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METHODS AND APPARATUS FOR PRODUCING CAST-IN-PLACE SHELLS AND PILES

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Fig. 1.

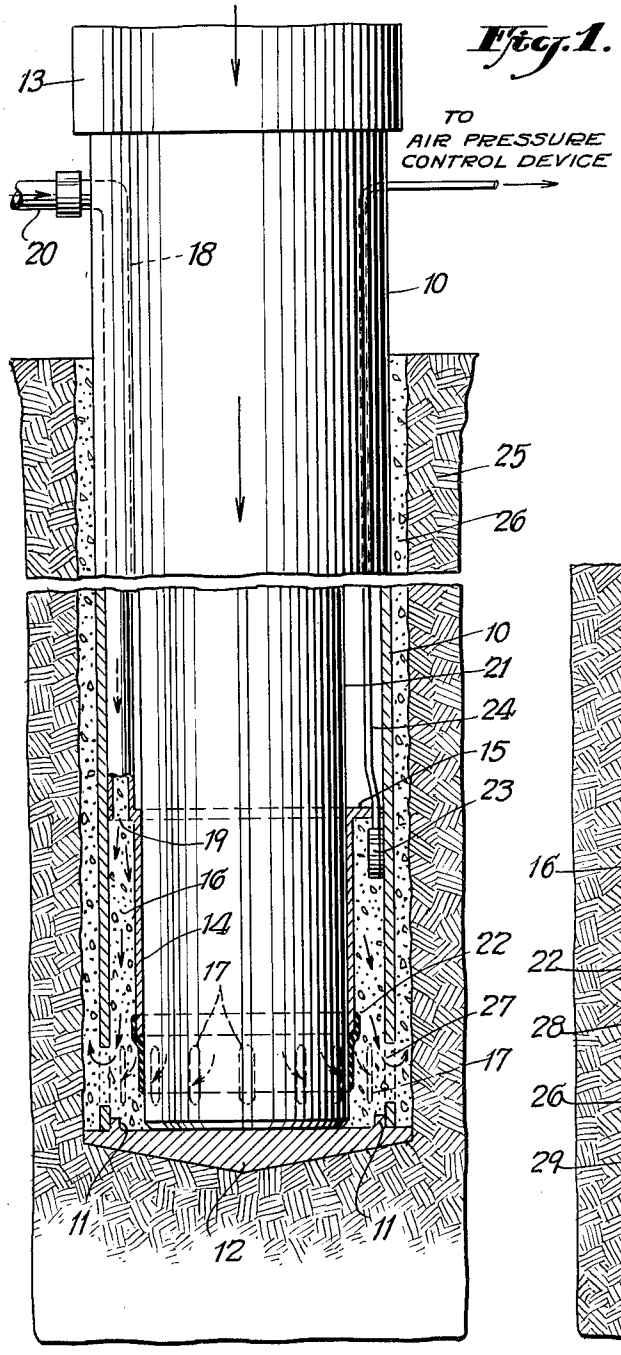
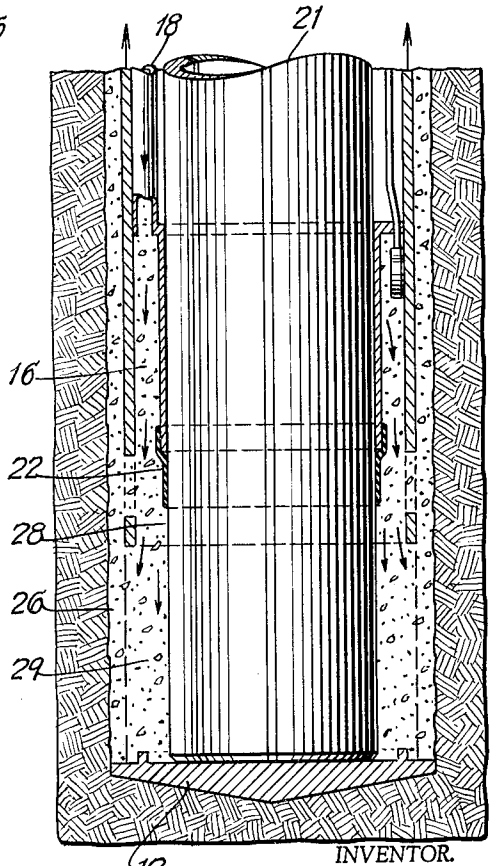


Fig. 2.



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Fig. 3.

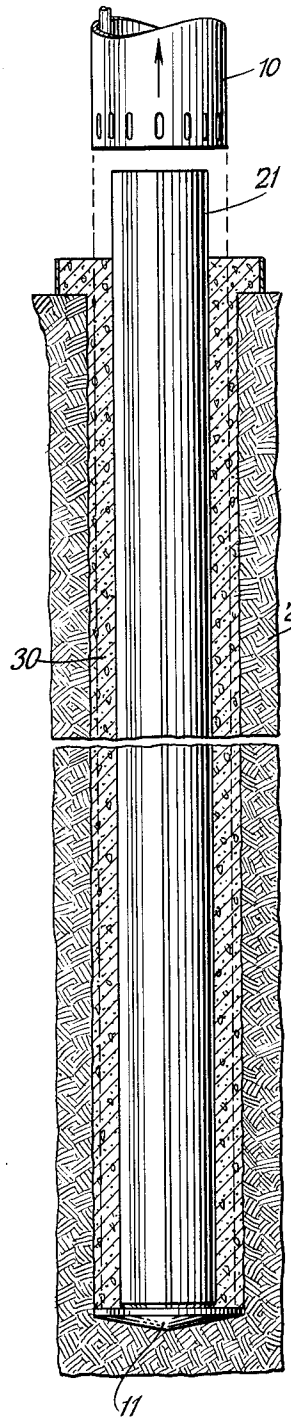


Fig. 4.

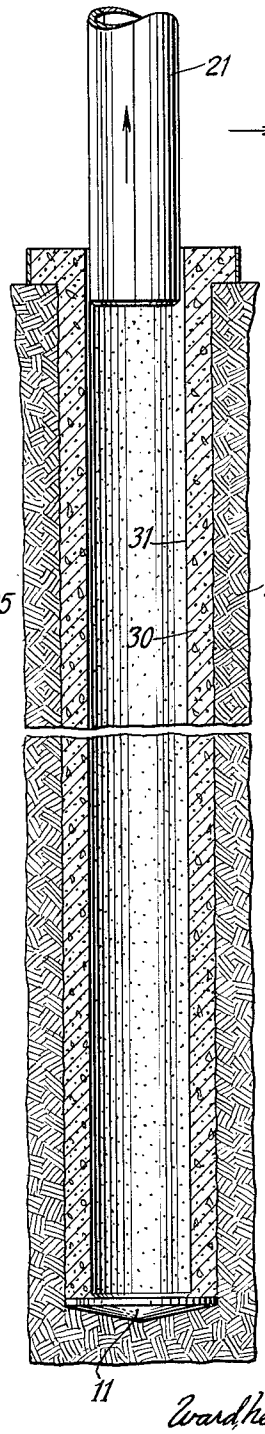
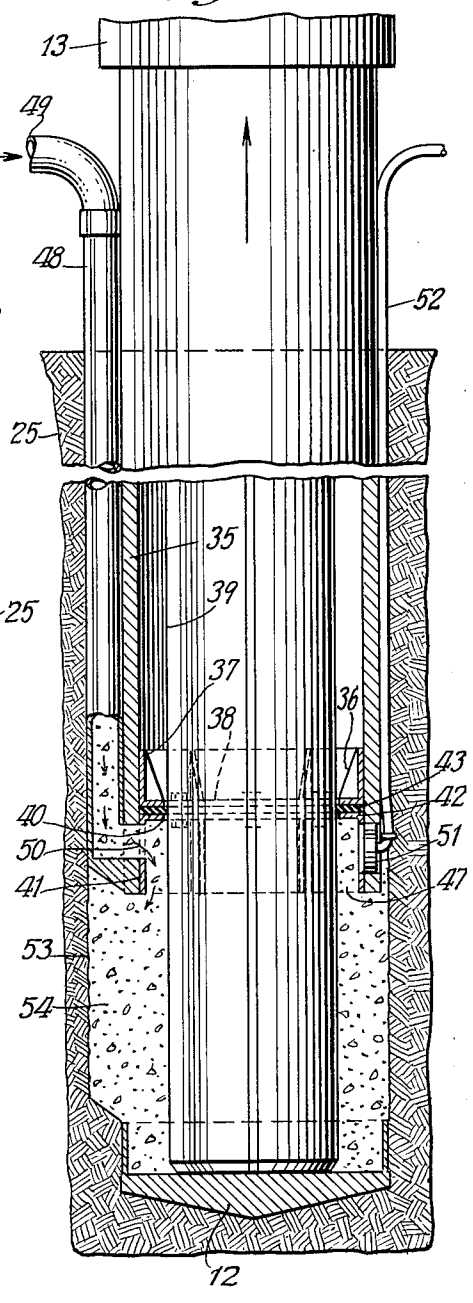


Fig. 5.



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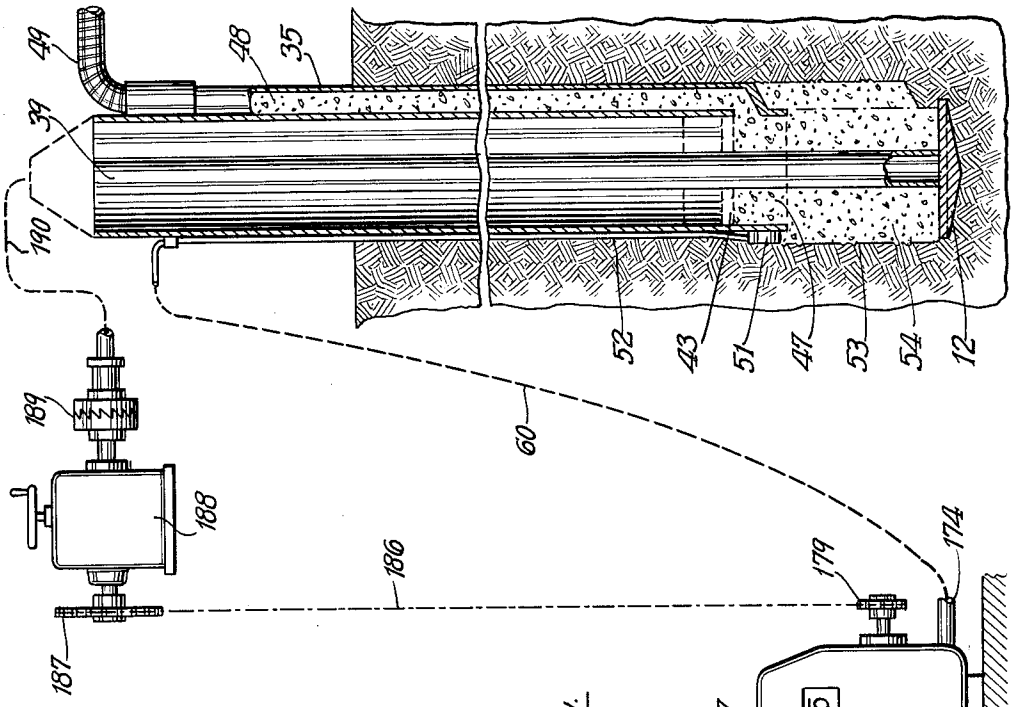


Fig. 6.

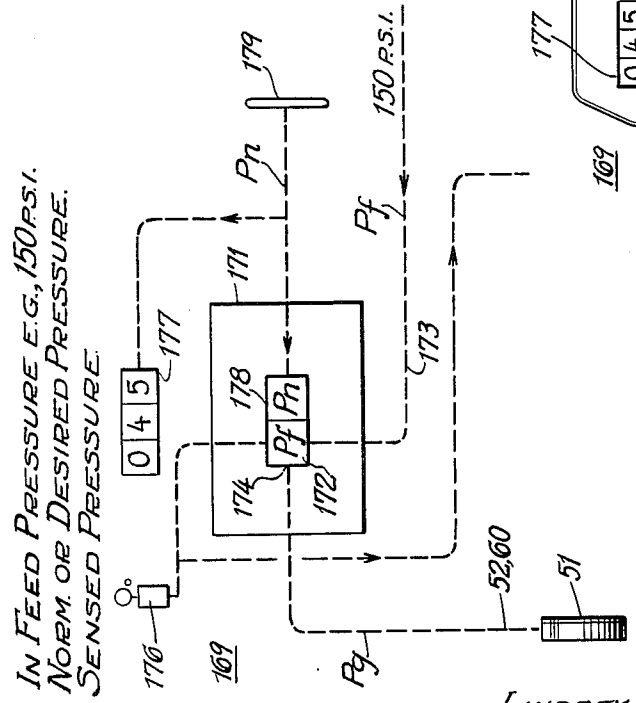


Fig. 7.

Pf = In Feed Pressure E.G., 150 P.S.I.
Pn = Nom. or Desired Pressure.
Pg = Sensed Pressure.

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Fig. 8.

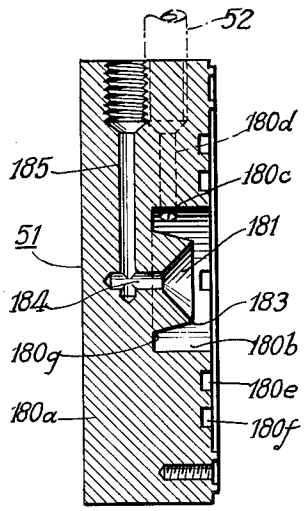


Fig. 9.

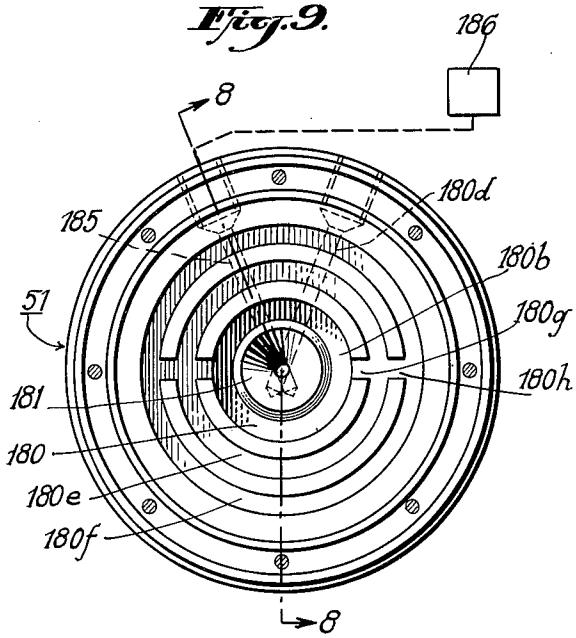


Fig. 10.

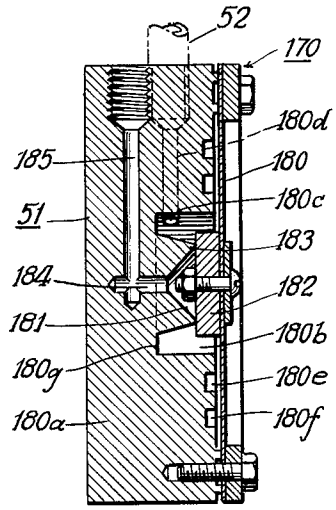
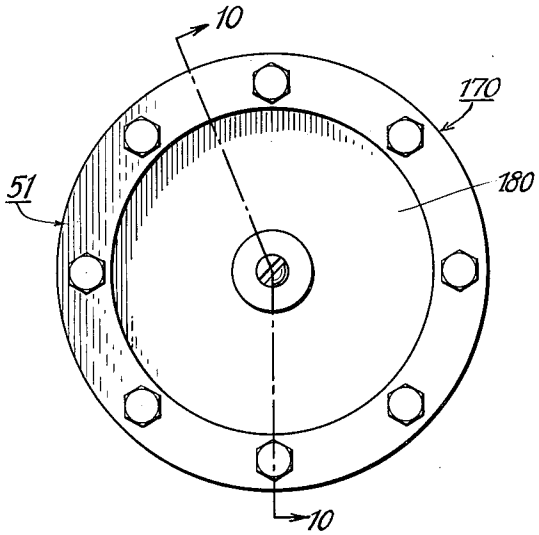


Fig. 11.



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Fig. 12.

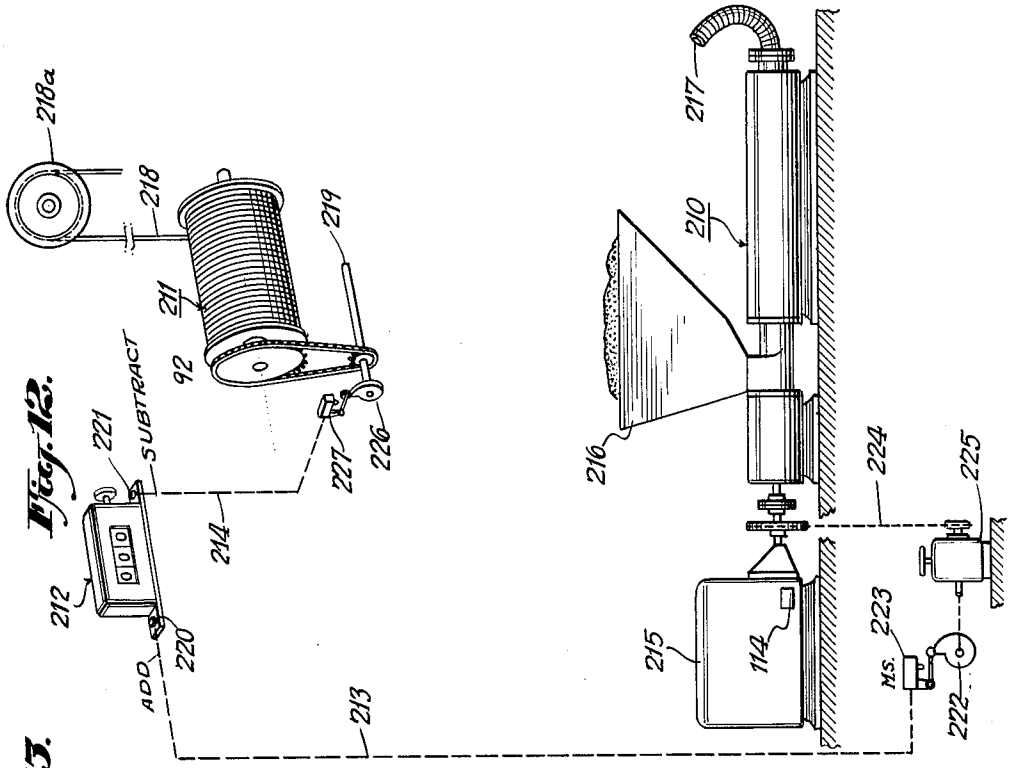


Fig. 13.

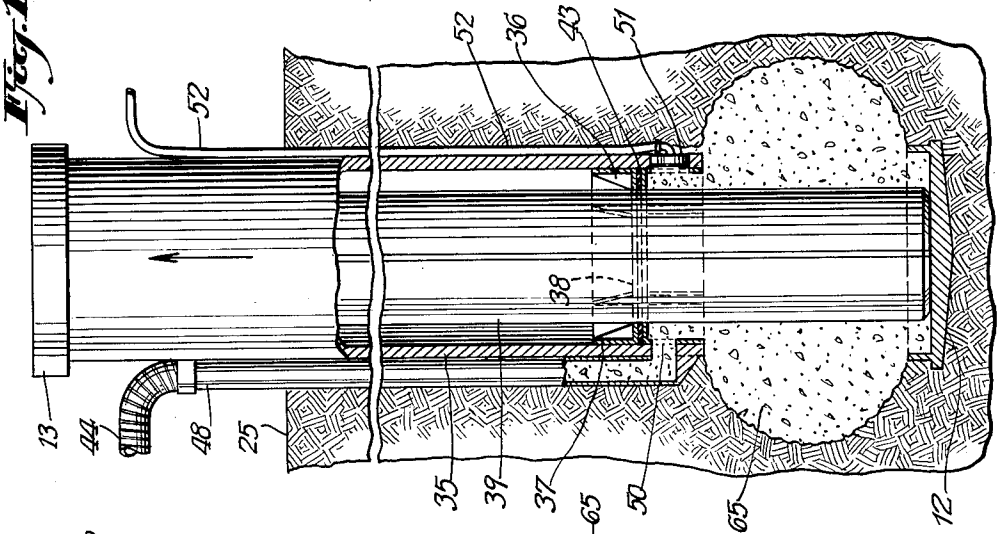
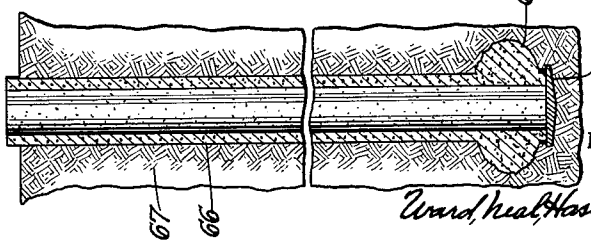


Fig. 14.



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METHODS AND APPARATUS FOR PRODUCING CAST-IN-PLACE SHELLS AND PILES

Lindsey J. Phares, Butler, N.J., assignor to Raymond International Inc., New York, N.Y., a corporation of New Jersey

Filed Mar. 1, 1962, Ser. No. 176,648
12 Claims. (Cl. 61—53.52)

This invention pertains to the production of cast-in-place concrete piles by first casting a tubular concrete shell in the ground and later filling this shell with concrete, and pertains more especially to improved methods and apparatus for forming such cast-in-place concrete shells.

Various proposals have, heretofore, been made for the placement of cast-in-place concrete shells, prominent among which is that of Patent 2,421,666, to Upson et al. and that of Upson's copending application Serial No. 800,018, filed March 17, 1959, now Patent No. 3,090,204, assigned to Raymond International Inc., which is also the assignee of this application. In accordance with the technique of said Upson et al. patent, a tubular casing is first sunk in the ground, and a tubular form of appreciably smaller diameter lowered concentrically into the casing and the annular space between the two filled with liquid concrete. The casing is then withdrawn while the concrete is still fluid so that it flows against the earth, and after the concrete has hardened and set sufficiently, the tubular form is withdrawn leaving the cast-in-place concrete shell.

In accordance with the procedure of said Upson application, a tubular casing and a coaxially disposed mandrel of considerably smaller diameter, resting on a boot plate, are driven into the ground, and the annular space therebetween filled with liquid concrete either during or subsequent to driving. The casing is then withdrawn while the concrete remains fluid and a tapered tube may be sunk about the mandrel to force the liquid concrete against the surrounding earth, the mandrel and tapered tube being thereafter withdrawn.

Both procedures aforesaid require considerable force to withdraw the casing against the frictional retarding force of the surrounding earth directly engaging the same as driven.

The present invention eliminates this difficulty and in addition provides a pressure casting technique which assures a dense and homogeneous cast-in-place concrete shell, all portions of the exterior of which press firmly against the surrounding earth with a force which is preselected and controlled as desired during the casting process.

The present invention provides both novel apparatus and novel methods employing the same for forming such cast-in-place concrete shells. The novel apparatus of the invention includes an outer steel casing of a length sufficient for forming a concrete shell of length required. Disposed interiorly of this casing near its lower end, in one modification of the invention, is a sealing ring positioned coaxially within the casing, said ring having an outer diameter corresponding substantially to the inner diameter of the casing, and being peripherally welded to the casing in a fluid-tight joint, and said ring having a central opening of substantially smaller diameter for slidable reception and positioning of a mandrel concentric with the casing, thereby with the mandrel inserted, to form an annular chamber below the sealing ring, open at its base and closed at the top by the sealing ring and the inner and outer cylindrical walls of which comprise the mandrel and inner casing wall, respectively. The mandrel may be cylindrical or may be provided with a slight taper for ease of withdrawal, for example, about

one inch in radius per 30 to 40 feet of length of the mandrel. Also a collapsible type of mandrel may be employed. The casing may also be cylindrical or tapered, or may have a cylindrical upper portion and a tapered lower portion, the taper being about 0.4 inch of radius per lineal foot of the casing. The sealing ring mounts an annular, flexible gasket of rubber or equivalent which projects inwardly sufficiently beyond the sealing ring to grip the mandrel in all positions of vertical displacement relative thereto, and whether the mandrel be of cylindrical or tapered configuration. In a further modification of the invention, the inner chamber wall comprises a short tubular member secured at its top to the inner periphery of the aforesaid sealing ring. A grouting pipe extends from the top of the casing down to this chamber and opens thereinto, this pipe being optionally disposed either exterior or interior to the casing.

In one method according to the invention, for forming a cast-in-place concrete shell, the casing and mandrel assembly aforesaid is centered on a boot plate of somewhat greater diameter than the casing, and the apparatus as thus assembled, is driven into the ground to the desired depth. During driving a hoseline extending to the upper end of the grout pipe, continuously supplies liquid concrete to the chamber at the base of the casing through the grout pipe, at a rate of flow and under a pressure such that as the boot and casing descend into the earth, the space formed between the boot and casing owing to the greater diameter of the latter, is progressively filled as rapidly as it is formed with the liquid concrete supplied thereto from the chamber through appropriately formed side wall slots at the base of the chamber. The pressure at which the liquid concrete is thus forced to flow outwardly against the surrounding earth is so controlled, with reference to the depth of penetration of the boot, as to prevent any collapse of the earth against the casing, and such as progressively to form and maintain a tubular filling of liquid concrete between the earth and casing as the boot and casing descend, the pressure being such as to force the liquid concrete firmly against the earth and into all irregularities and crevices.

The pressure and volumetric rate of flow at which the liquid concrete is thus supplied are preferably controlled in the manner set forth in a copending application of L. J. Phares et al. Serial No. 77,973, filed December 23, 1960 assigned to Raymond International Inc., incorporated by reference herein, and the essential disclosure of which is included herein as hereinafter set forth.

When the casing has thus been driven to the required depth, the casing is slowly withdrawn, while continuing the feed of liquid concrete to the chamber at a rate and pressure sufficient to fill the void formed by the receding casing and chamber or sealing ring assembly, thus to form a shell of liquid concrete of a radial thickness corresponding substantially to the radial distance between the mandrel and the periphery of the boot.

When the concrete has hardened and set sufficiently the mandrel is withdrawn, leaving the cast-in-place concrete shell, which after inspection for flaws, if found satisfactory, is filled with liquid concrete.

In a somewhat modified method according to the invention, the casing assembled on a boot plate is driven into the ground to the required depth, preferably without the mandrel, which is inserted after the driving is complete. The casing is thereupon slowly withdrawn while pumping liquid concrete through the grout line into the chamber at the base of the casing and thence into the space between the mandrel and earth left void by the receding casing and chamber assembly. After the casing assembly has been completely withdrawn and the concrete has hardened sufficiently, the mandrel is withdrawn leaving the cast-in-place shell thus formed.

It will be observed that in both the aforesaid methods, the mandrel is not removed until the concrete shell has been fully cast about it from base to top and the concrete has set, so that the frictional resistance against removal of the mandrel is considerable, although less for a tapered or collapsible mandrel than for one of cylindrical configuration. In accordance with a further important aspect of this invention, the frictional resistance against mandrel withdrawal is reduced to negligible proportions by applying to the mandrel a coating material which acts as a release coating between the metal of the mandrel and the concrete contiguous thereto. A suitable coating material for accomplishing this is that described and claimed in a copending application of Robert W. Childers and Richard K. Snow, Serial No. 193,180, filed May 8, 1962, assigned to Raymond International Inc. and comprising an aqueous solution of polyvinyl alcohol and the lignitic material obtained from sulfite waste liquor from paper mills, which is a calcium-lignin-sulfonate mixture, or more basically sulfonated lignin. As described in said application, an aqueous solution containing about 10% by weight each of the lignin salt and polyvinyl alcohol of 24–28 centipoises viscosity, 99.85% plus hydrolysis, and 5.5–7.5 pH, has been found to provide a highly effective release coating composition for purposes aforesaid.

Other release coating materials available on the market under various trade designations, but the compositions of which are generally unknown to the public are: a coating material designated "LL409" put out by Master Builders Company, Cleveland, Ohio, which is of molasses-like consistency. Another is "Rugasol C" sold by Sika Chemical Corporation, which is a water-soluble surface retarder; also "Rugasol F" put out by the same company which is a water-insoluble surface retarder. All of the foregoing materials may be applied to the mandrel by brush, roller or spray.

Withdrawal of the mandrel may be further facilitated by constructing it in sections joined by slip joints permitting slight relative movement of say an inch or so, whereby the sections may be successively broken away from the surrounding concrete a section at a time.

The cast-in-place concrete shells produced in accordance with my invention may be of cylindrical exterior and interior contour, or may be tapered exteriorly and/or interiorly, or may be cylindrical in the upper portion and tapered in the lower portion, depending on the contours of the casing and mandrel employed as above mentioned. The load-bearing capacity of the shell is enhanced by imparting an exterior taper thereto at least throughout the lower portion of the shell.

A further modification of the invention comprises the placement of cast-in-place concrete shells having a bulbous base, the casting of which is accomplished according to the invention by driving the casing and boot plate into the ground, and with the mandrel inserted withdrawing the casing to a height of about 2 to 3 feet while pumping liquid concrete via the grout line into the chamber at the lower end of the casing and thence into the space voided by the receding casing. In this modification, however, when the casing has been withdrawn to the extent indicated, the lifting of the casing is stopped while the pumping of the liquid concrete is continued. As a result the pressure of the grout below the casing chamber will increase to the point where it will displace the earth around the periphery of the grout already placed and produce a bulbous enlargement thereof, dependent in size on the grout pressure applied, the quantity of grout injected, and the character of the earth itself at that location. After a known and predetermined volumetric amount of grout has been placed, usually on the order of 8 to 12 cubic feet of volume outside the shaft of the shell, and as determined by the volumetric indicating apparatus of said Phares et al. application as hereinafter described, the withdrawal of the casing is recommenced and the balance of the shell placed in the manner above described. The

bulb thus formed serves to increase the carrying capacity of the resultant pile and thus permits the use of shorter piles than otherwise.

The advantages of my invention as compared to techniques heretofore employed are as follows: During the driving of the outer casing, the cementitious mixture can be continuously pumped into the above described chamber at the lower end of the casing, and thence into the small annular space around the outside of the casing, formed by the plowing action of the boot plate owing to its projection a small distance beyond the outside of the casing. The presence of this cementitious mixture on the outside of the casing acts as a lubricant in its initial state and thereby permits of easy pulling or withdrawal of the outer casing without resorting to heavy expensive pulling devices which would otherwise be required.

In addition, during the withdrawal of the casing there is only a small area throughout which the mandrel acting directly on the casing or through the cementitious mixture exerts a frictional retarding action against the casing withdrawal. This is due to the small area of contact between the mandrel and the sealing member or ring; also to the fact that the cementitious mixture is admitted only into the very short chamber at the lower end of the casing below the sealing ring. This feature also helps to greatly reduce the pulling force required to remove the outer casing as compared to what would be needed if the annular space between the mandrel and the outer casing were completely filled with the cementitious mixture throughout its entire length from the lower end to ground surface.

The procedure of pumping the cementitious mixture during driving as described above, together with the pumping of the mixture under pressure during the withdrawal of the outer casing, positively insures and takes advantage of all the frictional resistance built up in the ground by the driving of the outer casing. Since the soil surrounding the pile possesses some elasticity, the pressure between the cementitious mixture and the soil is maintained even after the pumping operation is completed.

As mentioned above, the pressure of the cementitious mixture injected at the lower end of the outer casing may be, and preferably is, controlled in accordance with the soil and earth pressure conditions encountered at each level as the casing is driven and withdrawn to assure complete filling of all space vacated by displacement of the apparatus. Also volumetric metering devices of the aforesaid Phares et al. application may be employed so that assurance can be had of placing the proper amount of cementitious mixture required. Preferred methods and apparatus for accomplishing these objectives are as set forth in the aforesaid Phares et al. application. In addition, the upward pressure thus exerted on the sealing ring assists in the casing withdrawal since it tends to push the casing upward and thereby reduces the pulling force required to withdraw the casing.

Since with the methods of forming cast-in-place concrete shells in accordance with the invention, the casing is withdrawn as well as the mandrel, no metal is left in the ground if a concrete boot plate is employed, and only an insignificant amount of metal left if a metal boot plate is used, which moreover is relatively cheap.

The cast-in-place concrete shells produced according to the invention are generally superior to those produced by previously known techniques owing to the pressure control and volumetric control of the progressively fed liquid concrete during casting, which tends to eliminate or minimize flaws. The shells may, of course, be interiorly inspected to assure freedom from flaws.

Having thus described the invention in general terms, reference will now be had for a more detailed description, to the accompanying drawings wherein:

FIGURES 1–4, inc., illustrate the method and apparatus for forming cast-in-place concrete shells in accord-

ance with the first modification of the invention above described. FIG. 1 is a view in axial sectional elevation of the outer casing, mandrel and boot assembly being driven into the ground, while supplying liquid concrete via the grouting pipe and chamber at the base of the casing to the space formed between the boot and casing. FIG. 2 is a view similar to FIG. 1, but showing the outer casing in process of being withdrawn, leaving the boot in place with the mandrel resting thereon, while continuing the supply of liquid concrete through the grouting pipe and chamber to the space left between the mandrel and outer diameter of the casing as the latter is being withdrawn. FIG. 3 is a view similar to FIG. 2, but with the outer casing completely withdrawn, and illustrating the now fully formed cast-in-place concrete shell, with the concrete still in the liquid state. FIG. 4 is a view similar to FIG. 3, but illustrating the withdrawal of the mandrel after the concrete has hardened and set sufficiently to permit this and showing the now fully completed cast-in-place shell itself.

FIGURE 5 is a view similar to FIG. 2 of the method and apparatus next described for forming the cast-in-place concrete shells, this view likewise showing the outer casing in process of being withdrawn, with the centrally disposed mandrel resting on the boot, and with liquid concrete being supplied through a grouting pipe to the chamber at the base of the casing to completely fill the space between the mandrel and the earth as the casing is being withdrawn.

FIGURES 6–11, inc., show the essentials of the apparatus for indicating and controlling the pressure at which the grouting is placed during withdrawal of the casing, FIG. 6 being a view partially diagrammatic and partially in axial sectional elevation through a pile placing assembly during withdrawal of the casing, to illustrate the manner in which the pressure is indicated and controlled by said apparatus. FIG. 7 is a digrammatic view of the pneumatic control circuits for the apparatus. FIGS. 8–11, inc., are views of a pressure sensitive device used in conjunction with said apparatus and responsive to the grout pressure, FIG. 8 being a view in sectional elevation thereof with parts removed, FIG. 9 a plan view with parts removed, FIG. 10 a sectional elevation, and FIG. 11 a plan view of the complete assembly.

FIGURE 12 is a more or less diagrammatic view partially in elevation and partially in perspective of the apparatus for indicating and controlling the volume of grouting placed in the casting of concrete shells in accordance with the invention.

FIGURE 13 is a view in axial sectional elevation of a pile placing assembly in accordance with FIG. 5, but illustrating the placement therewith of a pile shell having bulbous base; while FIGURE 14 is an axial sectional elevation of the completed cast-in-place concrete shell produced as in FIG. 13.

Referring to FIG. 1, the apparatus therein shown comprises a tubular steel casing **10**, of a length somewhat in excess of that of the pile to be formed, the casing being concentrically supported, by means of centering lugs, as at **11**, on a boot plate **12**, and being surmounted by a driving head **13**. Disposed within the basal portion of the casing **10**, is a short tubular steel member **14**, of a foot or so in length, preferably about one and one-half feet, this member being of substantially smaller diameter than the casing **10** as shown, and being connected thereto at its top by means of a horizontally disposed diaphragm or sealing ring **15**, thereby to form an annular chamber **16** between the inner shell **14** and the outer casing **10**, which is sealed at the top by the diaphragm ring **15**.

The inner shell **14** terminates at its base a few inches above the lower end of the outer casing **10**, at which point the casing is perforated at spaced points about its periphery by a series of slots, as at **17**, to provide outlets from the lower end of the chamber **16**, to the exterior of the casing **10**.

A grout pipe **18** extends from the top of the casing **10** down to the chamber **16** having entry thereinto through the diaphragm ring **15**, as at **19**. At its top the grout line **18** is connected to a flexible hoseline **20**, for supplying fluid concrete to the chamber **16**.

The inner diameter of the shell **14** is such as readily to admit insertion therein of a mandrel **21**, which may be cylindrical or tapered or of the collapsible type, and which extends the length of the casing **10**. In order to provide a seal between the shell **14** and mandrel **21**, to prevent the liquid concrete forced under pressure into the chamber **16**, from flowing upward between the shell **14** and mandrel **21**, there is provided a rubber sleeve **22**, which is sleeved at its upper end over the lower end of the shell **14**, and the lower end of which fits about the mandrel as shown. Disposed within the chamber **16** is a pressure sensitive device **23**, which is connected to an air pressure control line **24** for continuous indication of the pressure at which the liquid concrete is being supplied.

In the operation of the apparatus as shown in FIG. 1, for the production of cast-in-place concrete shells, the assemblage is driven into the ground **25** to the required depth, the mandrel prior to assembly having been precoated with the release coating composition above described. During driving, a suitable cementitious mixture such as liquid concrete is fed under pressure through the pipelines **20**, **18**, and into chamber **16**, at a rate such as to maintain the chamber filled at all times and also to provide sufficient excess to fill, as at **26**, the space between the casing **10** and earth **25**, produced by projection of the driving boot **12** beyond the casing, the flow of concrete to this end being from the chamber **16** through the slots **17** in the casing, as at **27**.

After the casing has been driven to the required depth as in FIG. 2, it is gradually withdrawn leaving the boot **12** in the ground with the mandrel **21** supported thereon as shown. During the casing withdrawal, the liquid concrete continues to be fed into the chamber **16** and thence through its now open-ended base, as at **28**, into the space **29** left momentarily void by the receding casing and chamber assembly **10**, **14**, **15**.

Referring to FIG. 3, the complete withdrawal of the outer casing assembly, as shown, leaves the cast-in-place concrete shell **30**, disposed still in the liquid state, between the mandrel **21** and the earth **25**. After the concrete has hardened and set, the mandrel is withdrawn, as in FIG. 4, whereby the interior **31** of the concrete shell may be inspected for flaws and filled with concrete, if satisfactory.

Referring to FIG. 5, there is shown a modified construction of the chamber assembly at the base of the outer steel casing **35**, consisting of an upper annular member **36** having a tubular, skirted portion **37** of outer cylindrical contour which fits snugly within and is welded to the inner wall of the casing, and from the base of which a flanged portion **38**, projects inwardly to a diameter to provide sufficient clearance for slidable reception of the centrally disposed mandrel **39**, which as in the FIG. 1 embodiment may be collapsible or non-collapsible and of cylindrical or tapered configuration, but preferably the latter and precoated with the release composition as aforesaid. Concentrically disposed beneath the upper skirted member **36** is a lower, annular member **40**, also consisting of a tubular skirted portion **41**, of the same outside diameter as the upper skirted portion **37**, and from the top of which, a flanged portion **42** extends inwardly beneath the upper flanged portion **38** to the same inner diameter for slidable reception of the mandrel **39** as aforesaid. Interposed between the flanged portions **38**, **42**, is an annular gasket **43** of rubber or equivalent, the inner edge of which peripherally grips the mandrel **39**, to prevent upward leakage or flow of liquid cement past the same. The upper and lower flanged portions and interposed gasket **36**, **42**, **43**, are bolted together, as at **44**. The central opening through the flanged portion **38**, **42**, is of suf-

ficiently greater diameter than the mandrel to permit withdrawal along a tapered mandrel of the slight taper above mentioned, while the rubber gasket **43** projects inwardly sufficiently beyond said flanged portion to grip the mandrel in all positions of displacement relative thereto and without binding owing to the flexibility of the gasket.

It will be observed that the skirt **41** of the lower member **40**, extends downwardly to the lower terminus of the outer casing **35**, thus forming between the mandrel and skirt **39**, **41**, an annular chamber **47** closed at the top by the flange and gasket assembly, but open at the base, as shown. A grout pipe **48** extends from a hoseline **49** at the top of the casing **35**, down to the chamber **47**, opening thereinto as at **50**. Although the grout line is shown as disposed exteriorly of the casing, it may also be disposed interiorly thereof as in FIG. 1. A pressure sensitive device **51** is mounted on the exterior surface of the skirted member **41** and is connected over a pipeline **52** to an air pressure control device, as in FIG. 1.

In the operation of the FIG. 5 modification, the casing **35** assembled on the boot plate **12**, is driven into the ground to the required depth. The mandrel **39** after precoating with the release coating composition aforesaid, may also be assembled on the boot plate prior to driving, but preferably is inserted in the position shown in the drawing, subsequent to driving. After the driving is completed and the mandrel inserted, the casing is slowly withdrawn while feeding liquid concrete over the conduits **49**, **48** to the chamber **47**, and thence into the space beneath the chamber between the mandrel **39** and earth space **53**, left void by the receding casing and chamber assembly, to form a cast-in-place shell **54** of liquid concrete. After the casing has been fully withdrawn and the concrete has hardened and set, the mandrel **35** is withdrawn to leave the concrete shell **54** cast in place in the ground.

As was pointed out above with reference to placement of the concrete shells in the manner described with respect to FIGS. 1–5, inc., during withdrawal of the casing, liquid concrete must be supplied through the grout line under sufficient pressure and at a volumetric flow rate such in relation to the rate of withdrawal of the casing, as to assure complete filling with liquid concrete of the void left by the receding casing. Also as above stated, this is accomplished in accordance with the method and apparatus described in the aforesaid Phares et al. application, sufficient of the apparatus of which is included in FIGS. 6–12 hereof for a description thereof as applied to the present invention.

FIG. 6 shows the apparatus for indicating the pressure at which the liquid concrete is injected into the casing chamber as applied by way of illustration to withdrawal of the casing in the FIG. 5 embodiment. The pressure sensitive element **51** is connected over the pipeline **52** which extends to the top of the casing **35**, thence over a flexible conduit **60** to the pressure control unit shown generally at **169**. This unit operates pneumatically on a comparative pressure basis, in the manner illustrated diagrammatically in FIG. 7.

Referring to FIG. 7, the device **169** comprises an element **172** into which is directed, via a pneumatic infeed line **173**, air at a selected constant feed pressure of say 150 p.s.i. The element **172** causes small charges of this high pressure air (Pf) to be directed through an exit port **174** into the conduit **52**, **60** which extends to the pressure sensing element **51**. Operatively connected to the element **172** is a signalling device **176**. The signalling device is preferably of the audible variety and each time the element **172** emits a charge or a pulse of the high pressure input air, the signal means **176** is actuated to make one signal, e.g. to ring a bell once.

In between these pulse of such high pressure air (Pf) there is made a comparison between: (a) a desired pressure norm (Pn) as shown on an indicator **177**, and (b) the grout pressure (Pg) as measured by element **51**, the comparison being made pneumatically via an element **178**. The indicator **177** shows by way of example, a norm pressure of 45 p.s.i. This indicates the norm pressure (Pn) against which a comparison is made with the pressure (Pg) at the sensing device **51**, this comparison being made by the coaction of the elements **172** and **178**.

The element **172** continues to discharge the pulses of high pressure air (e.g. at 150 p.s.i.) at intervals until the pressure in the element **51** reaches the preselected norm pressure, which latter is set or adjusted, as by means of a wheel or pulley **179**. Element **179** is operatively connected to the indicator **177** for changing the setting thereof to accord with the desired norm, and also is operatively connected to the comparator element **178**. When the pressure in the element **51** reaches the desired norm the signal means **176** ceases to operate.

The periodicity of the audible signals from **176** is a function of the degree of departure of the pressure (Pg) at the element **51**, from the desired norm (Pn), and as the desired norm is approached the periodicity of the signal decreases until eventually it ceases, indicating that the grout pressure at element **51** is not below the norm.

The pressure sensing element **51** in effect is a differential pressure diaphragm device the details of which are shown in FIGS. 8–11. It comprises a diaphragm proper **180**, the periphery of which is secured tightly to a diaphragm cup **180*a*** having a primary chamber **180*b*** therein which is in communication with the lower extremity of the conduit **52** via a port **180*c*** and a passage **180*d***. The primary chamber **180*b*** of the device **51** is separated from a secondary chamber **181** which is coaxial therewith and positioned interiorly of the chamber **180*b*** as shown. These primary and secondary chambers are normally separated from one another by means of a valve plate **182** which coacts wth a valve seat **183** of annular shape comprising the line of demarcation between the primary and secondary chambers **180*b*** and **181**. The valve plate **182** is secured to the diaphragm **180** and can shift into and out of engagement with the valve seat **183** in response to pressure differentials existing between the primary chamber **180*b*** and the grout pressure acting upon the righthand face of the diaphragm **180** as viewed in FIG. 10.

The primary chamber **180*b*** embraces not only a relatively deep portion **180*g***, but also concentric and relatively more shallow portions **180*e*** and **180*f*** which comprise annular grooves formed concentric with the two coaxial and concentric primary and secondary chambers **180*b*** and **181**. The concentric grooved portions **180*e*** and **180*f*** are in communication with one another via radially extending slots **180*g*** and **180*h***. Thus the air pressure in the element **172** (Pg) is the pressure in the primary chamber **180*b***.

Since the exterior face of the diaphragm **180** is exposed to the pressure of the liquid concrete **54**, FIG. 6, this pressure is exerted against the righthand face of the diaphragm **180**, and if such grout pressure exceeds that of the air pressure within the primary chamber **180*b*** the valve plate **182** will be pressed against the valve seat **183**. However, if during withdrawal of the casing **35**, FIG. 5, and during the injection of the grout into the cavity beneath the same over the grout line **49**, **48**, the casing is withdrawn at too fast a rate in relation to the rate of grout injection, the grout pressure will drop, and if it falls below the value set on the pressure indicator **177**, FIG. 6, for a given elevation of the casing chamber **47**, the air pressure within the primary chamber **180*b*** will exceed that on the righthand face of the diaphragm **180** and the valve **182**, **183** will open. This permits the theretofore trapped air in chamber **180*b*** to exhaust into the secondary chamber **181** and thence via an escape port **184** and a passage **185** (FIG. 9) to a check valve **186**, which causes the pressure within the chamber **180*b*** to drop to a value approaching atmospheric pressure.

At this stage the pressure comparator device **169** will

immediately start functioning and the signal device **176** will be activated to emit audible signals at a rapid periodicity dependent upon the degree of drop of the pressure below the norm, and immediately the operator, by controlling the rate at which the casing is being hoisted, will slow down its rate of withdrawal. In the meantime the device **169** will proceed to rebuild the pressure in the device **51**. The pulses of the infeed air (Pf) will continue intermittently to build up the air pressure within the device **51**, until it equals the external grout pressure, that is, the pressure sensed by the right-hand face of the diaphragm **180**, thereby to indicate when the grout pressure is restored to the selected norm (resulting from the slowing down of the drill withdrawal rate) as which time the audible signal **176** will cease.

Ordinarily the pressure at which the grouting must be injected in order to produce a solid and homogeneous cast-in-place concrete shell, progressively decreases with increasing elevation of the casing. At a casing penetration of about 40', a grouting pressure of 40 p.s.i. or more is usually required, which decreases at the rate of about 1 p.s.i. per foot of elevation of the casing base. Accordingly, the pressure setting for the control device **169**, as shown on the indicator **177** thereof, must be adjusted during the casing withdrawal to establish the proper grouting pressure at each level of the casing base. This may be accomplished manually, for example by manual adjustment of the element **179** at the rate of say 5 p.s.i. for each 5 foot increment of casing withdrawal. Alternatively, the adjusting element **179** may be operatively associated with means for adjusting the same precisely to accord with the level of withdrawal of the lower end of the casing. For example, as indicated in FIG. 6, the adjusting element **179** may comprise a pulley about which passes a belt **186** which also passes about a pulley **187** driven through a gearing **188** and a coupling **189** by a linkage **190**, extending, for example, to the jack shaft of the casing hoist.

FIG. 12 shows the essential components of an apparatus for feeding liquid concrete under pressure via the casing groutline and also for integrating and comparing the total volume of grouting pumped into the cavity left by a withdrawn casing. It comprises a positive displacement grout pump **210**, a hoist **211** for the casing, and an add-and-substract counter **212**, to which the drives for the pump and casing hoist are operatively and differentially linked as indicated at **213** and **214**, as discussed below.

The grout pump **210**, driven by motor **215**, and fed with liquid concrete from hopper **216**, discharges into a conduit **217**, which is connected, for example, to conduit **49**, FIG. 6, feeding into the groutline **48** and thence into chamber **47**. The casing **35**, FIG. 6, is withdrawn by means of the cable **218**, FIG. 12, of the power driven casing hoist drum **211**, the cable passing over a pulley **218***a* and thence to the top of the casing.

The volume of the liquid concrete injected into the chamber **47**, FIG. 6, in a given period of time can be expressed as a linear function of the number of revolutions which the pump **210** has made during that same period. The mechanical hoisting device **211** which raises the casing **35** makes it possible to express the movement of the casing in terms of revolutions on one of the several shafts comprising the drive for the drill hoist, for example, the jack shaft **219**, FIG. 12. Consequently, by means of the above described add-subtract counter **212**, it is possible to correlate the movement of the casing **35** with the volume of the grout pumped.

The apparatus for accomplishing this embraces the operative interconnection **213** between the pump **210** and one input **220** to the add-subtract counter **212**; and also the operative interconnection **214** between the hoist jack shaft **219** and the opposite input **221** to the add-subtract counter. The interconnection **213** between the pump **210** and said input **220** comprises a rotatable cam **222** which is capable of actuating once in each revolution, a microswitch **223**. The cam **222** is driven indirectly from the shaft of motor **215** through the sprocket and chain linkage **224** and an adjustable speed reduction unit **225** on the output shaft of which latter the cam **222** is mounted as shown. Thus, for each selected number of revolutions of the pump **210** there may be caused one revolution of the cam **222** effected by the interposed reduction unit **225**. Hence for each revolution of the cam **222** one unit is added to the add-subtract counter via the input **220**.

The other operative interconnection **214** to the add-subtract counter **212** includes another rotatable cam **226** which is mounted on the jack shaft **219**, and for each revolution actuates a microswitch **227** thereby to subtract one unit from the add-subtract counter via the input **221**.

In operation of the appartus employing the add-subtract counter **212**, the operator normally desires to adjust the various control elements to maintain a constant value such as zero on the counter. However, if the counter **212** during the withdrawal of the casing should exhibit the numeral 996 in a three-window counter, this is equivalent to minus 4 units and would indicate that 4 increments of cavity volume had been created during casing withdrawal which had not been matched by 4 increments of the cementitious mixture. Accordingly, the operator on observing this will either stop or slow down the rate of withdrawal of the casing in order to permit the volume of grout pumped into the cavity to catch up with the volume of the cavity available. On the other hand, if the operator should observe that the counter displays the numeral 4, this would indicate that 4 increments of cementitious mixture have been injected into the cavity, which are in excess of the number of increments of available cavity volume and hence it would indicate that there may be an excess of pressure of grout in the cavity or a porous lens in the earth and accordingly the operator normally will increase the rate of upward movement of the casing, for example by speeding up its rate of withdrawal, in order to bring the counter back to the value zero and thereby bring into balance the increments of grout with the increments of cavity volume.

The maintenance of the counter at the constant value, such as zero, can be accomplished by control of the casing rise speed of the hoist **211** and/or the speed of the pump **210**. Preferably, the grout pump is driven at a constant speed, for example, at 600 r.p.m. and the counter is maintained at zero or a constant value by manipulation of the rate of casing withdrawal.

The pressure and volume control apparatus above described with reference to FIGS. 6–12, inc., provide ideal instrumentalities for placing cast-in-place concrete shells having a bulbous base in accordance with the modification of the invention as above referred to and as illustrated in FIG. 13. In FIG. 13, the casing and mandrel assembly are the same as in FIG. 5, like elements being similarly designated by the drawing numerals. The casing **35** assembled on the boot plate **12** is driven into the ground and the mandrel **39** inserted in the same manner as in FIG. 5.

The casing is then slowly withdrawn while injecting liquid concrete through the grout line **48**. In this modification, however, after the casing has been withdrawn a distance of say 2 to 3 feet, the lifting of the casing is stopped, but the pumping of the grout is continued. The pressure of the grout below the lower end of the casing will thus increase to the stage at which it will displace the earth around the periphery of the grout theretofore pumped into the ground and thereby produce a bulbous enlargement below the casing of the concrete placement as shown at **65**, the extent of which depends on the grouting pressure applied, the amount of grouting placed and the character of the surrounding earth.

After a known and predetermined quantity of grout material has been pumped into the bulb area **65**, as de-

termined by the volumetric measuring apparatus of FIG. 12, the amount being usually on the order of 8 to 12 cubic feet, the withdrawal of the casing **35** is re-commenced with continued grout pumping, and the balance of cast-in-place shell completed in the manner above described with reference to FIG. 5. FIG. 14 shows at **66** the thus completed shell embedded in the surrounding earth **67**, after complete withdrawal of the casing followed by withdrawal of the mandrel. After inspection the shell, if found satisfactory, is filled with concrete.

As above stated, the purpose of the bulb **65** is to increase the carrying capacity of the resulting pile. This is important in certain ground conditions and in certain building loadings, because the lengths of the carrying piles may thereby be considerably decreased.

What is claimed is:

1. The method of forming a cast-in-place shell in the earth by means of a tubular casing having an internally disposed sealing ring member adjacent its base and a mandrel dimensioned to slide through said sealing ring in close fitting fluid sealing relationship therewith, said method comprising: driving the casing into the earth and thence withdrawing the same, but with the mandrel inserted prior to said withdrawal, and during said casing withdrawal, injecting liquid casting material under pressure into the space below the ring member, voided by the receding casing and ring member, and upon complete withdrawal of the casing and hardening of the casting material, withdrawing the mandrel.

2. The method of forming a concrete shell in the earth by means of a tubular casing having an internally disposed annular sealing means adjacent its base for slidable reception of said mandrel in sealed relation, said method comprising: concentrically assembling said casing and mandrel on a boot plate of larger diameter than the casing and driving into the ground to a selected depth while continuously injecting liquid concrete under pressure below the annular sealing means and into the space between the earth and the outer casing wall formed by the advancing boot plate of larger diameter, and upon penetration of said boot plate to said selected depth, withdrawing the casing while continuing to inject liquid concrete below said annular sealing means and into the space voided by the receding casing and sealing means, thereby to form a shell of liquid concrete between the earth and mandrel extending to the earth's surface when the casing is fully withdrawn, and after said concrete has hardened and set, withdrawing the mandrel.

3. The method of forming a concrete shell in the earth by means of a tubular casing having an internally disposed annular sealing means adjacent its base for slidable and sealed reception of said mandrel, said method comprising: coating said mandrel with a release coating material for minimizing adherence between the mandrel and the concrete, concentrically assembling said casing and mandrel on a boot plate of larger diameter than the casing and driving into the ground to a selected depth while continuously injecting liquid concrete below the annular sealing means and into the space between the earth and the outer casing wall formed by the advancing boot plate of larger diameter, and upon penetration of said boot plate to said selected depth, withdrawing the casing while continuing to inject liquid concrete below said sealing member and into the space voided by the receding casing, thereby to form a shell of liquid concrete between the earth and the mandrel extending to the earth's surface when the casing is fully withdrawn, and after said concrete has thereafter hardened and set sufficiently to permit withdrawal of the mandrel, thereupon withdrawing the mandrel.

4. Apparatus for forming cast-in-place concrete shells, comprising: a tubular metal casing of length sufficient for forming said shell, a pair of annular members, each having a tubular sleeve portion and an inwardly flanged ring portion, forming central openings of a common diameter, one said member being mounted within one end of said casing with its sleeve portion engaging the inner wall thereof throughout its periphery, the other said member being secured by its flanged portion to the flanged portion of the first said member with the sleeve portion thereof projecting to the end of said casing, a rubber-like gasket interposed between the flanged portions of said members, and a pipeline extending from the top of said casing to the lower annular member and having an opening through the skirt thereof.

5. The method of forming in the earth, a tubular concrete shell having an enlarged base as compared to the remaining upper portion of said shell, and by means of a tubular metal casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, and a boot plate for the casing, said method comprising: driving said casing assembled on said boot plate into the earth, inserting said mandrel through the ring member until it rests upon the boot plate, thereupon withdrawing the casing to a preselected height above said boot plate and during said withdrawal injecting liquid concrete under pressure into the space below the ring member which is voided by the receding casing and ring member, thereupon holding said casing at said preselected height while continuing to inject said liquid concrete in said manner until a preselected additional volume thereof has been injected below said ring member, sufficient to form said enlarged base, thereupon resuming the withdrawal of said casing while continuing to inject liquid concrete in the manner aforesaid until said casing has been fully withdrawn, allowing the concrete to harden and set and withdrawing the mandrel.

6. The method of forming in the earth, a tubular concrete shell having an enlarged base as compared to the remaining upper portion of said shell, and by means of a tubular metal casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, and a boot plate for the casing, said method comprising: driving said casing assembled on said boot plate into the earth, precoating said mandrel with a release coating material for minimizing adherence to the concrete, and inserting said mandrel through the ring member until it rests upon the boot plate, thereupon withdrawing the casing to a preselected height above said boot plate and during said withdrawal injecting liquid concrete under pressure into the space below the ring member which is voided by the receding casing and ring member, thereupon holding said casing at said preselected height while continuing to inject said liquid concrete in said manner until a preselected additional volume thereof has been injected below said ring member, sufficient to form said enlarged base, thereupon resuming the withdrawal of said casing while continuing to inject liquid concrete in the manner aforesaid until said casing has been fully withdrawn, allowing the concrete to harden and set and withdrawing the mandrel.

7. The method of forming in the earth, a tubular concrete shell having a base of enlarged transverse sectional area as compared to that of the remaining upper portion of said shell, and by means of a tubular metal casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, together with a boot plate for said casing, said method comprising: driving said casing and mandrel assembled on said boot plate into the earth, thereupon withdrawing the casing to a preselected height above said boot plate while injecting liquid concrete under pressure into the space below the ring member which is voided by the receding casing and ring member, thereupon holding said casing at said preselected height while continuing to inject liquid concrete below the ring member until a preselected additional volume thereof has been injected thereby to form said enlarged base, thereupon resuming withdrawal of the casing while continuing to inject liquid concrete into the space below the ring member voided

by the receding casing and ring member until said casing has been completely withdrawn, allowing the concrete to harden and set, and thereupon withdrawing the mandrel.

8. The method of forming in the earth, a tubular concrete shell having a base of enlarged transverse sectional area as compared to that of the remaining upper portion of said shell, and by means of a tubular metal casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, together with a boot plate for said casing, said method comprising: precoating said mandrel with a release coating material for minimizing adherence to the concrete, driving said casing and mandrel assembled on said boot plate into the earth, thereupon withdrawing the casing to a preselected height above said boot plate while injecting liquid concrete under pressure into the space below the ring member which is voided by the receding casing and ring member, thereupon holding said casing at said preselected height while continuing to inject liquid concrete below the ring member until a preselected additional volume thereof has been injected thereby to form said enlarged base, thereupon resuming withdrawal of the casing while continuing to inject liquid concrete into the space below the ring member voided by the receding casing and ring member until said casing has been completely withdrawn, allowing the concrete to harden and set, and thereupon withdrawing the mandrel.

9. The method of forming a concrete shell in the earth by means of a tubular casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, and a boot plate for the casing, said method comprising: driving the casing assembled on said boot plate into the earth and thence withdrawing the same, but with the mandrel inserted prior to said withdrawal, during said casing withdrawal continuously measuring the volume of space below said ring member voided by the receding casing and ring member, and continuously injecting liquid concrete into the space thus voided while measuring the volumetric amount thereof injected, adjusting the volume of liquid concrete thus injected to at least equal the said volume vacated by the said receding casing, and upon complete withdrawal of said casing and hardening of said concrete, withdrawing the mandrel.

10. The method of forming a concrete shell in the earth by means of a tubular casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, and a boot plate for the casing, said method comprising: driving the casing mounted on said boot plate into the earth and thence withdrawing the same, but with the mandrel inserted prior to said withdrawal, and during said casing withdrawal

continuously measuring the volume of space below said ring member voided by the receding casing and ring member, and continuously injecting liquid concrete into the space thus voided while measuring the volumetric amount thereof injected, and adjusting the volume of liquid concrete thus injected to exceed by a preselected amount the said volume vacated by said receding casing, and upon complete withdrawal of said casing and hardening of said concrete, withdrawing the mandrel.

11. The method of forming a concrete shell in the earth by means of a tubular casing having an internally disposed sealing ring member adjacent its base for slidable reception of a mandrel, and a boot plate for said casing, said method comprising: driving the casing mounted on said boot plate into the earth and thence withdrawing the same, but with the mandrel inserted prior to said withdrawal, and during said casing withdrawal, continuously injecting liquid concrete under pressure into the space below the ring member voided by the receding casing and ring member, while continuously measuring said pressure, progressively reducing said pressure during said casing withdrawal at a rate substantially proportional to the extent of said withdrawal, and upon complete withdrawal of the casing and hardening of the concrete, withdrawing the mandrel.

12. Apparatus for forming cast-in-place tubular pile shells, comprising: a tubular metal casing of a length for forming said shells, an annular sealing ring sealably fixed within said metal casing near its bottom end, said sealing ring having a central opening therein, a mandrel dimensioned to slide through said central opening in close fitting fluid sealing relationship with said sealing ring, and a fluid casing material transportable pipe line extending from the top end of said casing to said annular sealing ring and opening at a point below said sealing ring.

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