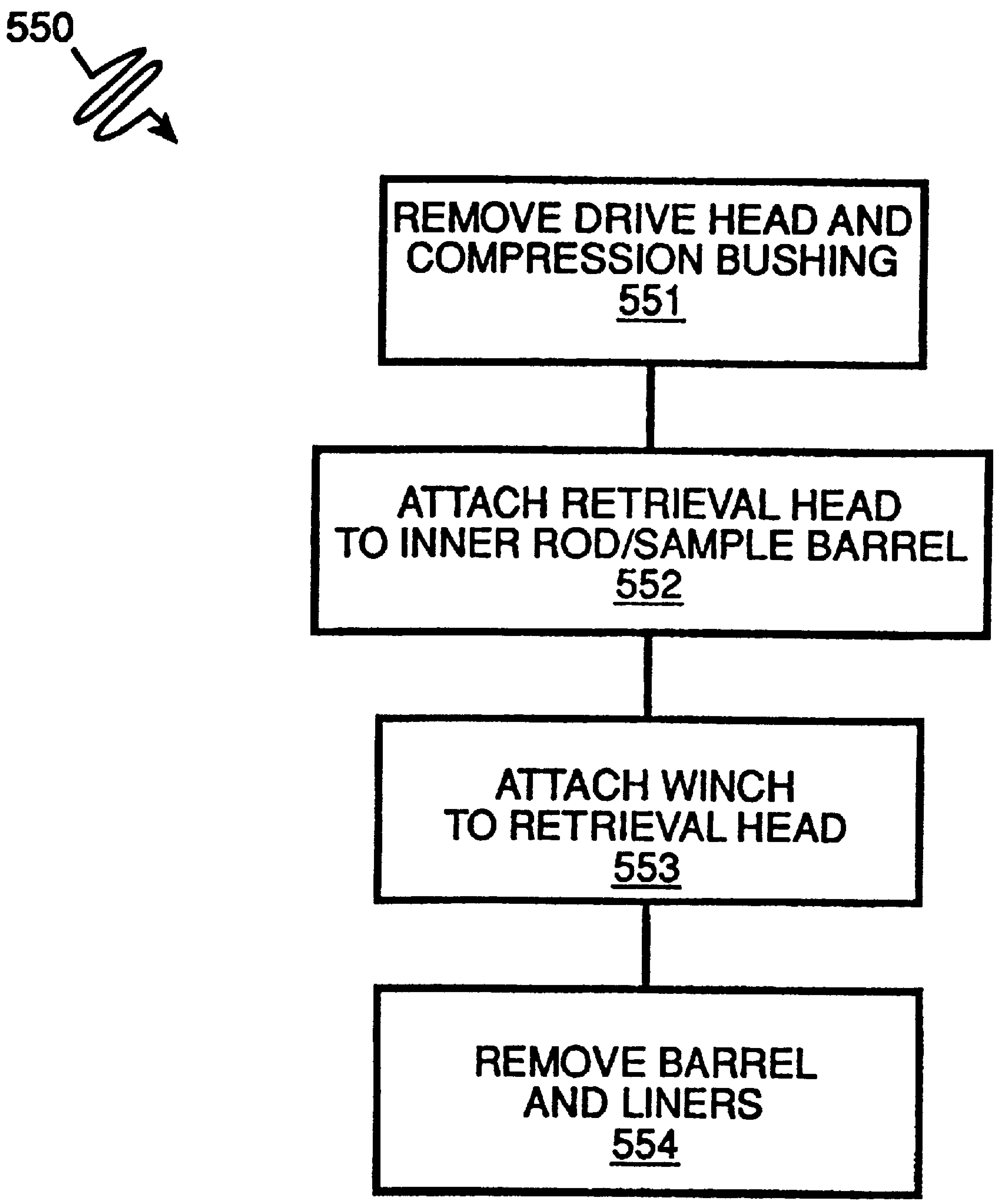
550
REMOVE DRIVE HEAD AND COMPRESSION BUSHING 551
ATTACH RETRIEVAL HEAD TO INNER ROD/SAMPLE BARREL 552
ATTACH WINCH TO RETRIEVAL HEAD 553
REMOVE BARREL AND LINERS 554

Figure 7

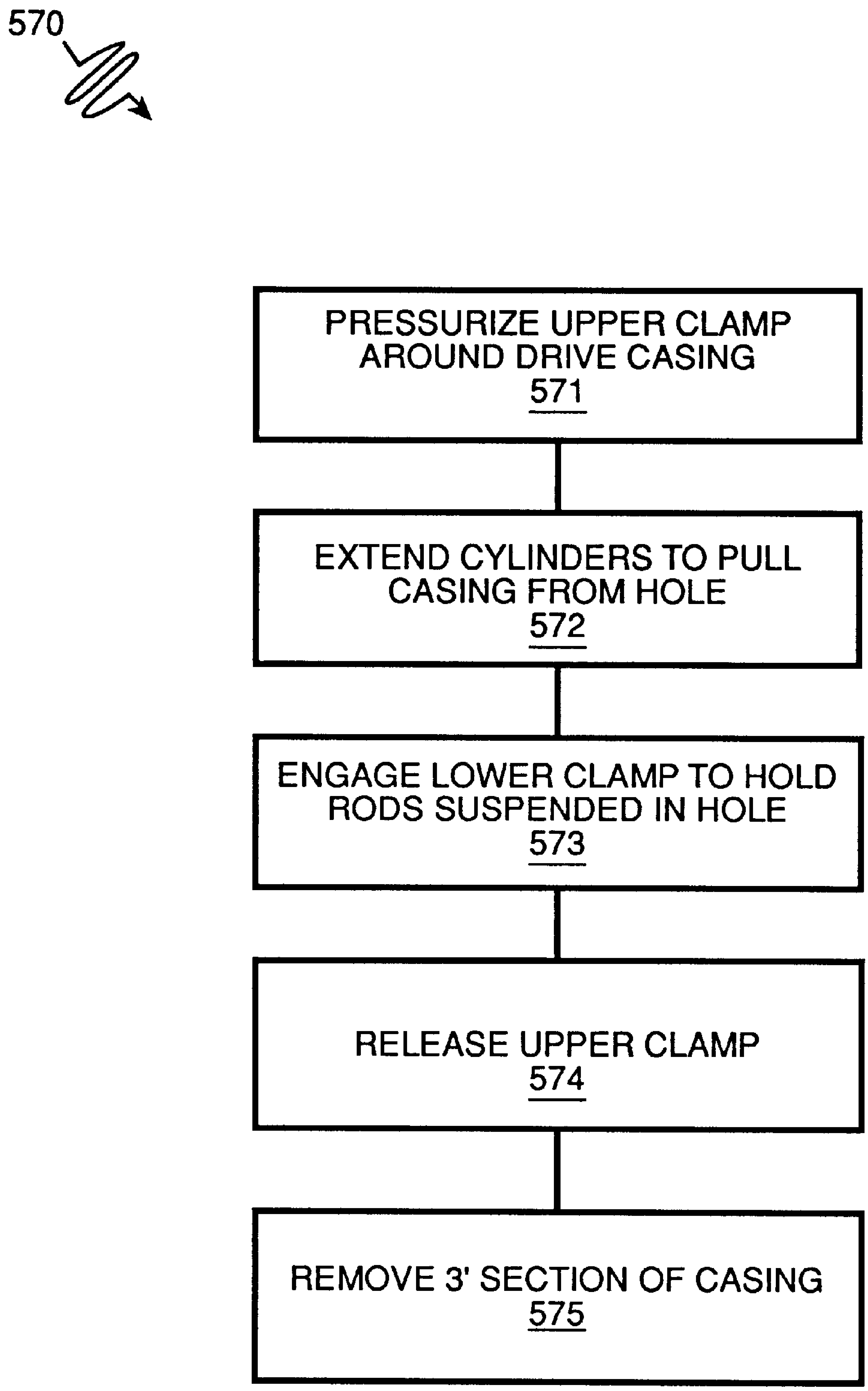
570
PRESSURIZE UPPER CLAMP AROUND DRIVE CASING 571
EXTEND CYLINDERS TO PULL CASING FROM HOLE 572
ENGAGE LOWER CLAMP TO HOLD RODS SUSPENDED IN HOLE 573
RELEASE UPPER CLAMP 574
REMOVE 3' SECTION OF CASING 575

Figure 8

SOIL SAMPLING SYSTEM WITH SAMPLE CONTAINER RIGIDLY COUPLED TO DRIVE CASING

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

This is a continuation of application Ser. No. 07/954,987 filed Sept. 30, 1992, hereby abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to soil sampling systems and, more particularly, to hollow-tubed soil samplers. A major objective of the present invention is to provide for enhanced collection of soil samples for chemical or physical analysis.

Contamination of soils is a major environmental concern. Toxic compounds can remain in the soil for years, and can seep into groundwater, causing serious environmental and health problems. Because contamination is often located many feet below the surface, identifying and treating contaminated soils can be problematic.

In a typical system for sampling for soil contamination, soil samples are collected at discrete levels. A hollow-stem auger powered by a large motor drill rig is typically used. The drilling rig can weigh as much as 30 tons, and is typically mounted on a large truck. The auger is typically about 8" in diameter. The outside has a spiral flighting that aids travel through the soil and that removes the waste dirt ("cuttings") from the borehole. During drilling, the hollow auger is plugged.

After the initial soil depth to be investigated is reached, and while the auger is in place in the ground, the plug is removed. Next, a hollow cylindrical drive sampler is inserted into the hole created by the auger. The drive sampler is driven, via a drive rod and hydraulic or pneumatic hammer, ahead of the lead auger into the soil to be sampled. Soil is forced into the hollow center of the drive sampler, which can contain stainless steel or brass sample sleeves. A large winch, usually attached to a mast about 20' tall, then engages the drive rod, and the drive rod, sampler, sleeves, and soil are removed, leaving an open hole. For the next sample, the auger drills to the next depth to be sampled, and the process is repeated.

In cases of chemical contamination, contaminated soil may be confined to thin soil layers, sometimes only an inch or two thick. The discrete sampling of many previous systems, often taken at intervals of several feet, can miss areas of contamination and yield false negative results.

Furthermore, where contamination is encountered, the cuttings created by the typical augering system and brought to the ground surface, are also often contaminated, and must be disposed of as hazardous waste. Such disposal is often difficult and very expensive, because the soil requires special handling and disposal.

Single-rod non-auger drilling systems are sometimes used to sample relatively shallow depths. Single-rod systems can often be driven by more compact drilling rigs, but they are associated with other problems. To retrieve the sampler from the soil, skin friction of the soil must be overcome, requiring a significant amount of pull. In addition, because the borehole is not continuously cased off, contaminants from upper levels often slough off and contaminate lower levels, leading to false positive readings.

The drilling rig and winch in the typical prior art system can often harm the environment around the area to be tested.

As described above, the entire system can be over 20' tall, weigh 30 tons, and be mounted on a truck 20' long. A rig in place can disrupt traffic. Landscaping around the area to be tested can be destroyed. If the area to be tested is under an existing structure, roofs or walls may have to be removed. Providing access for the equipment can also be destructive, time-consuming, and expensive.

What is needed is a soil sampling system that is compact and efficient, that allows for continuous, accurate soil samples to be collected, and that minimizes the amount of cuttings created during sampling.

SUMMARY OF THE INVENTION

In accordance with the present invention, a soil sampling system includes a double-rod sampler and a driving rig. The double-rod sampler includes a casing and inner sample barrel, along with sample liners, that are driven simultaneously into the soil to be sampled. The system allows a vertically continuous sample to be collected while casing off the hole, thus sealing the borehole from sloughed-off contaminants from higher levels to minimize false readings of contamination.

The drive casing and sample barrel (with sample liners) are driven simultaneously into the ground. The barrel and liners are then removed, while the drive casing stays in place. New sample liners are placed in the sample barrel, and a new length of drive casing and an inner rod are attached. The liners, barrel, drive casing, and inner rod are then driven a further distance into the ground, and the process is repeated.

Minimal cuttings are created by the double-rod sampling system. Since the sample rod system is narrow (for example, the system can be only 2.25" in diameter at the widest point that enters the ground as opposed to 8" typical of systems in the prior art), far fewer cuttings are created. Most of the soil displaced by the double-rod system is retrieved in the sample barrel; the rest is compressed into the surrounding soil. The double rod system also does not have flightings that can carry contaminated cuttings to the surface, as does the hollow-stem auger.

Removal of the sample from the soil is much easier than in the prior art. Because the borehole is sealed off by the drive casing, there is no soil-skin friction to overcome when retrieving the sample barrel. Removal of the sample barrel (containing the soil samples in the sample liners) is easier and quicker, improving the speed and efficiency of the system of the invention as compared to previous systems.

The rig driving the soil sampling system can be significantly more compact than is typical in the prior art. It can be mounted on a conventional skid loader, and thus can be conveniently moved into locations that would not accommodate a conventional drilling rig. The rig can be configured to slant drill and can even drill horizontally. The double-rod sampling system can thus sample under buildings or existing structures without the necessity of dismantling or destroying them. Thus, the invention provides for reliable and effective sampling of contaminated soils, even at sites where access is restricted.

In a method in accordance with the invention, a drive casing, sample barrel, and sample liners are driven simultaneously into the soil to essentially the same depth. Thus, all portions of the borehole are sealed off while the sample is obtained, preventing sample contamination from sloughed-off soil from higher levels. In addition, the sample barrel and liners can be removed and replaced while the drive casing stays in place.

The method of the invention of taking and retrieving samples facilitates the taking of continuous samples. The bottom sample depth attained by one round of sampling becomes the top sample depth of the next round of sampling. A continuous sample is thus obtained and even thin layers of contamination are retrieved, thus maximizing sampling reliability. These and other features and advantages of the present invention are apparent in the following description with reference to the drawings below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a double-rod sampling system in accordance with the present invention, emphasizing components used in driving the sampler.

FIG. **2** is a block diagram of the double-rod sampling system of FIG. **1**, but emphasizing components used in retracting the sampler.

FIG. **3** is a schematic perspective view of a rig of the system of FIGS. **1** and **2**.

FIG. **4** is a schematic sectional view of a portion of the double-rod sampler of FIGS. **1** and **2**.

FIG. **5** is a flow chart of a method of using the double rod system of FIGS. **1** and **2**.

FIG. **6** is a flow chart of substeps of step **510** of the method of FIG. **5**.

FIG. **7** is a flow chart of substeps of step **550** of the method of FIG. **5**.

FIG. **8** is a flow chart of substeps of step **570** of the method of FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the present invention, a double-rod soil sampling system **100** comprises a sampling rig **110** and a double-rod sampler **150**, a shown in FIGS. **1** and **2**. Sampling rig **110** includes three driving systems: a hydraulic hammer **112**, hydraulic vibrators **114**, and hydraulic pressure cylinders **116**, shown in block diagram in FIG. **1**. Respective drive controls include hammer controls **118** (including a hammer slide control that horizontally positions hammer **112** and a hammer pounding control the controls the pounding of hammer **112**); a vibrator control **120**; and a pressure control **122**.

Sampling rig **110** also includes two retraction systems and their controls, as shown in block diagram in FIG. **2**. A sample retrieval system includes a winch control **202** and a winch **204**. A sampler retrieval system includes an upper clamp control **206**, controlling upper clamp **208**, and a lower clamp control **210**, controlling lower clamp **212**. The controls are mounted on the rig and control the respective driving and retracting systems of FIGS. **1** and **2**. Sampling rig **110** drives and retracts a double-rod sampler **150** and its components, shown in block diagram in FIGS. **1** and **2**.

In double-rod sampler **150**, a drive shoe **152** is attached to a *non-rotatable* drive casing **154**. Next, sample liners **156** are placed inside a sample barrel **158**, which in turn is placed within drive casing **154**. A drive head **160** is then attached to the top of drive casing **154**, rigidly coupling drive casing **154** and sample barrel **158**. Double-rod sampler **150** is then driven into the soil by one or a combination of the drive systems of rig **110**.

Drive head **160**, drive casing **154**, sample barrel **158**, sample liners **156**, and drive shoe **152** are thus driven into the soil as a unit. When the bottom depth for a round of sampling is reached, drive head **160**, drive casing **154**, sample barrel **158**, sample liners **156**, and drive shoe **152** are in the same relative positions they were in before being driven into the soil. Sample liners **156** are filled with soil sample. In the preferred embodiment, the bottom edges of drive casing **154**, sample barrel **158**, and sample liners are at the same level, with the bottom edge of drive shoe extending about 1.8" below that level. In other embodiments, the bottom edge of drive casing **154** can extend up to 12" below the bottom edge of sample liners **156**.

Once sample liners **156** are filled with a sample, winch **204** is attached to sample barrel **158**. Winch control **202** then causes winch **204** to pull sample barrel **158**, containing sample liners **156**, from the soil. Drive casing **154** can be left in the soil to case off the hole while the barrel and liners are removed.

New sample liners can then be placed into sample barrel **158**, and sample barrel **158** and liners **156** can then be replaced within drive casing **154**. An additional length of drive casing can then be attached to the drive casing in the soil. An inner rod **162** can be attached to the sample barrel to keep the sample barrel and liners pressed to the bottom of double-rod sampler **150**. Inner rod **162** is a three-foot steel tube about 1.5" in diameter. The upper end of inner rod **162** is female threaded, and the bottom end is male threaded, so that lengths of inner rod can be coupled together. Use of the inner rod allows for the use of only one segment of sample barrel. Because inner rod **162** is attached for sampling only after the first round of sampling, it is shown in the block diagrams (FIGS. **1** and **2**) in dashed lines. Drive head **160** is then replaced, and system **100** is ready for another round of sampling.

The pressure, hammer, and vibration systems*, each of which is suitably used as a direct push system,* can be operated singly or in any combination to drive sampler **150** into the ground. The selection of drive mechanisms is operator controlled, based on soil conditions and monitoring of the driving process.

Winch **204** is attached indirectly to sample barrel **154**. Winch **204** is then operated alone to retrieve sample barrel **158** and sample liners **156** for each round of sampling. When the sampling procedure is completed, upper clamp **208** is clamped to drive casing **154**, and pressure cylinders **116** are operated in reverse to remove drive casing **154** and drive shoe **152** from the ground. Upper clamp **208** and lower clamp **212** are operated independently. When sampler **150** is retracted over 3' from the ground, the upper clamp can be released, and the upper 3' section of drive casing can be removed. During this removal, lower clamp **212** is clamped to a lower section of drive casing to keep sampler **150** suspended in the borehole. Upper clamp **208** is then reclamped, lower clamp **212** is released, and the procedure is repeated.

Rig **110**, shown in perspective view in FIG. **3**, is a compact mounting system for hammer **112**, vibrator **114**, pressure device **116**, and winch **204** of FIGS. **1** and **2**. The rig weighs about two tons, and can be approximately 8'×3'×3'. Rig **110** drives and retracts the double-rod soil sampler shown schematically in FIG. **4**. Soil sampler **150** is placed within the jaws of an upper clamp **208**, beneath a hammer housing **302**. Hydraulic hammer **112** is a jackhammer-type pile drive housed in rectangular hammer housing **302**. One example of such a hammer is the OKADA model OKB301, as available for purchase in September 1992, from Okada Company, Osaka, Japan. The hydraulic hammer delivers energy of about 250 ft. lbs. per blow, with variable rates of about 800–1300 blows per minute. The hammer blows are delivered by a piston that is hydraulically moved up and down within hammer housing **302**. A hammer foot **304** contacts drive head **160** to force double-rod sampler **150** into the soil. The hydraulic hammer is particularly useful in penetrating soil conditions such as unconsolidated sediments or gravel deposits. The number and force of blows required to advance the sampler depends on the compaction/density and composition of the soil being sampled. For example, for a given force, very dense sand can take more than five times as many blows to advance the sampler a given distance than would loose sand; hard clay can take more than ten times as many blows than would very soft clay.

A hammer slide **306** slides hammer **112** horizontally by means of interlocking slots to position it over sampler **150** for maximum striking effectiveness, and to move hammer **112** out of the way so that the winch line can be attached to retrieve sample barrel **158** and sample liners **156** after a round of sampling. Hammer slide **306** is bolted to a hammer support stanchion **308**. Hammer support stanchion **308** is fitted with rollers **310** that allow it to move vertically to position hammer foot **304** to contact or release soil sampler **150**.

Pressure cylinders **116** transmit pressure to double-rod sampler **150** through a rectangular upper-clamp-drive housing **312**. Pressure cylinders **116** can provide up to 14,000 pounds per square inch of continuous pulldown pressure. Hydraulic pressure cylinders **116** can also be operated in reverse for retraction of double-rod sampler **150**.

Upper clamp **208** clamps onto drive casing **154**, activated by hydraulic cylinders (not shown) housed inside upper-clamp-drive housing **312**. Upper clamp **208** steadies and guides double-rod sampler **150** and applies pull-down force from hydraulic cylinders **116** as sampler **150** is driven into the soil. Extension springs **314** compress when pressure is applied to clamp **208**. Upper clamp **208** can also transmit vibrations from vibrators **114**, located inside upper-clamp-drive housing **312**, when the vibrators are activated. The vibrators are industrial vibrators typically operated at a range of 50–125 Hertz (Hz). The vibrations help reduce soil friction, and thus help ease the sampling rods into the soil. Upper clamp **208** is also clamped to the drive casing during retraction of the drive casing from the borehole.

Lower clamp **212** (not shown so as not to obscure other features) is located about three feet directly below upper clamp **208**. The lower clamp contains a hydraulic cylinder only, not vibrators. Lower clamp **212** holds drive casing **154** during retrieval, preventing it from falling into the borehole.

To retrieve sample barrel **158**, hammer slide **306** moves hammer **112** out of the way. Drive head **160** is removed from the exposed drive casing, and a retrieval head is screwed on. The retrieval head is threaded for attachment at the lower end, and has a bail at the upper end. Wire rope from winch **204** is attached to the bail. Winch control **202** is then operated to cause winch **204** to pull sample barrel **158** from drive casing **154**.

When the sampling is completed and the final sample barrel and liners have been removed from the drive casing, the remaining components of the sampler are retrieved from the borehole. Upper clamp **208** is closed around drive casing **154**. Pressure cylinders **116** are then operated in reverse to pull the remaining components of double-rod sample **150**, including drive casing **154** and drive shoe **152**, about 5' from the ground. (Alternatively, the sample barrel and liners can be retrieved along with entire double-rod sampler **150** instead of being removed first.) Upper clamp **208** is then disengaged, and the upper 3' section of drive casing can be unscrewed and removed from sampler **150**.

During the removal of the upper section of drive casing **154**, lower clamp **212** remains clamped to drive casing **154** to prevent sampler **150** from falling into the borehole. After the upper section of drive casing is removed, upper clamp **208** is then reclamped to a lower portion of drive casing **154** and the procedure can then be repeated.

Rig-mounted drive and retraction controls **320** include pressure cylinder control **122**, which controls the pressure applied through housing **312** and through hammer housing **302** via hammer slide **306** and hammer support stanchion **308**. A hammer pounding control **322** controls the rate of hammer blows applied through hammer foot **304**. A hammer slide control **324** activates hammer slide **306** to position hammer foot **304** horizontally over drive head **160**.

Upper clamp control **206** controls two hydraulic clamp cylinders inside clamp drive housing **312**. Upper clamp control **206** can be operated to close clamp **208** around drive casing **154**, or can be operated in reverse to release drive casing **154**.

Vibrator control **120** operates hydraulic vibrators **114** in the preferred range of 50–125 Hz. Vibrators **114** are especially useful in eliminating side wall friction so that drive casing **154** (containing sample barrel **158** and sample liners **156**) slides easily into the soil.

Lower clamp control **210** controls a hydraulic clamp cylinder (not shown) inside the lower frame of rig **110**. Lower clamp control **210** can be operated to close the lower clamp around drive casing **154**, or in reverse to release drive casing **154**. As discussed above, the lower clamp does not vibrate.

Winch control **202** operates winch **204**; winch **204** provides 300 pounds of line pull. Controls **320** are mounted together on rig **110** to provide ease of use.

Double-rod sampling system **100** can drive slant borings up to 90° from the vertical (i.e., horizontally), providing the capability of sampling under buildings and in areas difficult to access by vertical drilling. In using this feature, rig **110** is angled as desired on its mounting. For angles less than 90°, the system is typically mounted on a conventional skid loader. Mounting the rig on a skid loader makes it easily transportable to testing sites, and easily maneuverable once on the site.

The double-rod sampler comprises cylindrical metal tubes, shown schematically (not to scale) in FIG. **4**. The outermost cylinder comprises three-foot segments of drive casing **154**. Each segment is a 2.125" outer diameter and 1.687" inner diameter hollow tube of heat-treated steel. One end of each drive casing segment is male-threaded at 2.5 threads per inch with a thread depth of 0.01 inches. The opposite end is female-threaded, so that drive casing tube segments **154** can be screwed together.

At the bottommost segment, the drive casing ends in a drive shoe **152**. Drive shoe **152** is female-threaded to fit onto the male-threading of drive casing **154**. Drive shoe **152** is a hollow steel tube, about 4.125 inches in length with an outer diameter, at its widest, of 2.25". The steel in drive shoe **152** is heat-treated, so that it can withstand forces of hammering and pushing. The final 0.75" of drive shoe **152** tapers to provide a wedge shape for easier soil entry. Drive casing **154** and drive shoe **152** together make up a drive-casing assembly **402** that forms the outermost sheath of double-rod sampler **150**. Drive shoe **152** facilitates soil entry of drive casing **154** and sample barrel **158**, and extends about 1.8" below the bottoms of sample barrel **158** and sample liner **156**.

Sample barrel **158** is disposed inside drive casing **154**. Sample barrel **158** is a three-foot long tube of carbon steel with a 1.625" outer diameter and 1.527" inner diameter. An expansion coupler **404** is male-threaded to attach to sample head coupling **406**. Expansion coupler **404** has a hole through it through which an expansion bolt **408** threads. As expansion bolt **408** tightens against coupler **404**, a rubber expansion bushing **410** compresses vertically.

As expansion bushing **410** is compressed by a head **412** at the lower end of expansion bolt **408**, the bushing spreads horizontally to engage inner surface **414** of sample barrel **158**, thereby rigidly coupling expansion bolt **408** to sample barrel **158**. At the opposite end of expansion bolt **408**, a hexagonal head **416** provides a grip site for ease in removal of bolt **408**. Expansion nut **418** tightens to further secure expansion bolt **408**.

Sample head coupling **406** is a hollow cylinder of carbon steel. The top of sample head coupling **406** is female-threaded so as to attach the male-threaded end of a compression bolt **420** (in the first round of sampling) or, alternatively, to attach the male-threaded end of an inner rod **162** (not shown in FIG. **4**) in subsequent rounds of sampling. Inner rod **162** is a hollow tube of carbon steel, male-threaded at the lower end and female-threaded at the upper end so that lengths of inner rod can be attached to each other. Inner rod **162** is sized to thread onto compression bolt **420** and to fit within sampler **150**.

The lower end of compression bolt **420** screws onto sample head coupling **406**. The upper end of compression bolt **420** extends through drive head **160**. Compression bolt **420** and associated compression bushing **422** push sample barrel **158** against drive shoe **152** (via lower sample head coupling **406**, expansion coupler **404**, expansion bushing **410**, and expansion bolt **408**).

After the initial 3-foot advance of sampler **150**, three-foot segments of inner rod **162** are rigidly coupled to sample barrel **158** via lower sample head coupling **406**, expansion coupler **404**, and expansion bolt **408**.

Six 6-inch by 1½ inch-diameter stainless steel sample liners **156** fit inside sample barrel **158**. When drive casing **154** and sample barrel **158** are advanced, soil is driven into sample liners **156**. Sample liners **156** can then be removed for analysis by chemical or geologic laboratories. Sample liners **156** are dimensioned to be compatible with existing standardized laboratory requirements.

A method **500** of the invention is shown in overview in FIG. **5**. The steps of method **500** are broken down into more detailed substeps in FIGS. **6**, **7**, and **8**. The first round of a multi-round sampling proceeds as follows. At step **510**, a fresh sample barrel is prepared, as shown in FIG. **5**. The following substeps **511–514** of step **510**, shown in FIG. **6**, are undertaken to prepare the barrel: Sample liners **156** are inserted, at substep **511**, into sample barrel **158**. An expansion bushing **410** and other inner components, including expansion bolt **408**, are attached, at substep **512**, to the sample barrel. A drive shoe **152** is screwed onto drive casing **154** at substep **513**. The sample barrel (with rigidly attached expansion bushing **410** and expansion bolt **408**) is placed, at substep **514**, into drive casing **154**. Drive head **160** is then attached, at step **530**, to rigidly couple the sample container and drive casing **154**, as shown in FIG. **5**. The coupled drive casing and sample container are then driven, at step **540**, into the soil to a sample bottom depth.

As the sampler is driven into the soil, sample liner **156** becomes filled with soil. When sample liner **156** is filled with a soil sample, it is removed, at step **550**, from the drive casing. Substeps **551–554** of step **550** are shown in FIG. **7**. To effect removal, drive head **160** and compression bushing **410** are removed, at substep **551**, from sample barrel **158**. A retrieval head, threaded at one end and with a ball at the other, is screwed onto sample barrel **158** at substep **552**. Line from winch **204** is then fed through the bail to attach the winch to the retrieval head, at substep **553**. Winch **204** is then activated to remove sample barrel **158** and sample liners **156**, at substep **554**. The first round of sampling is complete.

To proceed with another round of sampling, sample barrel **158** is prepared again, at step **510**, as shown in FIG. **5**. A section of inner rod is then attached, at step **521**, to sample barrel **158**, as shown in FIG. **5**. A new 3' section of drive casing is threaded onto drive casing **154**, at step **522**. Drive head **160** is then attached, at step **530**, and the method proceeds as described above. Subsequent rounds of sampling vary in minor ways. The retrieval head is attached, at substep **552**, to inner rod **162** instead of to sample barrel **154**. A new section of inner rod is attached to the inner rod, at step **521**, instead of to sample barrel **158**. Otherwise, the method proceeds as described above.

When sampling is finished, the remaining sampler components are removed, at step **570**, from the ground. Substeps **571–575** of step **570** are shown in FIG. **8**. To effect removal, upper clamp **208** is pressurized, at substep **571**, to close around drive casing **154**. Pressure cylinders **116** are then extended, at substep **572**, to pull drive casing **154** several feet from the borehole. Lower clamp **212** is then engaged, at substep **573**, to hold drive casing **154** and other sampler components to prevent them from falling into the borehole. Upper clamp **208** is then released, at substep **574**. The uppermost 3' section of drive casing **154** is then unscrewed and removed, at substep **575**. If further sections of casing are to be removed, substeps **571–575** can be repeated.

Use of the apparatus and method of the invention creates minimal cuttings. Soil is displaced only about ¼" on a side, and is generally compressed into the surrounding soil.

Materials other than steel can be used to manufacture the soil sampler. The rig of the invention can be configured in many different ways, so long as the claimed functions are enabled. Alternative embodiments employ other dimensions of rig **110** and sampler **150**. The rig may be mounted on other than skid loaders (for example, on a small truck, forklift, or four-wheel drive vehicle), or may be free standing.

The system is compatible with standard sample liners as preferred by testing laboratories, but can be used with other sample liners. Alternatively, the invention does not require a separate sample barrel and liners; one cylinder can suffice for both functions. Except where particularly specified, the term "drive" applied to advancing the double-rod solid sampler comprises all methods of advancing the sampler, including pounding, hammering, continuous pressure, intermittent pressure, and vibration.

Normally, it is contemplated that the sampler will be driven straight down or at a small angle from the vertical. However, the invention provides for drilling at greater angles from the vertical, horizontally, and even in an upward direction. Each sample has a minimum depth from surface and a maximum depth from the surface. When the sampler is driven straight down, the maximum depth is at the bottom of the sample. When the sampler to driven horizontally, the maximum sample depth is the furthest distance of the sample from the surface through which the sample was accessed.

The double-rod system is compatible with other uses of accessing subsurface volumes. The system can be used to measure or collect groundwater samples. For example, a piezometer can be disposed within the drive casing after the sample barrel has been removed and prior to removing the drive casing. The piezometer can then be used to measure water levels. Similarly, a soil vapor extraction well can be disposed within the drive casing after the sample barrel has been removed. The soil vapor extraction well can then be used to extract vapor samples.

The double-rod system can be used in soil venting. Soil venting is typically used to increase the activity of bacteria already in the soil. The bacteria consume hydrocarbons, and soil venting is used to accelerate the process of cleaning the soil. To vent soil, a length of perforated small-diameter polyvinyl chloride (PVC) pipe, sized to fit the inner diameter of drive casing **154**, can be disposed within the drive casing instead of a sample barrel and liners after the sample barrel has been removed and prior to removing the drive casing. Bacterial nutrients such as oxygen and nitrogen can then be pumped into the soil. In some cases, the temperature can be elevated to improve bacterial activity. The pipe need not be PVC and need not be perforated. These and other modifications to and variations upon the described embodiments are provided for by the present invention, the scope of which is limited only by the following claims.

What is claimed is:

1. A method for extracting a subsurface sample comprising the steps of:

rigidly coupling a sample container to a drive casing;

driving said drive casing until said sample container attains a maximum sample depth; and

removing said sample container from said drive casing.

2. A method as recited in claim **1** wherein at the end of said driving step, the depth of said sample container and the depth of said drive casing are at most 12" apart.

3. A method as described in claim **1** wherein while said sample container is removed from said drive casing, said drive casing remains at the depth it attains when said sample container attains said sample depth.

4. A method as described in claim **1** wherein said sample container is in direct contact with said sample.

5. A method for extracting a soil sample comprising the steps of:

rigidly coupling a sample container to a drive casing assembly;

driving said drive casing assembly below a sample bottom depth so that said sample container attains said sample bottom depth; and

removing said sample container from said drive casing.

6. A method for collecting a continuous soil sample comprising the steps of:

rigidly coupling a sample container to a drive casing;

driving said drive casing down until said sample container attains a first sample bottom depth;

removing said sample container from said drive casing;

rigidly coupling a second sample container to said drive casing while said drive casing remains at the depth it attained when said sample container attained said first sample bottom depth; and

driving said drive casing downward until said second sample container attains a second sample bottom depth, the distance between said second sample bottom depth and said first sample bottom depth being not more than twice the length of said second sample container.

7. A method for extracting a soil sample comprising the steps of:

inserting sample liners into a sample barrel;

placing said sample barrel into a drive casing;

attaching a drive head to rigidly couple said sample barrel and said drive casing;

driving said sample liners, said sample barrel, and said drive casing simultaneously into soil to be sampled until said sample liners obtain a sample;

attaching a winch to said sample barrel; and

retracting said sample barrel and said sample liners from said drive casing.

8. A method as described in claim **7** wherein after said retracting step, sample liners are again placed in said sample barrel, a segment of inner rod is attached to said sample barrel, a second length of drive casing is attached to said drive casing, and said sample liners, said sample barrel, and said drive casing are simultaneously driven into said soil.

9. An apparatus for extracting a soil sample comprising:

drive casing means for casing off a borehole;

sample container means for containing a soil sample obtained from said borehole;

drive head means for rigidly attaching said sample container means and said drive casing means; and

drive means for simultaneously driving said sample container means and said drive casing means into soil.

10. An apparatus as described in claim **9** wherein said drive means includes a pressure drive means, a hammer drive means, and a vibratory drive means, said vibratory drive means operating within a preselected frequency range of from 50 to 125 Hertz.

11. An apparatus as described in claim **10** wherein said pressure drive means, said hammer drive means, and said vibratory drive means independently drive said sample container into soil.

12. A method of collecting a subsurface soil sample, comprising the steps of:

assembling a double-rod sampler including

i) a drive casing,

ii) a sample container within said casing, and

iii) a drive head means for drivingly connecting said casing and said sample container means;

direct pushing, without rotation, said double-rod sampler through said drive head means by engaging said drive head means with a direct push system to thereby drive said drive casing and said sample container into the soil as a unit and to fill said sample container means with a soil sample during advancement of said double-rod sampler,

terminating said direct pushing of said double-rod sampler to thereby locate said double-rod sampler at a predetermined position in the soil, and

withdrawing said sample container means upwardly through said drive casing while said drive casing remains stationary at said position.

13. A method as defined in claim 12, wherein said soil sample container includes a sample barrel, and

said method further comprises the step of removing said soil sample from said sample barrel after the withdrawal of said sample container means.

14. A method as defined in claim 13, wherein said sample barrel receives a sample liner for receiving and containing said soil sample during said advancement of said double-rod sampler, and wherein *said removing of said soil sample includes removing said liner from said sample barrel with the contained soil sample therein.*

15. A method as defined in claim 13, and further comprising the steps of:

adding a segment of drive casing to an upper end of drive casing of said double-rod sampler after withdrawal of said sample container means,

reinserting said sample barrel while adding a section of an inner rod between said sample barrel and said drive head means,

direct pushing, without rotation, said double-rod sampler to advance said double-rod sampler as a unit from said predetermined position to a second predetermined position to fill said sample container means with a consecutive soil sample,

again withdrawing said sample container means upwardly through said drive casing while said drive casing remains stationary at said second position, and

removing said consecutive soil sample from said sample barrel.

16. An apparatus for extracting a soil sample comprising:

a double-rod sampler, said double rod sampler further comprising:

drive casing means for casing off a borehole;

sample container means for containing a soil sample obtained from said borehole;

drive head means for rigidly attaching said sample container means and said drive casing means, said rigid attachment enabling said sample container and said drive casing to be simultaneously driven into soil,

said drive head means having a drive means engaging portion whereby said sample container means and said drive casing means are simultaneously driven by said drive head on driving engagement of said drive head by a drive means.

17. An apparatus as defined in claim 16, wherein said apparatus further comprises a drive means selected from the group consisting of: pressure drive means, a hammer drive means, and vibrating drive means.

18. An apparatus as defined in claim 17, wherein said drive means includes independently operable pressure drive means, a hammer drive means, and vibrating drive means.

19. An apparatus for extracting a soil sample comprising:

a double-rod sampler including:

drive casing means for casing off a borehole,

sample container means within said casing means and having an open lower end for receiving a soil sample, and

drive head means for engagement by a non-rotating direct push system and for drivingly connecting said casing means and said sample container means during direct push by said direct push system,

whereby said casing means and said sample container means are so constructed and arranged to be driven simultaneously into the soil through said drive head means on driving engagement of said drive head means by said direct path system.

20. An apparatus as defined in claim 19, wherein:

said drive casing terminates at a lower end in a drive shoe,

said drive shoe comprising a hollow steel tube having a tapered outer surface at a forward edge for easier soil entry.

21. An apparatus as defined in claim 20, wherein:

said sample container means includes:

a sample barrel having a lower open end adjacent said drive shoe for receiving a soil sample through said shoe as said casing means and said sample container means are simultaneously driven into said soil.

22. An apparatus as defined in claim 16, wherein

said casing means terminates at the lower end thereof in a drive shoe, and

said sample container means includes a sample barrel having a lower end thereof adjacent said drive shoe.

23. An apparatus as defined in claim 22, wherein

said casing means includes a plurality of connectable segments, and

said sample container means further includes, a plurality of connectable inner rods extending between said drive head means and said sample barrel.

24. An apparatus as defined in claim 23, further comprising:

a compression bushing disposed between an uppermost one of said inner rods and said drive head means.

25. An apparatus as defined in claim 22, further comprising:

a removable sample liner received in said sample barrel.

26. A method of collecting a subsurface soil sample, comprising the steps of:

assembling a double-rod sampler including

(i) a drive casing;

(ii) a sample container within said casing, and

(iii) a drive head means for drivingly connecting said casing and said sample container means;

driving said double-rod sampler through said drive head means by engaging said drive head means with a drive system to thereby drive said drive casing and said sample container as a unit such that the relative positions of the drive casing and sample container remain the same throughout said driving steps and to fill said sample container means with a soil sample during advancement of said double-rod sampler in the soil;

terminating said driving of said double-rod sampler to thereby locate said double-rod sampler at a predetermined position in the soil; and

withdrawing said sample container means upwardly through said drive casing while said drive casing remains stationary at said position.

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