June 22, 1965 F. RUSCHE 3,190,078

PILE DRIVING MANDREL ASSEMBLY

Filed June 11, 1962 5 Sheets-Sheet 1

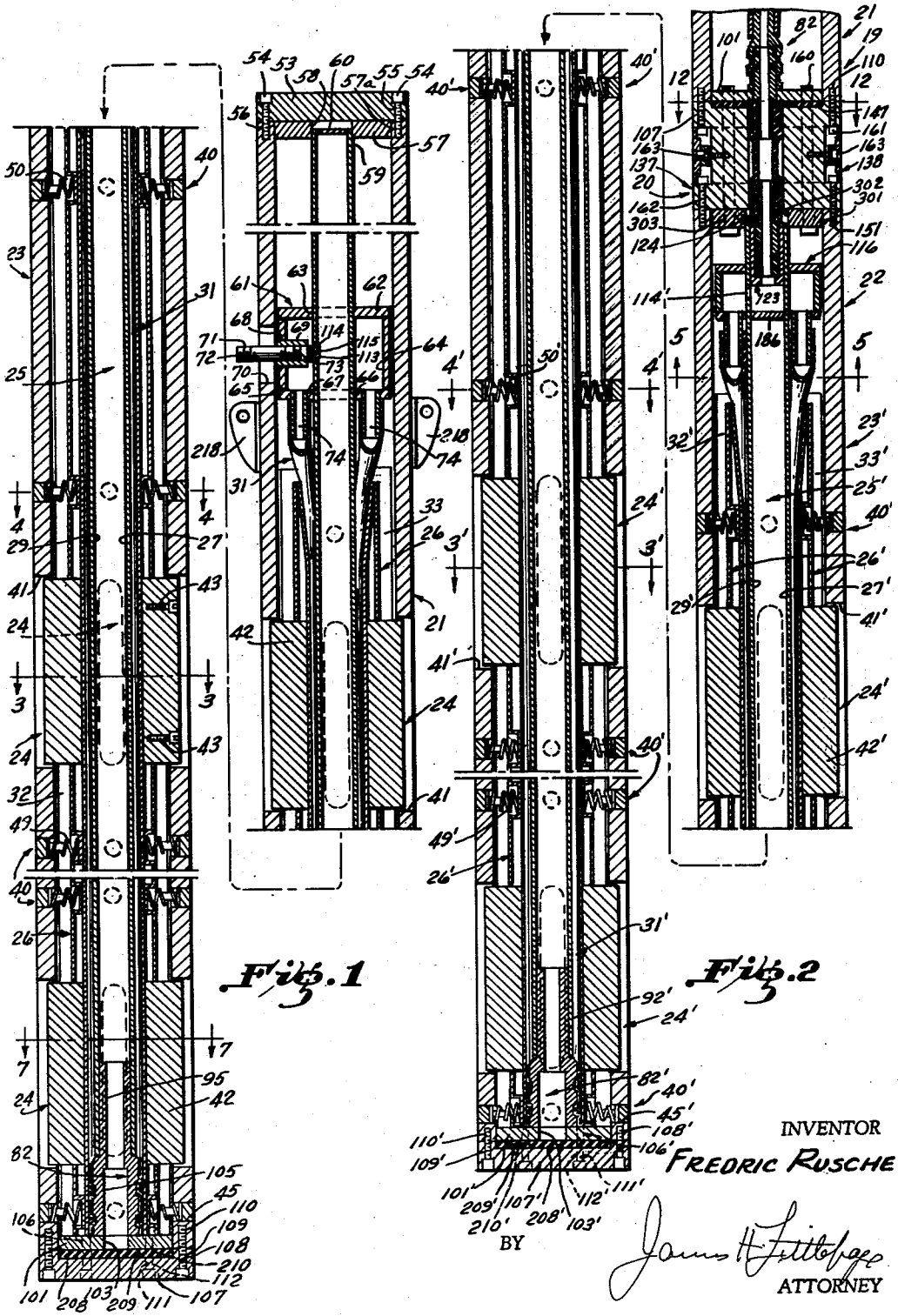


Fig. 1

Fig. 2

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PILE DRIVING MANDREL ASSEMBLY

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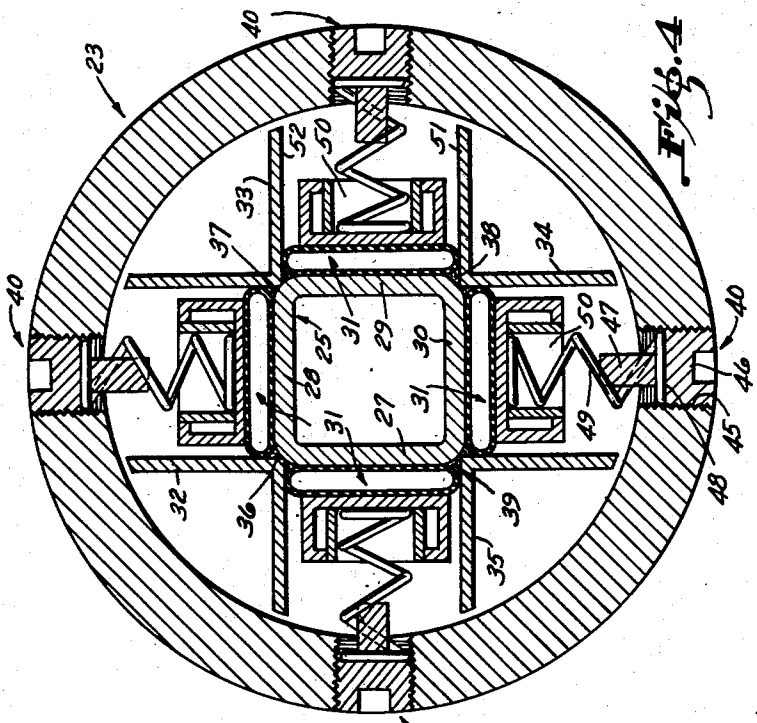


Fig. 4

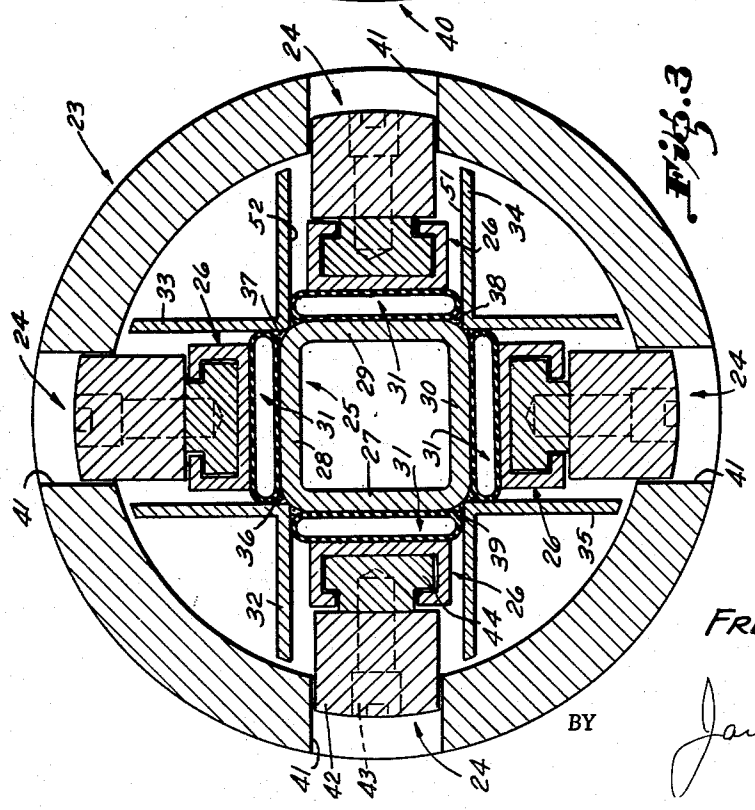


Fig. 3

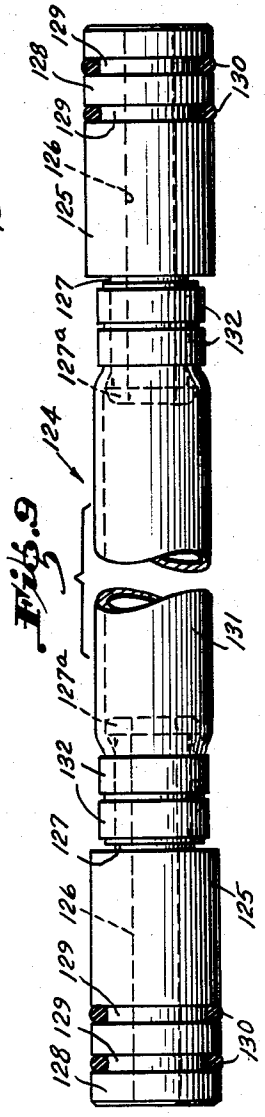


Fig. 9

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PILE DRIVING MANDREL ASSEMBLY

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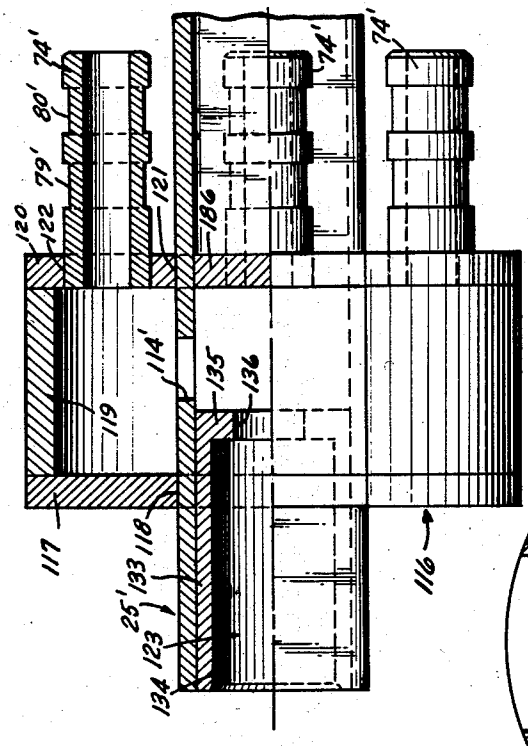


Fig. 6

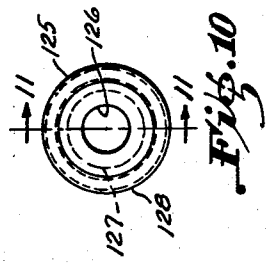


Fig. 10

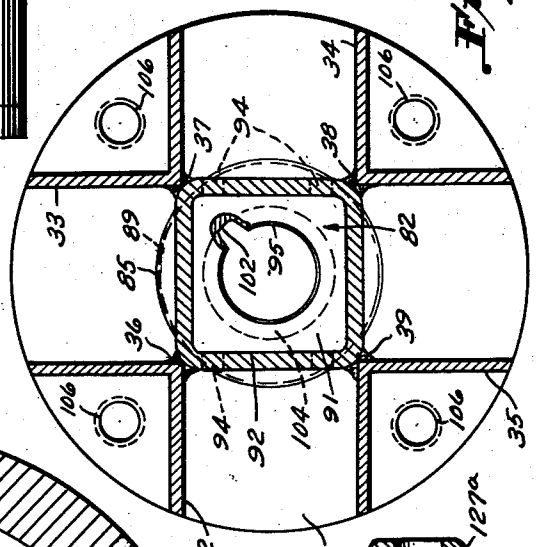


Fig. 7

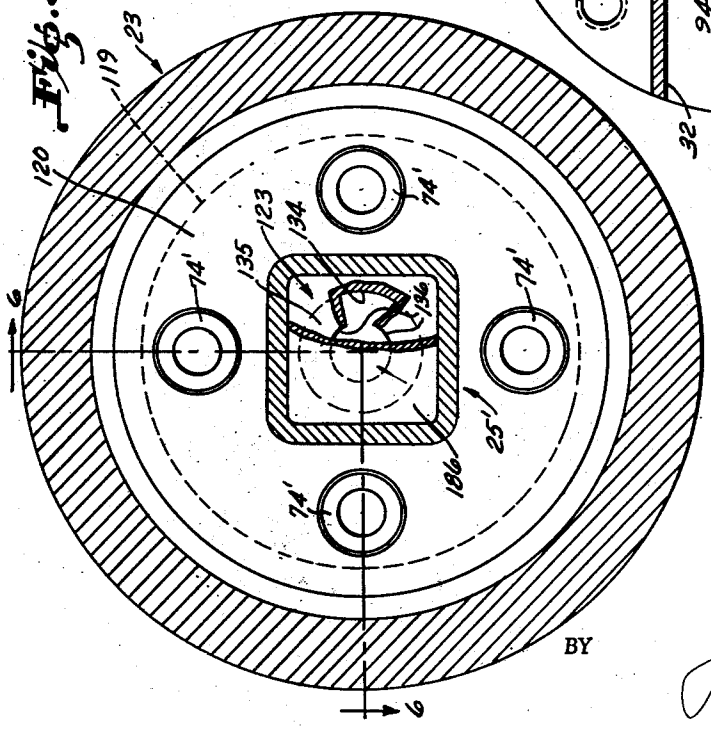


Fig. 5

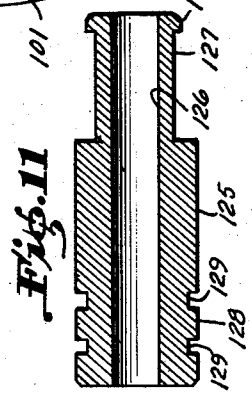


Fig. 11

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PILE DRIVING MANDREL ASSEMBLY

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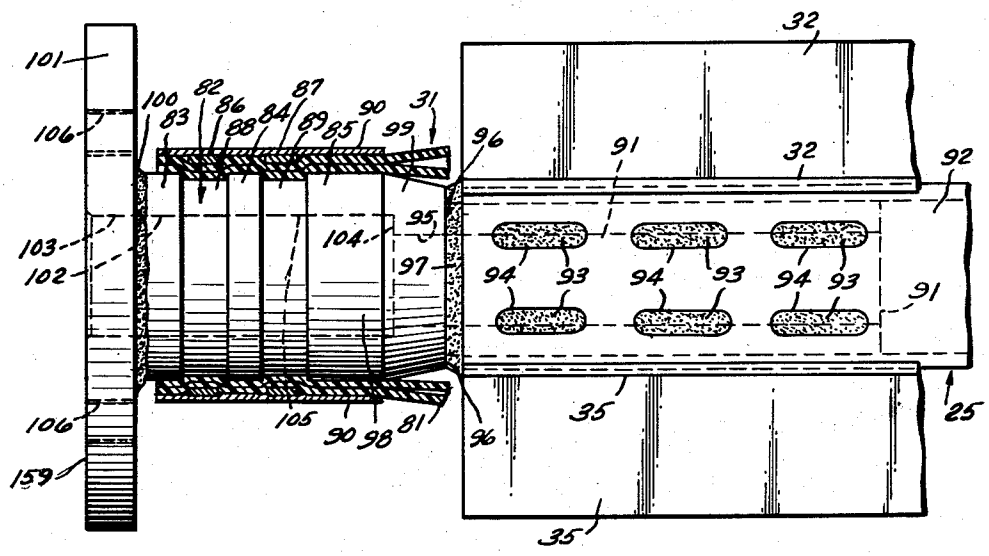


Fig. 8

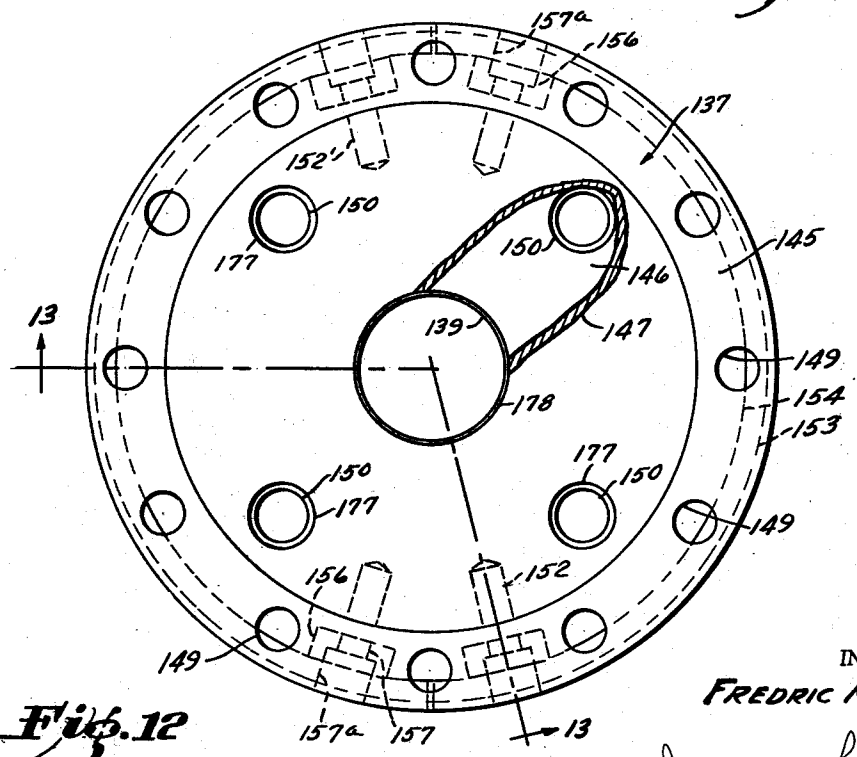


Fig. 12

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PILE DRIVING MANDREL ASSEMBLY

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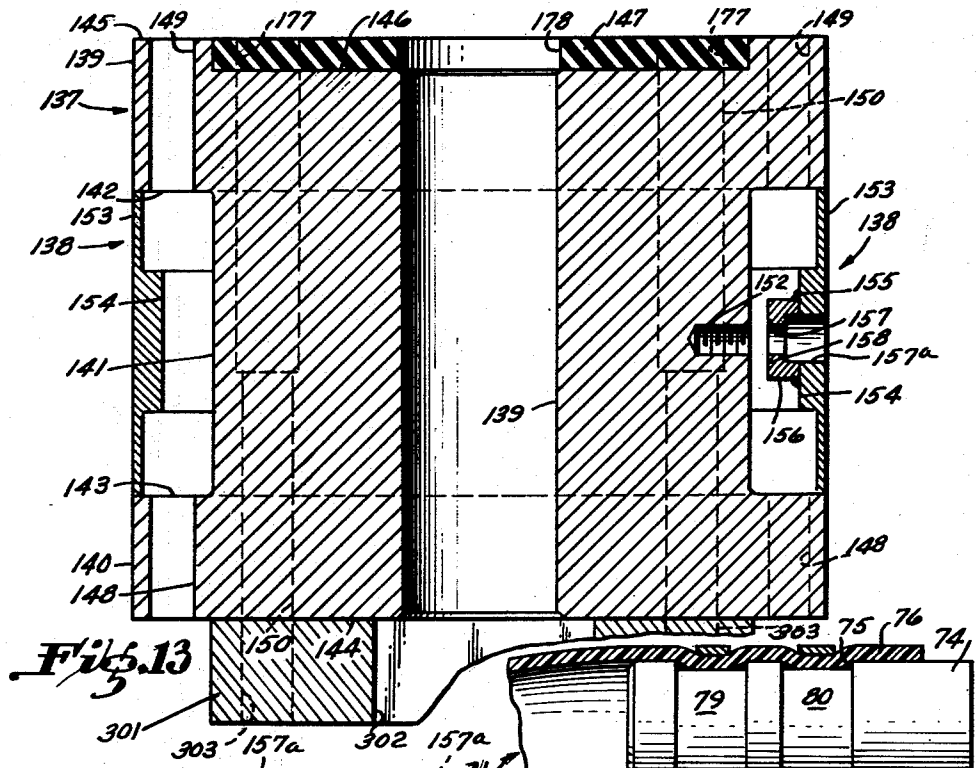


Fig. 13

Fig. 15

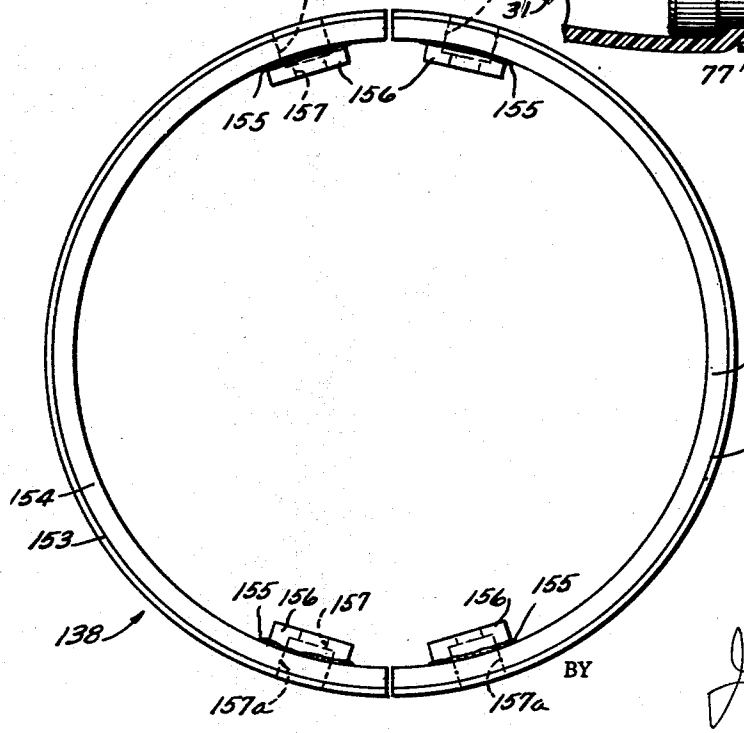


Fig. 14

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United States Patent Office 3,190,078 Patented June 22, 1965

3,190,078

PILE DRIVING MANDREL ASSEMBLY

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Filed June 11, 1962, Ser. No. 201,672
9 Claims. (Cl. 61—53.72)

This invention relates to a mandrel assembly for driving tubular pile shells a considerable distance into the earth. More particularly, the invention relates to an elongated mandrel structure composed of a plurality of individual, similar, relatively short mandrel sections or units rigidly joined together by novel coupling means to produce a relatively long assembly for driving pile shells a relatively great distance into the ground.

The individual mandrel sections which are joined together to form the elongated mandrel assembly mentioned hereinabove are of the hydraulically or pneumatically actuated expandable plug type and are similar in many respects to the various mandrel embodiments shown and described in my U.S. Patent No. 3,006,152.

These expandable plug mandrel sections are designed to be inserted into the interior of a tubular pile shell (most usually a hollow corrugated-wall type shell) to provide interior support for the shell during driving thereof. Each mandrel includes a plurality of axially spaced, angularly distributed, radially expandable individual shell engaging and gripping plugs which are expanded by means of inflatable envelope or bladder means so as to grip the innermost surfaces of the corrugations of a shell in such manner as to hold the shell rigid with the inserted mandrel during driving of the shell. Preparatory to driving, the mandrel is inserted into the shell to be driven in a collapsed or contracted condition, i.e., the individual plugs are radially contracted, and then, after insertion, the plugs are expanded radially to grip the shell at spaced points along the interior thereof so that the shell may be driven into the ground by blows imparted to the top of the mandrel. After the shell has been driven to the depth desired, the plugs of the inserted mandrel are again contracted and the mandrel is withdrawn from the now-driven shell and reused in like fashion for driving additional pile shells.

Where it is necessary to drive piling to a depth greater than the length of any of the individual hollow piling shells available, it is necessary to follow one of the following two procedures. In the first procedure, a first shell is driven in the manner described hereinabove until the top of such shell is left protruding a short distance above ground level. Then the driving mandrel is contracted and withdrawn from the first shell and a second shell, with the same or another similar mandrel inserted fixedly therein, is aligned above and coaxial with the first shell. Next the bottom of the second shell is welded or otherwise rigidly fastened to the top of the first partially driven shell. After the first and second shells are thus connected, blows are imparted to the top of the mandrel in the second shell and the joined first and second shells are given into the ground to the depth desired. Of course, if an even deeper piling is required than can be achieved by utilizing the combined lengths of the first and second shells, then an additional shell (or shells) may be connected to the top of the last-driven shell and the entire (three or more) shell fabrication may then be driven to produce the piling depth required.

The major disadvantage inherent in this procedure is the fact that only the top shell of such a multiple shell pile assembly contains a rigidifying mandrel during driving. Due to this fact, the lower shells are subject to bending and/or collapse since they have no positive internal mandrel support during driving.

In the second procedure for driving tubular pilings

deeper than the length of any individual shells available, a first and a second shell are joined together prior to the driving of either shell (or after a first shell has been driven most of its length into the ground and its driving mandrel removed). Then a mandrel assembly, of the type which constitutes the subject matter of this invention, substantially coextensive in length with the overall length of the joined first and second shells, is inserted within and expanded so as to rigidly support both the first and second shells. With the mandrel assembly thus located in the coupled pile shells, the shells are driven to the depth desired and the mandrel assembly is then contracted and removed. The final depth of piling required will dictate how many pile shells must be joined together and will also dictate the length of the mandrel assembly required to support the joined shells all along their combined length during the driving operation.

It will be noted that this second driving procedure overcomes the major disadvantage set forth hereinabove relative to the first driving procedure since, in the second procedure, the shell assembly is rigidly supported throughout its entire length by the mandrel assembly during the driving operation. Due to this rigid support, all portions of the shell assembly are positively restrained from bending or collapsing during driving. Thus, one object of the invention is to provide a pile driving mandrel assembly capable of adequately supporting a plurality of joined pile shells for driving.

Another object of the invention is to provide a mandrel assembly with a hollow exterior core, the vertically extending exterior profile of which, no matter where viewed, is substantially a straight line.

A yet further object of the invention is to provide an elongated rigid mandrel assembly composed of a plurality of individual mandrel units rigidly, but removably, coupled together end to end whereby the entire assembly may be utilized together, or at least one of the individual mandrel units comprising the mandrel assembly may be removed or uncoupled and used separately.

Another object is to provide a rigid mandrel assembly composed of a plurality of coupled together individual mandrel sections or units of the expandable plug type.

Another object of the invention is to provide, in an elongated expandable plug type mandrel assembly, fluid distribution means for channeling pressurized fluid to the expandable bladder, or envelope means by which the plugs are expanded.

A still further object is to provide reliable coupling means for joining relatively short individual mandrel units end to end to form a rigid, relatively long mandrel assembly. These coupling means are designed so as to allow pressurized working fluid to pass between adjacent mandrel sections or units.

Yet another object is to provide means for shrouding the coupling means whereby a relatively smooth exterior surface is provided along the entire exterior surface of the mandrel assembly to reduce the possibility of the mandrel assembly's jamming or binding within the pile shell assembly to the point where easy removal becomes impeded.

The preceding as well as other objects of the invention will become apparent from the remainder of the specification and from the drawings.

In the drawing which form a part of this application:

FIGURE 1 is a broken view in axial section through one of the individual mandrel units which comprises a portion of my novel mandrel assembly. In this view, the subject mandrel unit is coupled to a solid bottom plate adapting it for use separate from the remainder of the assembly to be described;

FIGURE 2 is a broken view in axial section showing

another individual mandrel unit rigidly joined to the lower end of the mandrel unit of FIGURE 1, by means of a coupling assembly. Some portions are omitted for clarity;

FIGURE 3 is a partial cross-sectional view to enlarged scale, with certain parts omitted, taken on the line 3—3 of FIGURE 1 or 3'—3' of FIGURE 2. (Since the cross-sections taken on either of the lines indicated are identical, a single figure is deemed sufficient to show the details of construction of the respective mandrel units.);

FIGURE 4 is a partial cross-sectional view in enlarged scale, with certain parts omitted, taken on the line 4—4 of FIGURE 1 or 4'—4' of FIGURE 2. (Again, since the cross-sections taken on the lines indicated are identical, a single figure is deemed sufficient to clearly show the details of construction of the respective mandrel units.);

FIGURE 5 is a partial cross-sectional view to enlarged scale, with certain portions broken way, taken on the line 5—5 of FIGURE 2;

FIGURE 6 is a partial offset sectional view taken on the line 6—6 of FIGURE 5;

FIGURE 7 is a partial cross-sectional view, to enlarged scale and with certain parts omitted or broken away, taken on the line 7—7 of FIGURE 1;

FIGURE 8 is an elevational view of the construction of FIGURE 7 showing, however, several additional elements in section;

FIGURE 9 is a detailed elevational showing, partly in section and to enlarged scale, of a conduit assembly utilized to distribute working fluid between individual mandrel units of my mandrel assembly;

FIGURE 10 is an end elevational view of one of two identical bushings employed in the conduit assembly of FIGURE 9;

FIGURE 11 is an axial section taken on the line 11—11 of FIGURE 10;

FIGURE 12 is a cross-sectional view, to enlarged scale and with certain parts broken away, of a coupling assembly utilized in rigidly joining adjacent mandrel units together taken on the line 12—12 of FIGURE 2;

FIGURE 13 is an offset sectional view taken on the line 13—13 of FIG. 12, partially broken away;

FIGURE 14 is a detailed plan view to enlarged scale of two identical shroud assemblies which form a part of the coupling assembly of FIGURES 12 and 13; and

FIGURE 15 is an enlarged elevational view partly in section showing certain details of a nipple-to-bladder joint used to feed pressurized fluid to the bladder means.

Referring now to the drawings by reference numerals, 19 designates generally the mandrel assembly of the invention. Assembly 19 includes a coupling assembly designated generally as 20, an upper individual mandrel unit or section designated generally as 21, see FIGURES 1 and 2, and a lower individual mandrel unit or section designated generally as 22, see FIGURE 2. Since units 21 and 22 are identical in many structural details, description of certain portions of unit 21 will serve to fully describe like portions of unit 22. Where particular elements of units 21 and 22 are identical, unprimed numbers will be used when referring to the elements of unit 21, and the same numbers primed will be used when referring to unit 22.

Some of the components of mandrel unit 21 (and unit 22) are a tubular external driving core, designated generally as 23; a plurality of sets of radially movable shell-gripping plug assemblies, designated generally as 24, arranged in circumferentially and axially spaced relation to one another around and along core 23 in a manner to be described; an internal tubular column of rectangular cross-section designated generally as 25; a plurality of identical channel-shaped plug rails designated generally as 26, one plug rail 26 being spaced radially outwardly from each of the respective sides 27, 28, 29 and 30 of

column 25; a plurality of axially elongated inflatable bladders or envelopes designated generally as 31, one of the bladders 31 being positioned between each plug rail 26 and the particular side of column 25 most closely adjacent thereto so that inflation of each bladder forces its related plug rail 26 outwardly; a plurality of vertically extending, L-section centralizers 32, 33, 34 and 35 which are aligned with and attached, as by weldments 36, 37, 38 and 39, respectively, to the four exterior corners of column 25; and a plurality of spring assemblies, designated generally as 40, whose purpose is to force the plug rails 26 inwardly when bladders 31 are deflated.

Driving cores 23 and 23', as best seen in FIGURES 1 to 4, are thick-walled tubular members of substantially uniform circular cross section. At selected locations along cores 23 and 23' are formed a plurality of vertically spaced groups of axially elongated spaced apertures 41 in each of which a plug 42 of one of the plug assemblies 24 is located. As will be noted apertures 41 are slightly larger than plugs 42 so that plugs 42 can move freely radially inwardly and outwardly relative to apertures 41 when bladders 31 are expanded and contracted. To insure that the plugs 42 will move simultaneously with plug rails 26, each plug 42, as best seen in FIGURE 3, is fastened to the outer face of a plug-guide 44 of block-like, generally T-shaped cross-section by means of socket-headed cap screws 43 which pass through apertures provided therefor in plugs 42, and screw into internally threaded apertures provided in the plug-guides 44. Plug-guides 44 fit fairly loosely, or float within plug rails 26 so that plugs 42 may accommodate themselves as required to the inside surface of a pile shell when they are expanded outwardly against same.

Spaced from apertures 41, but axially aligned therewith in cores 23 and 23' are vertically spaced groups of internally threaded apertures 45 (see FIGURE 4) in each of which is located a matingly threaded abutment screw-plug 46. Each plug 46 forms one part of each spring assembly 40, the remaining components of which will now be described.

As best seen in FIGURE 4, each screw plug 46 is screwed into each aperture 45 to such an extent that its outer end lies radially within the outer wall of the core. The inward end of each screw plug 46 is reduced to form a spring guide portion 47, and a spring abutment face 48, and surrounding each guide portion 47 and compressed between each face 48 and an adjacent plug rail 26 is a spring 49. So that the inner end of each spring 49 will be somewhat confined in its movement relative to the plug rail 26 against which it bears, there are provided, one for each spring, a plurality of hollow sockets 50 which are welded, or otherwise fastened to the plug rails 26. It will be seen that the inner end of each spring 49 is located in a socket 50.

The purpose of spring assemblies 40, as will be apparent is to force plug rails 26, and thereby plug assemblies 24, inwardly when bladders 31 are deflated. It should be noted at this point that each plug rail 26 is constrained in its movement by the fact that each plug rail 26 lies between two spaced opposing parallel faces provided by the legs of two adjacent centralizers. Such faces, for example, are numbered 51 and 52 in FIGURES 3 and 4.

Returning now to FIGURE 1, as has been heretofore stated, mandrel unit 21 is capable of being used separately exactly as it is shown for driving pile shells. To this end, unit 21 includes a top end plate 53 which is rigidly fastened to the top edge of core 23 by means of a plurality of socket-headed cap screws 54, the top portions of which are located in counter-bored smooth-walled apertures 55 formed in top plate 53, and the bottom threaded portions of which extend below top plate 53 and matingly engage with internally threaded vertically oriented holes 56 in the top of core 23. The top face of end plate 53 is the surface provided to receive directly or indirectly the blows of a pile driving hammer (not shown).

Immediately below end plate **53**, and fastened to the bottom thereof as by means of welding or the like, not shown, is a plate **57** having a peripheral wall **57***a* with an outside diameter just slightly less than the inside diameter of core **23** and having a vertically extending, centrally located, substantially rectangular aperture **58** therethrough. The inside dimensions of aperture **58** are just slightly larger in all respects than the outside dimensions of the top **59** of hollow column **25**, and as will be seen in FIGURE 1, top **59** lies freely within and is adapted to be guided in any slight movements up and down by aperture **58**. Welded or otherwise fastened within, and completely sealing the top of column **25**, is a sealing plate **60** for a purpose to be described. Wall **57***a* aids in preventing plate **53** from moving laterally relative to core **23**.

Spaced downwardly from column top **59** and surrounding column **25** is a generally annular fluid distributing manifold designated generally as **61**. As seen in FIGURE 1, manifold **61** consists of a top wall **62** having a substantially square aperture **63** located centrally therein, a vertically extending annular side wall **64** which engages the underside of top wall **62** and is joined in fluid tight relation thereto by means of welding or the like, not shown, and a bottom wall **65**, having a substantially square aperture **66** located centrally therein as well as a plurality of round apertures **67** for a purpose to be described. Bottom wall **65** is fastened in fluid-tight relationship to the lower edge of side wall **64**. Column **25**, as will be noted, is surrounded by manifold **61**, and the manifold's top and bottom walls are fastened in fluid-tight relation to the column by means of welding or the like, not shown.

At one location in the side wall **64** of manifold **61** is formed a circular aperture **68**, and in aperture **68** is affixed by means of welding, not shown, an internally threaded, horizontally oriented short nipple **69**, the outer end of which lies substantially flush with the outer face of side wall **64**, and the inner end of which lies within manifold **61** and ends just short of the side **29** of column **25**. A circular opening **70** considerably larger in diameter than the outside diameter of nipple **69** is provided through core **23** adjacent the outer end and coaxial with nipple **69**.

The purpose of opening **70** is to allow a connector tube **71** having external threads **72**, **73** on the opposite ends thereof to be threadedly engaged within the outer end of nipple **69**. In order to inflate bladders **31**, a suitable valved source of pneumatic or hydraulic pressure (not shown) is connected to the outer end of tube **71**. Thus pressurized fluid is caused to pass through tube **71**, and nipple **69** into manifold **61**. Once inside manifold **61**, such fluid is directed to the four individual bladders **31** by way of four vertically oriented tubular nipples **74**, each of which has its upper end welded or otherwise fastened in fluid-tight relationship within one of the apertures **67** formed through bottom wall **64**. To the bottom end of each nipple **74** is fastened, by means of an epoxy glue or like adhesive layer **75** (see FIG. 15), the top end **76** of one of the bladders **31**. To insure the integrity of these bladder-to-nipple joints, additional means are provided in the form of conventional hose clamps schematically shown at **77**, **78** which, when tightened around a bladder end **76** on a nipple **74** cause portions of the bladder to be depressed and held firmly in external grooves **79** and **80** formed on each nipple **74**.

Each bladder **31** preferably, but not necessarily, is formed of a length of high pressure rubber, or the like, fire hose, and as best seen in FIGURE 1, extends downwardly from a nipple **74**, has the central portion of its length interposed between the exterior face of a side of column **25** and the inside face of an adjacent plug rail **26**, and has its lower end **81** flattened, then glued and clamped to a core assembly, designated generally at **82**. (See FIGURE 8 for details of this core assembly.)

Specifically, the bottom end **81** of each bladder **31** is sealed off by glueing same together in flattened condition. Then the flattened bladder ends are placed against and

glued (by adhesive not shown) to the exterior raised portions **83**, **84** and **85** of assembly **82** and are clamped thereto by means of conventional hose clamps shown schematically as **86**, **87** which cause portions of the bladder to be depressed into clamping grooves **88** and **89**. After the tube ends are clamped thusly, several layers of fine woven glass cloth are tightly wound around the core assembly as at **90** and this cloth is finally thoroughly impregnated with a flexible epoxy or the like adhesive (not shown).

Core assembly **82**, FIGURES 1, 7 and 8, more particularly, includes a substantially square (in cross-section) axially apertured upper portion **91**, the outer dimensions of which are only slightly smaller than the inside dimensions of the lower end **92** of column **25**. As shown, portion **91** is inserted upwardly within end **92** and is fastened therein by means of weldments **93** which are layed into elongated weld-receiving apertures **94** formed through end **92**. The aperture which extends vertically completely through portion **91** and communicates with the interior of column **25** is designated **95**. The lower limit of the exterior of portion **91** is defined by a radially extending ledge **96** upon which the horizontal lower end of column **25** bears and to which such lower end is fastened all around by welding **97**. Core assembly **82** further includes a circular (in cross-section) apertured intermediate portion **98** which is integral with and depends from portion **91**. Portion **98** on its outer periphery is provided with the raised portions **83**, **84** and **85**, and the two clamping grooves **88** and **89** previously mentioned. Between ledge **96** and raised portion **85** on intermediate portion **98** lies a frusto-conical surface **99**.

To the lower end of the intermediate portion **98** of core assembly **82** is fastened as by welding **100** a flange-forming end plate **101**. The aperture in portion **98**, designated **102**, communicates and is coaxial with aperture **95** (the majority of which is located within portion **91** but part of which extends into portion **98**), but is larger in diameter than aperture **95**. Both apertures **95** and **102** are also coaxial and communicate with an aperture **103** in end plate **101** which is of substantially the same diameter as aperture **102**. Apertures **102** and **103** and the ledge **104** joining apertures **95** and **102** combined to provide a socket **105**, the purpose of which will be made clear as the description proceeds. Spaced between aperture **103** and the outer radial edge of end plate **101** are a series of four vertically oriented, internally threaded apertures **106** for a purpose to be described.

When mandrel unit **21** is to be employed as a separate pile driving entity (the condition shown in FIGURE 1), its lower end is completed by a circular bottom plate **107** which has formed in its upper face a shallow circular depression **208** equal in diameter to the diameter of end plate **101**. In depression **208** is seated a conforming resilient, preferably Neoprene rubber pad **209** the purpose of which is to act as a shock mount for those portions of the mandrel unit which are supported thereon, namely, column **25**, core assembly **82** and their adjuncts. By means of pad **209** some of the force of hammer blows applied to the top end plate **53** will be damped out so as to prevent fatigue or other damage to the internal workparts of the mandrel unit. Bottom plate **107** is rigidly fastened to the bottom edge of core **23** by means of a plurality of socket-headed cap screws **108**, the bottom portions of which are located in counter-bored smooth-walled apertures **109** providtd in bottom plate **107**, and the threaded portions of which extend above bottom plate **107**, and the threaded portions of which extend above bottom plate **107** and matingly engage with internally threaded vertically oriented holes **110** in the bottom of core **23**. Also, when unit **21** is employed alone, four cap screws **111** located in counter-bored apertures **112** in bottom plate **107** pass upwardly through apertures **210** provided therefor in pad **209** and have their upper threaded ends fastened in the apertures **106** of end plate

101 thereby fixing the lower end of column 25 relative to core 23.

When mandrel units 21 and 22 are coupled together into an elongated assembly and used concurrently, as will be described, bottom plate 107 is removed from unit 21 and then the bottom-most surfaces of core 23 and core assembly 82 are engaged, respectively, with the tops of the coupling unit 20 and another shock pad 147, to be described.

Centralizers 32, 33, 34 and 35, it will be noted, extend upwardly from a point just above ledge 96 (FIGURES 1 and 8) to a point just below the lower ends of the nipples 74 on the manifold 61. Thus these centralizers provide the guidance and restraint desired and required for the proper functioning of the plug rails 26 and bladders 31, but do not interfere with the manifold 61.

The fluid-distribution system of unit 21 includes one further feature not previously described. This feature is a removable, externally threaded plug 113 which is located in an internally threaded aperture 114 formed through side 29 of column 25 and located coaxial with nipple 69. In the outer end of this plug is formed a wrench-receiving socket 115 used in loosening and tightening the plug and, as will be noted in FIGURE 1, plug 113 is smaller in outside diameter than the inside diameter of nipple 69 so that (after removal of tube 71) plug 113 can be removed by unscrewing same out of column 25 and withdrawing same out through nipple 69. With plug 113 removed, it will be seen that actuating fluid entering tube 71 will fill not only the bladders 31, but also the entire interior of column 25 and core assembly 82. However, plug 113 is removed only when mandrel units 21 and 22 are employed as a coupled elongated assembly, as will be further described. When unit 21 is used separately, that is, detached from unit 22, plug 113 is threaded tightly into aperture 114 so that no fluid can pass into column 25.

So that mandrel unit 21 can be conveniently handled by means of a cable or hook on a crane or the like, apertured, radially oppositely and outwardly projecting lugs or ears 218 are welded, or otherwise attached, to the exterior of core 23 immediately below opening 70.

The operation of mandrel unit 21 as a separate pile driving entity will now be desecribed:

First unit 21, for example, with an overall length of 45 feet is lowered (by employing a crane cable attached to ears 18) into the interior of a 40 foot long, vertically oriented hollow corrugated or smooth wall pile shell (not shown) until the bottom of unit 21 is substantially even with the bottom of the shell and the top five feet of unit 21, including the ears 18, the manifold enclosing portion of core 23 and tube 71 remain exposed above the top of the shell. (FIGURE 6 of Patent No. 3,006,152, previously mentioned, shows an arrangement similar to that just described.) Next a source of pneumatic or hydraulic pressure is attached to tube 71 by means of the threads 72 thereon and pressurized fluid quickly fills and expands the bladders 31. As bladders 31 expand, they force plug rails 26 and gripping plugs 42 outwardly thus forcing the plugs 42 into holding contact with the interior surface of the pile shell. Concurrently with the outward movement of rails 26 the springs 49 of the spring assemblies 40 are compressed. Now, while the fluid pressure is maintained in bladders 31, the pile shell and mandrel unit combination, just described, is located over the ground where the pile shell is to be driven. Hammer blows are then applied to the top surface of top end plate 53 and, thus, mandrel 21, and the pile shell rigidly held relative thereto are driven into the earth to the distance desired.

After the desired driving of the shell has been accomplished, the pressurized fluid source is turned off and as fluid pressure in the bladders 31 drops the springs 49 expand and force the plug rails 26 inwardly. As rails 26 move they carry with them plugs 42, thereby releasing the mandrel unit 21 from the pile shell. The mandrel unit 21 is now withdrawn upwardly out of the driven pile shell and is in condition for reuse either separately or in combination with mandrel unit 22 as will be described later.

Mandrel unit 22 incorporates several features which differ significantly from similar features in mandrel unit 21. The first of these features is the manifold assembly of unit 22, designated generally as 116. Manifold assembly 116, seen enlarged in FIGURE 6, resembles manifold assembly 61 of unit 21 in that it surrounds and is sealed in fluid-tight relation to the exterior of column 25'. Also, similarly to assembly 61, assembly 116 includes a top wall 117 having a substantially square aperture 118 located centrally therein, a vertically extending annular side wall 119 and a bottom wall 120, having a substantially square aperture 121 located centrally therein as well as a plurality of round apertures 122 which receive the upper ends of nipples 74' which are identical in construction and function to the nipples 74 of mandrel unit 21. Manifold assembly 116, however, differs from manifold assembly 61 in that its side wall 119 is not apertured as is side wall 64 of assembly 61. Such is the case because actuating fluid does not enter manifold 116 via a connector tube the likes of tube 71 in mandrel unit 21 but, rather, pressure fluid is conducted into manifold 116 by means of a connector socket designated generally as 123 and a conduit assembly designated generally as 124 which provides a channel for fluid to flow from the lower end of mandrel unit 21 thereinto, as will be described. Connector socket 123 is best shown in FIGURES 2, 5 and 6 while assembly 124 and the details thereof are clearly shown in FIGURES 2, 9, 10 and 11. Reference is now made to these respective figures.

In FIGURE 9 the entire conduit assembly 124 is shown separately. It consists of two identical but oppositely oriented cylindrical bushings 125, 125 each of which (see FIGURES 10 and 11) is axially apertured throughout its length as at 126. One end of each bushing consists of a portion 127 of relatively small outside diameter which is bounded on one of its ends by a radially extending flange 127*a*. The opposite end of portion 127 is bounded by a relatively large outside diameter portion 128 which extends to the opposite end of the bushing in constant diameter except where its periphery is interrupted by two O-ring receiving grooves 129, 129. In each of the grooves 129 are located identical conventional O-ring seals 130 for a purpose to be described.

Extending between and attaching the two bushings 125 to each other is a short length of conventional stiff-walled high pressure hose, or the like, 131, the opposite ends of which, as clearly seen in FIGURE 9, surround portions 127 and 128 of the bushings 125 and are held thereto by conventional hose clamps which are schematically shown at 132. The flanges 127*a* prevent the clamps from sliding off of portions 127 when pressurized fluid is introduced into hose 131 as will be described.

Connector socket 123, as best shown in FIGURE 6, is oriented coaxially within column 25' and consists of an extended wall portion 133, the outside contour of which is substantially square in cross-section and dimensioned so as to fit snugly into the substantially square interior of column 25' and the interior surface 134 of which is circular in cross-section, and a bottom wall 135 which is integrally joined to the wall portion 133 and provided with a central circular aperture as at 136 for a purpose to be described. It should be here noted that socket 123 does not block aperture 114'. After insertion into column 25' socket 123 is welded thereto (by welds not shown) so that the tops of the column and socket are flush with one another and are located (see FIGURE 2) snugly within a substantially square aperture 302 located in a circular plate 301 (similar to plate 57) to be further described. Before socket 123 is welded into column 25', however, a substantially square blocking plate 186 is welded hori-

zontally into the interior of column 25' coplanar with wall 120 of manifold 116. The purpose of plate 186 is to seal off column 25' so that fluid coming into the column via conduit assembly 124 and socket 123 cannot flow into the lower portion of column 25', but, rather, is channeled through aperture 114' into manifold 116, and then into bladders 31' via nipples 74'.

Conduit assembly 124, it will be noted, has its lower end located within socket 123 and its upper end located in the socket 105 of core assembly 82. The O-ring seals 130 prevent pressurized fluid from leaking out of the conduit assembly into the sockets 105 and 123.

The coupling assembly 20 employed for joining mandrel units 21 and 22 into a unitary relatively long mandrel assembly will now be described with reference being made to FIGURES 2, 12, 13 and 14 of the drawings. In FIGURE 2 will be seen the assembled parts of coupling assembly 20, namely a coupling unit designated generally as 137 and two identical shroud assemblies designated generally as 138, 138. Referring now to FIGURES 12 and 13, the main portion of coupling assembly 137 is seen to comprise a heavy casting, or the like, the periphery of which is circular in all horizontal cross sections. Attached to the under surface of the main portion by means of welding or the like, not shown, is a multi-apertured locator and stabilizer plate 301 to be described further. Extending through unit 137 concentric with the vertical axis thereof is a circular aperture 139 through which conduit assembly 124 passes when mandrel units 21 and 22 are joined together as shown in FIGURE 2. This aperture 139 is only slightly larger in diameter than the outside diameter of the bushings 125 (on hose 131) and, thus, the hose is restrained from any substantial lateral movement since it is substantially confined with coupling unit 137. Centrally located in stabilizer plate 301 is a substantially square vertically oriented aperture 302 which, as seen in FIGURE 2, is coaxial with aperture 139 and snugly receives and steadies the top end of column 25', and has loosely located therein the mid-portion of conduit assembly 124.

The top large diameter exterior portion 139 and the bottom large diameter exterior portion 140 of coupling assembly 137 are of the same outside diameter and both portions 139 and 140 have the same outside diameters as cores 23 and 23', but are of larger outside diameter than the central exterior portion 141 of unit 137, thereby providing an upper horizontal ledge 142 and a lower horizontal ledge 143 for a purpose to be described hereinafter. The bottom face or undersurface of the main portion of coupling unit 137 is denoted 144, and the top face is denoted 145. Formed in top face 145 is a circular depression 146 provided to receive a circular rubber damping or shock pad 147 (see FIGURE 2) which is present to provide a shock absorbing seat for core assembly 82 of mandrel unit 21 atop coupling unit 137 when units 21 and 22 are coupled together into a unitary mandrel assembly, as will be described shortly. Extending vertically through pad 147 are a plurality of apertures 177 which are identical in number and layout or spacing to and alignable with apertures 150 in coupling unit 137 which will shortly be further described, and a central aperture 178 which, when pad 147 is seated in depression 146 is coaxially aligned with aperture 139. Also, extending vertically through stabilizer plate 301 are a plurality of apertures 303 which are identical in number and layout or spacing to and alignable with apertures 150 and 177 for a purpose to be described.

In addition to aperture 139, coupling unit 137 contains three groups of vertically extending bolt-receiving apertures, namely: apertures 148 which extend vertically from bottom ledge 143 to bottom face 144; apertures 149 which extend vertically from top ledge 142 to top face 145; and counter-bored apertures 150 which extend from the bottom of depression 146 to the bottom face 144. Apertures 148 are identical in number and layout or spacing to and alignable with the holes 110 in the lower end of core 23, and apertures 149 are identical in number and layout or spacing to and alignable with a plurality of internally threaded vertical holes 151 which are formed in the top end of core assembly 23' for a purpose which will shortly become apparent. Likewise, apertures 150 and 303 are identical in number and layout or spacing to and alignable with apertures 106 in end plate 101, and, thus, apertures 150 and 303 bear the same angular relationship to apertures 148 and 149 as do apertures 106 to holes 110.

In addition to the various apertures thus far enumerated as being provided in coupling unit 137 there are formed in this unit, at the mid-height of the central portion 141 thereof, four radially horizontally extending internally threaded holes 152 (see FIGURES 12 and 13) to be utilized in joining the shroud assemblies 138 to the coupling unit 137 in a manner to be described.

The shroud assemblies 138 (best seen in FIGURES 13 and 14) each comprises a semi-circular band having an integral strengthening rib 154 located centrally on the concave face thereof. Near each end of each rib 154 is affixed, as by welds 155, a cup-shaped socket 156 having a circular aperture 157 formed through the bottom 158 thereof. The sockets 156, as best seen in FIGURE 12, are located on assemblies 138 in coaxial alignment with apertures 157*a* formed through band 153 and rib 154 so that apertures 157 and 157*a* may be radially aligned with the threaded holes 152 in coupling unit 137 for a purpose to be described later.

The actual coupling together of coupling assembly 20 and mandrel units 21 and 22 to form my mandrel assembly 19 is accomplished as follows. Units 21 and 22 are positioned so that the two units are substantially coaxially aligned with each other with the bottom plate 107 of unit 21 spaced a distance, somewhat greater than the vertical extent (length) of coupling unit 137, from that end of core 23' which is adjacent socket 123. Now bottom plate 107 is removed from unit 21 by removing the several cap screws 108 and 111. (Plate 107 at this time is put away or stored since it is not required until unit 21 is to again be used independently.) The damping pad 147 is next placed in depression 146. Then these two components (137 and 147) are interposed between the facing ends of mandrel units 21 and 22 with the exposed side of plate 147 facing the unobstructed face 159 (see FIGURE 8) of end plate 101, and, subsequently, elongated bolts 160 are inserted into apertures 303, thence through apertures 150 and 177 (after same are aligned with each other and with apertures 303) and finally bolts 160 are screwed tightly into the threaded apertures 106 in end plate 101 (after apertures 106 have been aligned with apertures 303, 177 and 150).

Next, one end of conduit assembly 124 is entered into the exposed end of the aperture 302 of the stabilizer plate 301 of coupling unit 137 and the just-mentioned end is then pushed, in sequence, through the apertures 302, 139 and 178 and into core assembly 82 until the O-ring-including bushing 125 thereon is seated and sealed firmly within socket 105. Now the apertures 149 in the coupling unit 137 are aligned with the threaded holes 110 in core 23 and, subsequently, a plurality of bolts 161 are entered into the ledge 142 end of the apertures 149 and then pushed through apertures 149 and screwed tightly into holes 110. When bolts 161 are tight, the heads thereof seat firmly on ledge 142. The coupling unit 137 is now rigidly attached to mandrel unit 21.

At this juncture mandrel unit 22 is moved axially of itself toward the exposed circular face of stabilizer plate 301 and during such movement the bushing 125 on the free end of conduit assembly 124 is guided into the open end of socket 123. Continued movement and manipulation of mandrel unit 22 toward and relative to coupling unit 137 serves to seat the O-ring-including bushing 125 fully within socket 123, simultaneously locates

plate 301 snugly within the top of core 23' with the exposed area of face 144 of the coupling unit 137 in abuttment with the end of core 23' and locates the free end of column 25 within aperture 302. It is here pointed out that hose 131 is sufficiently stiff to force the bushing 125 into socket 123 as just described.

Next the apertures 148 in the coupling unit 137 are aligned with the threaded holes 151 in core 23' and, subsequently, a plurality of bolts 162 are entered into the ledge 143 end of the apertures 149 and then pushed through apertures 149 and screwed tightly into the holes 151. When bolts 162 are tight, the heads thereof seat firmly on ledge 143. Mandrel units 21 and 22 are now rigidly coaxially attached to each other and to coupling unit 137.

Now, in order to provide the mandrel assembly thus formed with a substantially smooth outer surface from its lower end upwardly to ears 218, whereby it has no projections or indentations which might become engaged with the interior surfaces of the corrugations on a pile shell (and thus bind the assembly in the shell making withdrawal difficult), the two shroud assemblies 138 are placed in position radially outwardly of portion 141 of coupling unit 137 as seen in FIGURES 2 and 13, and assemblies 138 are subsequently rigidly attached to unit 137 by socket-headed cap screws 163, the heads of which nest in the sockets 156 of assemblies 138 and the threaded shanks of which pass inwardly through apertures 157 in assemblies 138 and are screwed tightly into the threaded holes 152 in coupling unit 137. The shroud assemblies also serve a secondary function; that of preventing dirt or other debris from filling the space bounded by ledges 142, 143 and portion 141. Thus bolts 161 and 162 are shielded from dirt and damage which might impair assembly or disassembly of the mandrel assembly 19. Components 20, 21 and 22 having now been rigidly coupled together, the elongated mandrel assembly is ready to be utilized for driving deep piling except for one important step which must still be performed. That step is the complete removal of plug 113 from mandrel unit 21. The method of removing this plug has been previously described.

The operation of my novel mandrel assembly 19 (20, 21 and 22 coupled together) will now be described:

The first step in using assembly 19 is to position same within the interior of an elongated pile shell or casing (not shown) so that at least that portion of the assembly above the lower ends of lugs 18 protrudes from the shell. The shell may be a single elongated tubular member, but more usually will be composed of at least two relative short lengths of casing, butt-welded together coaxially end to end to form a relatively long shell. (The assembly 19, obviously, may be positioned within the elongated pile shell as a precoupled unit, or, alternately, the assembly 19 and long shell may obviously be "built-up" or fabricated on location from their respective components. Due to the relatively great weights of the components now being discussed, a crane is normally employed to handle same. Ears 218, as has previously been mentioned, are provided for cable or hook handling of these components.)

Once assembly 19 is positioned within the pile shell, a source of pressurized fluid is attached to tube 71 on mandrel unit 21. Part of the pressurized fluid from the source then flows into manifold 61, thence through nipples 74 filling and expanding bladders 31, while concurrently more of the fluid flows through aperture 114 filling column 25, then sequentially conduit assembly 124, column 25' down to blocking plate 186, aperture 114', manifold 116 and nipples 74', and finally bladders 31' which upon being filled expand like bladders 31.

As bladders 31 and 31' expand they force outwardly and into holding contact with the interior of the surrounding pile shell plugs 42 and 42', respectively. The pressure of the bladder-expanding fluid, of course, must be maintained sufficiently high during this phase of the operation and during the actual driving of the shell so that substantially no relative movement takes place between the shell and assembly 19. At this juncture the combined shell and mandrel structure is ready for driving as desired. Driving is accomplished by applying hammer blows directly or indirectly to the top of plate 53.

After the shell has been driven to the depth desired, the pressurized source supplying the bladder-expanding fluid is cut off allowing springs 49 and 49' to force plug rails 26 and 26', and consequently plugs 42 and 42', inwardly out of holding engagement with the now-driven shell. Mandrel assembly 19 may now be withdrawn from the driven shell and reused or disassembled as desired.

Although the relatively long mandrel assembly 19 is here shown as being composed of but two relatively short mandrel sections 21 and 22, it is to be understood that where required a still longer mandrel assembly may be achieved by removing blocking plate 186 and bottom end plate 107' from mandrel unit 22 and coupling another mandrel unit identical to unit 22 to the bottom of unit 22 by means of an additional coupling assembly and a conduit assembly identical to assemblies 20 and 124, respectively. Plate 186 is removed so that pressurized fluid may flow downwardly into the lower portion of column 25'.

It is to be further understood that various other changes may be made in the invention without departing from the spirit thereof. For example, under certain circumstances, it may be desirable to construct cores 23 and 23' of tubular material which exhibit constant cross-sections other than circular and/or to taper these cores outwardly from their bottom ends to their top ends in such manner the mandrel assemblies appear as elongated frusto-conical or frusto-pyramidic structures.

Having now described my novel mandrel assembly and the operation thereof, what I claim and desire to secure by Letters Patent is:

1. A fluid pressure operated, expanding plug type mandrel assembly for driving hollow tubular pile shells and the like elongated forms comprising: first and second coaxially aligned external tubular cores insertable within said forms, said cores each having radial apertures therethrough; a driving head engaged with one end of said first core to receive and transmit heavy blows to said first core axially thereof; gripping plugs received in said apertures for radial movement into and out of gripping engagement with said forms; fluid pressure inflatable means in each core acting radially of said plugs to urge same outwardly to produce said gripping engagement; elongated pressure transmiting means between each of said inflatable means and the plugs in each core to transmit force to and guide said plugs; coupling means inserted between and joining said first core to said second core; and fluid distribution means for channeling pressure from a source of pressurized fluid to the bladder means in said first and second cores.

2. The combination of claim 1 wherein portions of said fluid distributing means pass through an aperture in said coupling means.

3. An elongated mandrel assembly comprising: a first tubular core having a substantially constant circular periphery throughout its length; a second tubular core having substantially the same constant circular periphery throughout its length as said first core; a first tubular column and socket assembly locattd coaxial with and within said first core; a second tubular column and socket assembly located coaxial with and within said second core; a first end plate affixed to one end of said first assembly; a second end plate affixed to one end of said second assembly, said first and second end plates being of substantially the same diameter as the inside diameter of said cores and each having one face located substantially flush with one end of the core in which it is located; a bottom plate removably attached to said one end of said first

core and to the end plate therein; a top plate adapted to receive hammer blows removably attached to end of said second core opposite said one end; means on one side of said top plate supporting the end of said second assembly, opposite the end to which said second end plate is fixed, against lateral movement; coupling means, having a first and a second end, joining said first and second cores together into rigid coaxial alignment, said coupling means exhibiting in cross section an external periphery of substantially the same constant outside diameter as said first and second cores; means on said first end of said coupling means supporting the end of said first assembly, opposite the end to which said first end plate is fixed, against lateral movement; and means joining said second end of said coupling means to the end plate in said second core.

4. The combination of claim 3 including first shock-absorbing means located between said second end of said coupling means and the end plate in said second core, and second shock absorbing means between said bottom plate and the end plate in said first core.

5. A pile driving mandrel assembly for driving hollow pile shells comprising: upper and lower mandrel units each including an elongate substantially closed wall rigid tubular unit having at least one aperture means therein, expressible pile-shell engaging means in said aperture means, expansible bladder means for expressing said pile-shell engaging means, and means for retracting said expressible pile-shell engaging means; a driving head on the upper end of the upper mandrel unit adapted to receive hammer blows and to transmit the same axially to the wall of the upper unit; handling means on the upper end of the upper unit below the driving head; means adjacent the upper end of the upper unit and below the driving head for introducing pressure fluid to the expansible bladder means therein; a hollow interior coupler of closed wall configuration for mechanically coupling the lower end of the upper unit to the upper end of the lower unit, said coupler including means extending through the hollow interior thereof establishing a fluid connection between the bladder means in both sections; said upper and lower units and said coupler being coaxial with one another and the exterior radially disposed wall surfaces on the upper unit below said handling means and the exterior radially disposed wall surfaces on said lower unit and the exterior disposed surfaces on said coupler being so shaped and dimensioned that any plane passed simultaneously through said surfaces and the common axis of said units and coupler intersects the peripheral extremities of said exterior surfaces along a common straight line.

6. A fluid pressure operated pile driving mandrel assembly for driving hollow tubular pile shells comprising upper and lower coaxially aligned cores insertable within said forms; said upper core having a driving head on the upper end thereof; each core having a hollow rigid central column extending substantially from end-to-end therein, expansible fluid pressure inflatable bladder means on the outer side of said hollow central column, means on the outer side of said fluid pressure inflatable bladder means for engaging the inner side of a pile shell; a manifold for channeling fluid under pressure to said fluid pressure inflatable bladder means, and means for establishing a fluid connection between the hollow interior of the central column to the manifold; the lower end of the hollow central column of the upper core and the upper end of the hollow central column of the lower core each having an inner portion thereof of circular cross-section; means for establishing a fluid connection from a source of pressure fluid to the manifold in the upper core; coupling means having a hollow interior for mechanically connecting the lower end of the upper core to the upper end of the lower core; and conduit means extending through the hollow interior of the coupling means for establishing a fluid connection between the lower end of the hollow rigid column of the upper core and the upper end of the hollow rigid column of the lower core.

7. The combination claimed in claim 6, said conduit means including a tube having nipple means of circular exterior an each end sealingly and slidably engaging, respectively, within the inner circular portions of the lower end of the hollow central column of the upper core and the upper end of the hollow central column of the lower core.

8. A pile driving mandrel assembly comprising: an upper mandrel section including a first closed-wall tubular core having at least one aperture therein; a lower mandrel section including a second closed wall tubular core having at least one aperture therein, each of said sections including plug-including means located in each of said apertures adapted to be moved radially of said sections into and out of gripping engagement with the interior of a hollow tubular pile shell; expansible bladder means in each section for moving said plug means in one direction; means coupling said upper section above and coaxial with the lower section; and fluid distributing means for introducing pressurized fluid into said upper section and for channeling said fluid to the bladder means in said sections, said fluid distribution means including a first manifold in said upper section, a second manifold in said lower section, and fluid conduit means joining said first and second manifolds, said bladder means in said upper section being joined to said first manifold to receive pressurized fluid therefrom and said bladder means in said lower section being joined to said second manifold to receive pressurized fluid therefrom.

9. The combination of claim 8 including removable plug means in said conduit means for preventing fluid flow to said second manifold when said plug means is installed in said conduit means.

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