Oct. 31, 1961 F. RUSCHE 3,006,152

PILE DRIVING MANDREL

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Fig. 1

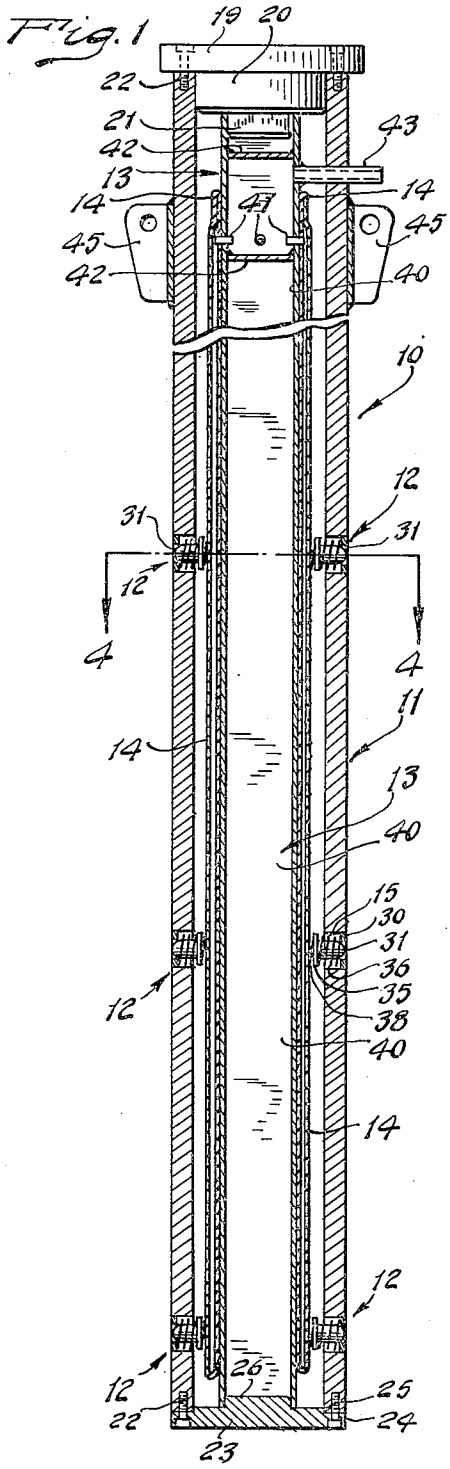
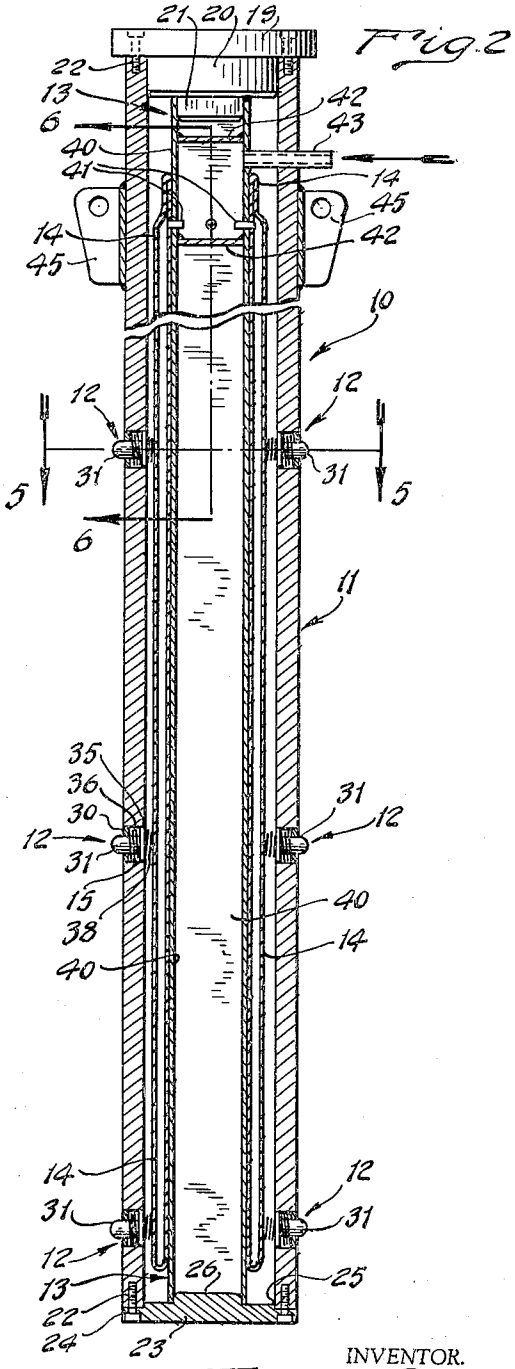


Fig. 2



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Fig. 3

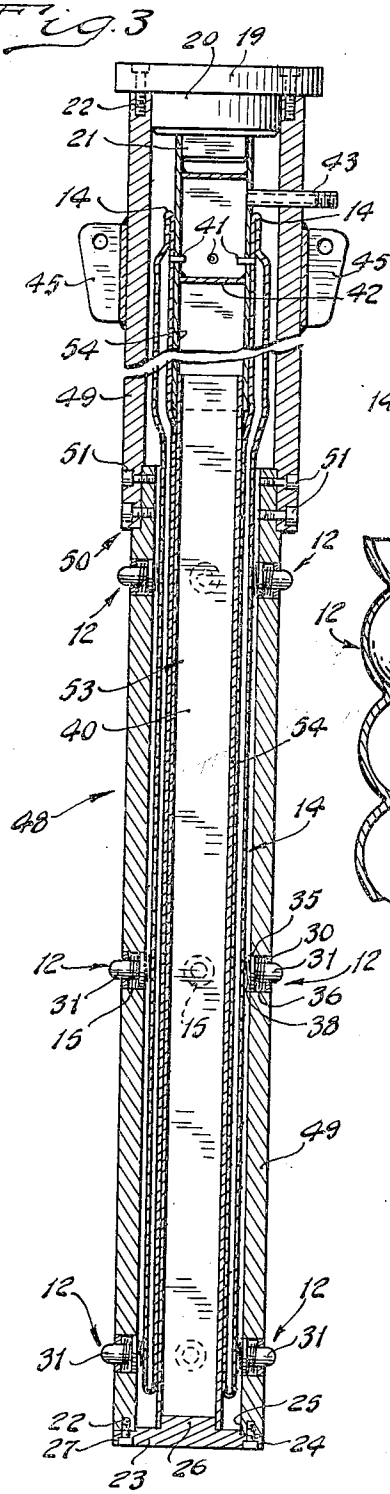


Fig. 6

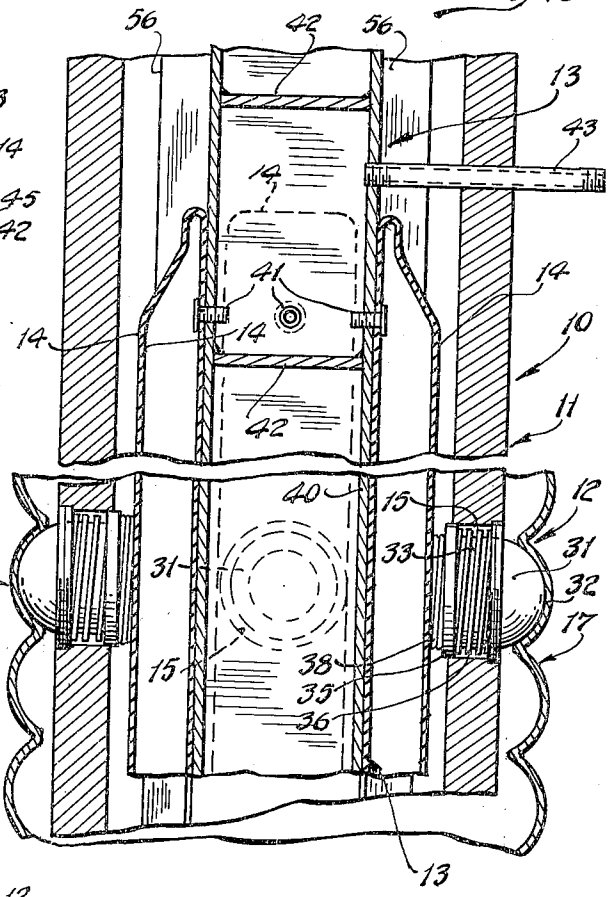


Fig. 7

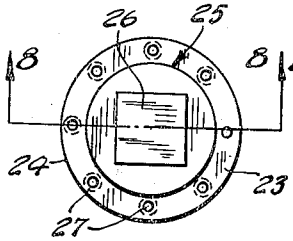
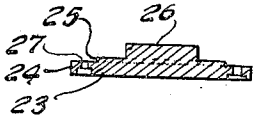


Fig. 8



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Fig. 4

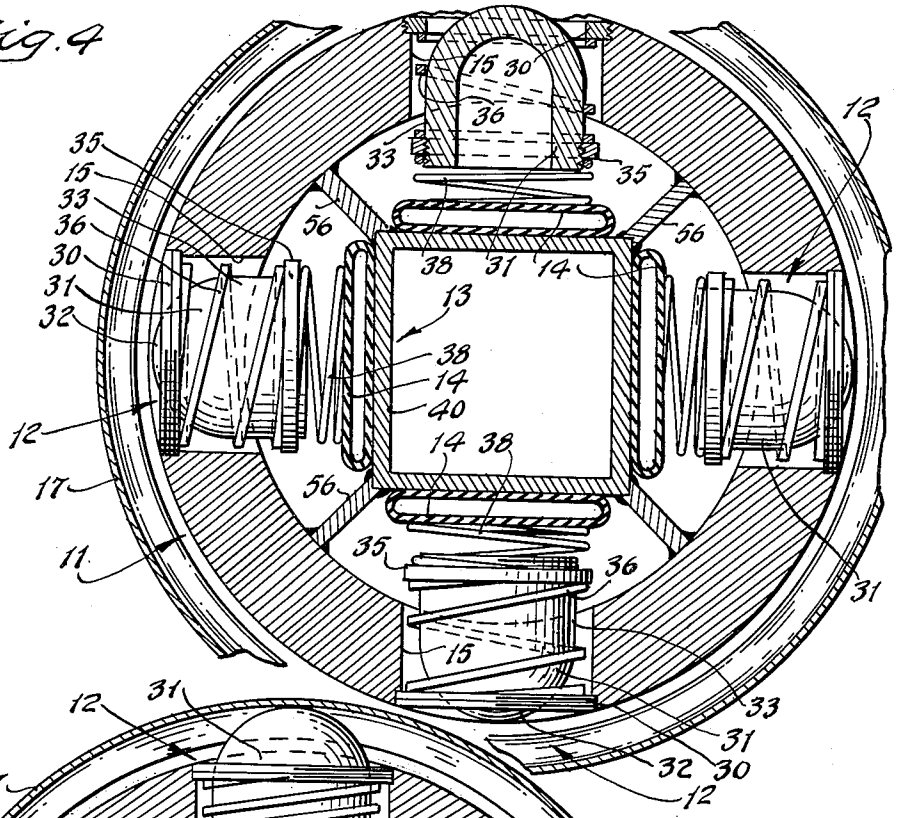
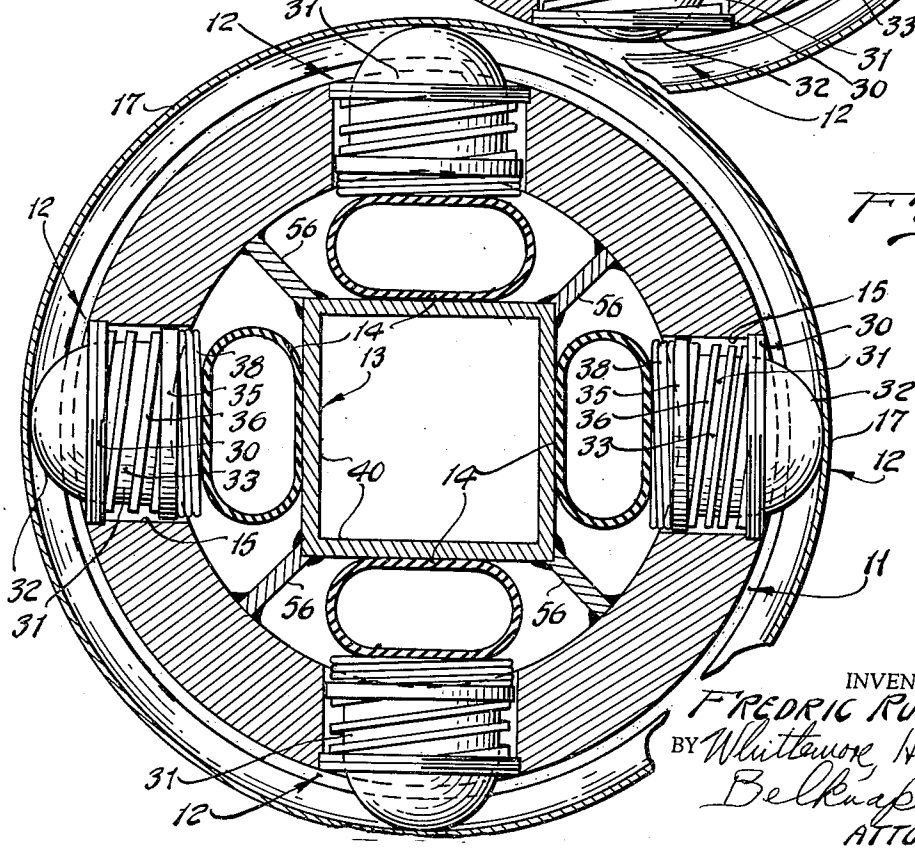


Fig. 5



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Fig. 9

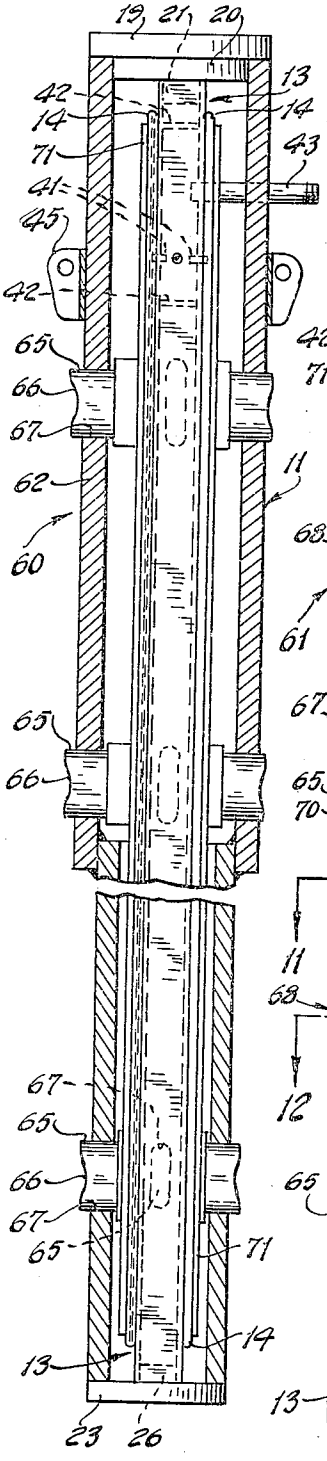


Fig. 10

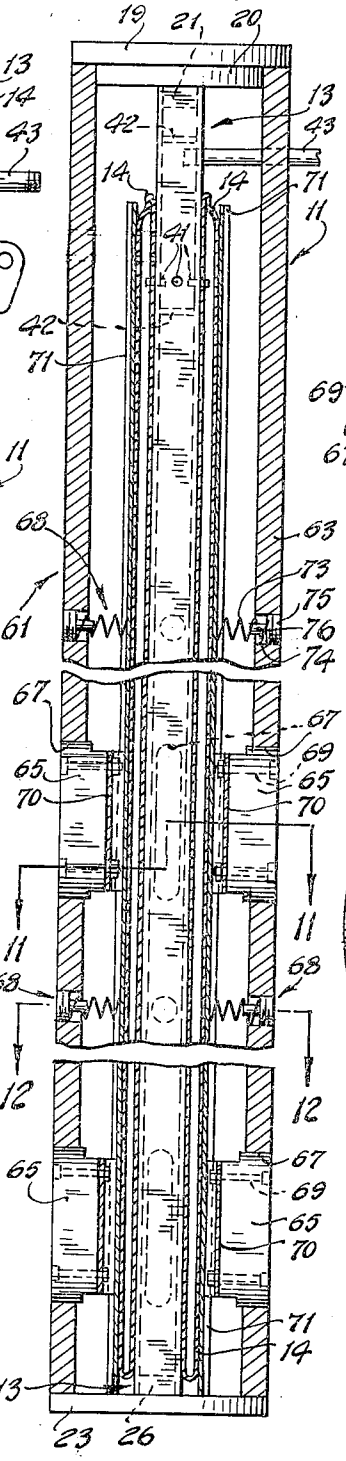
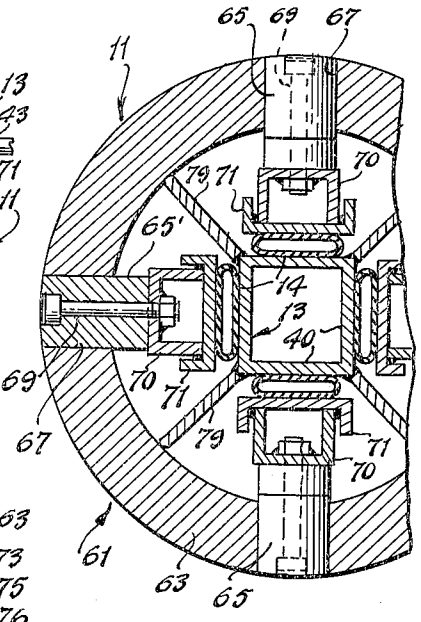


Fig. 11



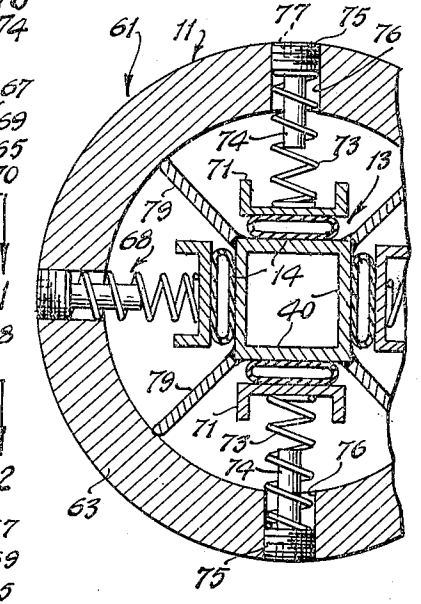


Fig. 12

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PILE DRIVING MANDREL

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Fig. 13

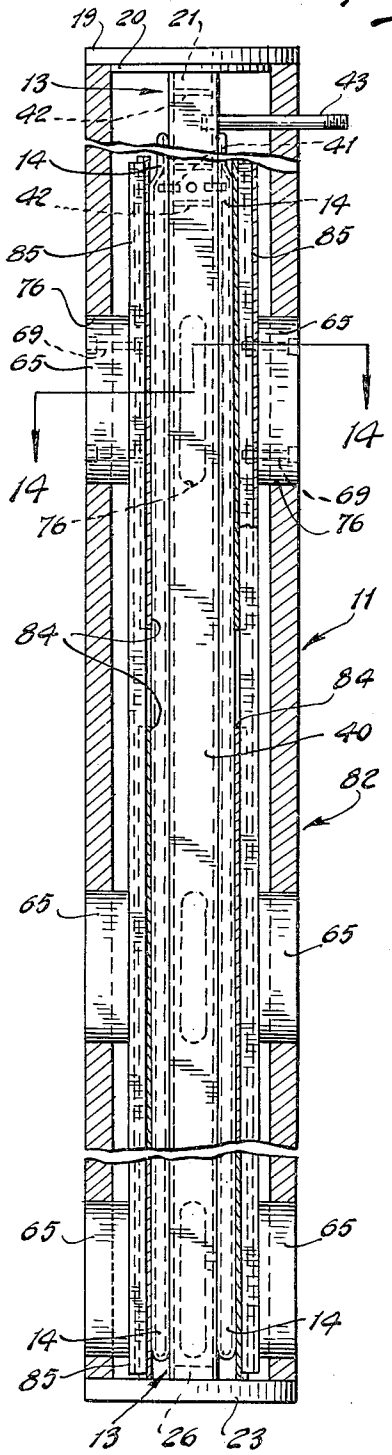


Fig. 14

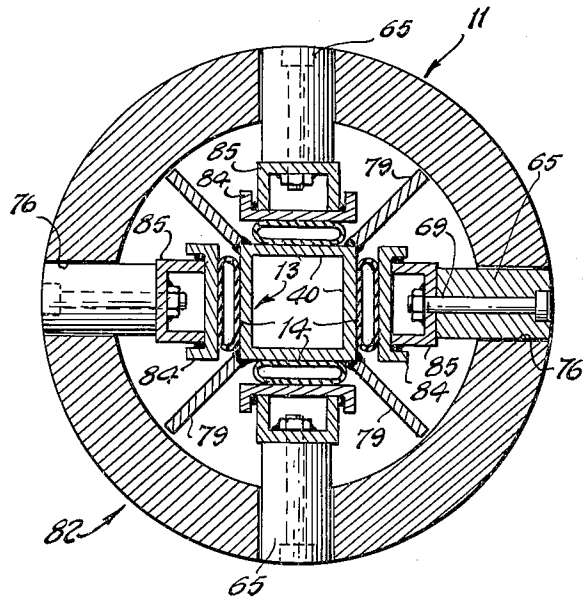
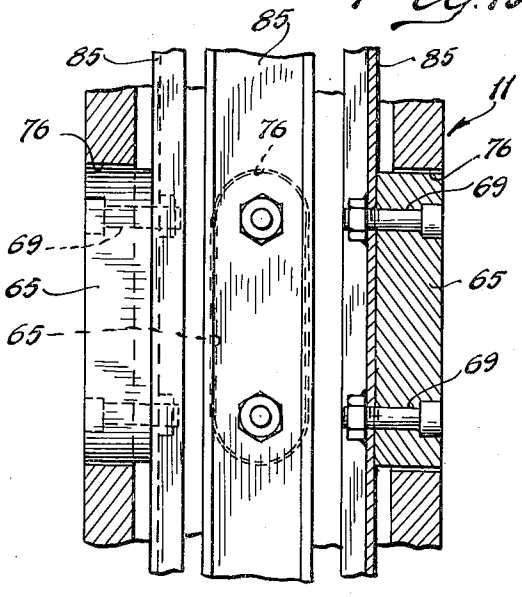


Fig. 15



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PILE DRIVING MANDREL

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Fig. 18

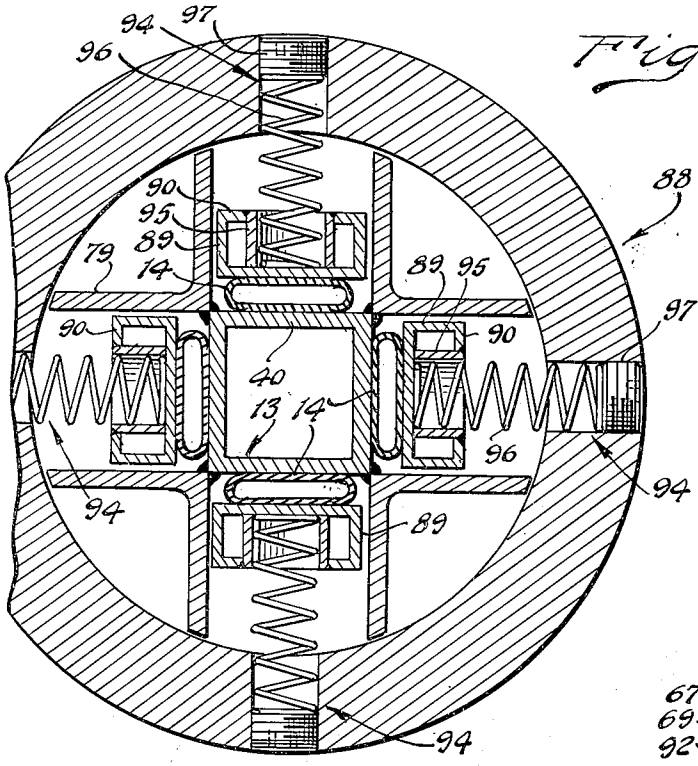
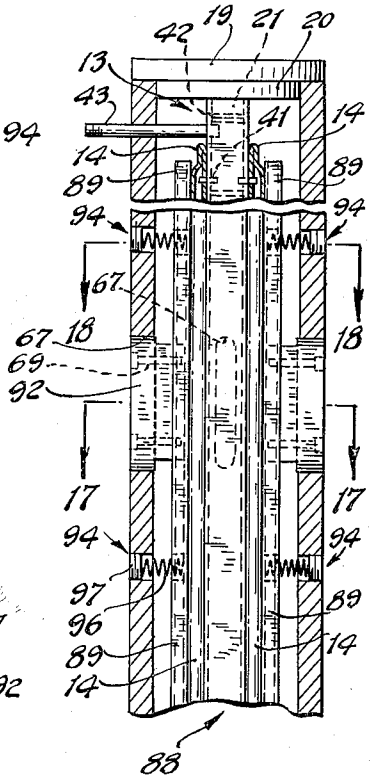


Fig. 16



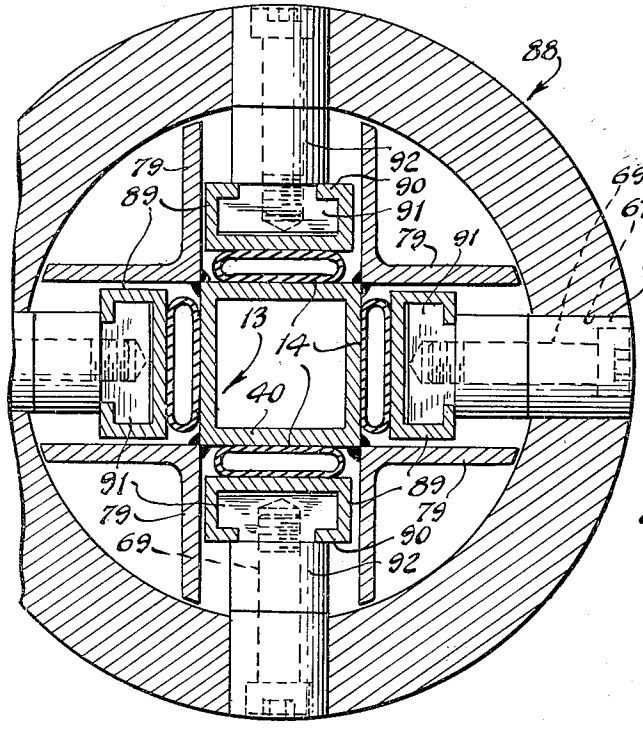


Fig. 17

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United States Patent Office 3,006,152 Patented Oct. 31, 1961

3,006,152

PILE DRIVING MANDREL

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Filed Apr. 17, 1959, Ser. No. 807,126
15 Claims. (Cl. 61—53.72)

The present invention relates to an improved mandrel for driving corrugated pile shells into the earth, and, more particularly, to a mandrel incorporating a hydraulically or pneumatically expanded mechanism to grip the interior of the pile in the driving thereof. In respect to this fluid pressure operated characteristic, the present mandrel represents a further development of the principle underlying the construction and operation of the mandrel of my copending application, Serial No. 570, 881, filed March 12, 1956; in which mandrel there are a pair of opposed, oppositely acting shell-gripping leaves or sections of generally semi-cylindrical cross section, expanded by means of a series of inflatable envelopes or bladders therebetween to grip the corrugations of the pile shell in the driving thereof.

In order to drive the pile shell the mandrel must be capable of being inserted into the shell in a radially collapsed condition, then expanded to grip the shell along its entire length (in the case of the mandrel of my application identified above), and it must incorporate a suitable expanding mechanism, of the sort hereinafter described, which may be expanded to grip the shell so that the latter may be driven into the ground by blows imparted to the mandrel proper.

Although mandrels of the so-called split-leaf type have been very successfully operated in widely spaced localities, to drive pile shells in soil conditions which differ greatly, it has been found that when the leaves of this type of mandrel are expanded by an appropriate internal mechanism, a plane of weakness exists along the longitudinal axis of the mandrel, perpendicular to the direction of radial expansion of the mandrel leaves, i.e., along the plane of the space between the mandrel leaves in which the internal expanding mechanism is carried. The resultant tendency to bend laterally under heavy driving impact gives rise to the possibility of an angularly offset or "dog-legged" pile shell being driven, and a resultant possibility of the mandrel sticking therein and being difficult or impossible to withdraw.

Furthermore, it is evident that a mandrel which is made up of two or more sections, segments or leaves is not as capable of resisting the destructive forces of vibration and repeated hammer blows as is a more solid type of mandrel or core having the requisite expanding mechanism contained therein.

It is therefore an object of the invention to provide a pile shell driving mandrel comprising an axially elongated core or mandrel of substantially continuous cross section, other than at the local points in which it carries its shell-gripping means. Such means are in the form of a plurality of axially spaced and distributed, radially expansible, individual pile engaging and gripping plugs, elements or fingers. These plugs are radially expanded by means of axially elongated inflatable envelopes or bladders, and the plugs operate radially in openings formed along the length of the core.

In accordance with the invention, the core is of hollow tubular or cylindrical cross section, of ample radial thickness to give it the desired strength and rigidity to resist bending deflection under blows. This core is internally equipped with an axially elongated column of rectangular box-like cross section, the column and core being coextensive in their axial direction, and the column being braced within the center of the core by radially extending strut elements welded to it and to the core at the

opposite ends of these elements. It is against the four sides of the internal column that the inflating envelopes or bladders are disposed, the column sides supporting the inflatable members in their expanded condition, in which they urge the shell gripping plugs outwardly in radial openings in the core to engage the corrugations of the pile shell.

Another object is to provide a pile driving mandrel of the expandable plug type referred to above, in which the internal bracing and bladder supporting column to which reference is made may be employed as an air pressure manifold, with appropriate fittings to the interior of the envelopes or bladders by which they are inflated pneumatically or hydraulically from an appropriate source of fluid pressure.

Another object is to provide an expanding plug type of mandrel, characterized by a relatively solid core (in distinction to mandrels of the split-leaf type), in which the radially expanding, shell-gripping plugs (in one embodiment of the invention) may be provided as individual sub-assemblies capable of being readily removed from the mandrel, once the latter is withdrawn from the pile shell, for inspection, repair or replacement. To this end, the plug assembly may consist of a retaining ring threaded for removable mounting on the outer end of the opening in the mandrel core in which the plug operates, the plug being provided with an annular abutment shoulder, between which and the retaining ring a suitable coiled plug retracting spring acts to urge the plug radially inwardly. The force of this retracting spring is opposed and overcome by the inflatable member of the invention, when inflated, and the plug is urged under great force against the corrugation of the shell to grip the same for driving.

Another object of the invention, in the embodiment just referred to, is to provide a plug type mandrel as described, in which the plug assembly further comprises a holding spring for each plug, preferably selected of greater force than the retracting spring, whose function is to maintain the plug in the core opening, so that the plug will not fall radially inwardly to the interior of the mandrel core.

In other forms the plugs may either be fixedly yoked to members extending lengthwise of the coil, or may have a floating mount on such members to minimize wear over a protracted period.

Another object of the invention is to provide a pile driving mandrel of a relatively continuous cross section type, as distinguished from the split-leaf type, which may be also continuous in length, i.e., coextensive with the shell to be driven or greater in length than the shell, or which may be made up of a plurality of individual segments or sections bolted endwise to one another to afford a strong joint capable of withstanding the tremendous bending stresses to which the mandrel is subject in operation.

A further object is to provide a pile driving mandrel whose expanding plugs may be made of any desired outline or section, i.e., semi-spherical, square or rectangular, and of either smooth or rough surface characteristic, if roughning is desired to increase the frictional engagement of the plug with the corrugated shell being driven.

Yet another object is to provide a mandrel as described, which can be made up of a plurality of relatively short sections or segments, bolted or otherwise secured together at their ends. This enables a mandrel to be assembled to handle different pile driving depths. Furthermore in accordance with the invention, convenient lengths of different diameter may be bolted together to constitute the mandrel, thereby enabling it to conform to any particular design criterion which the designer of the foundation to be driven may elect to use for the shape of its

pile. In a built-up mandrel of this type, the expanding mechanism of the respective bolted lengths may be suitably coupled together at the points of junction of the latter, in any appropriate manner.

In all embodiments of the invention, it is an object to provide mandrel improvements wherein pile gripping plugs or fingers of different types may be individually expanded by inflatable provisions of the sort referred to above, with improved means for mounting the plugs for expanding engagement by the inflatable members, and with different types of spring provisions for retracting the plugs upon deflection of said members.

The foregoing as well as other objects will become more apparent as this description proceeds, especially when considered in connection with the accompanying drawings illustrating the invention, wherein:

FIG. 1 is a broken view in axial section through an elongated pile driving mandrel in accordance with the invention, showing the latter in the deflated condition of its expanding means and the withdrawn condition of its shell-gripping plugs;

FIG. 2 is a view similar to FIG. 1 illustrating the mandrel with its plugs radially expanded by the inflated envelopes or bladders of the mandrel;

FIG. 3 is a view generally similar to FIGS. 1 and 2, but showing a mandrel in accordance with a modification of the invention, in which a plurality of mandrel core members of convenient length are assembled endwise by bolting;

FIG. 4 is a fragmentary view in enlarged scale and in horizontal section on line 4—4 of FIG. 1;

FIG. 5 is a similar view in horizontal cross section on line 5—5 of FIG. 2;

FIG. 6 is a fragmentary view in vertical axial section along a line corresponding to line 6—6 of FIG. 2;

FIG. 7 is a top plan view of a foot plate of the improved mandrel, showing provisions for mating or tieing the latter to the core of the mandrel and its internal bracing column;

FIG. 8 is a view in vertical section along line 8—8 of FIG. 7;

FIG. 9 is a view in longitudinal section, similar to FIGS. 2 and 3, illustrating a further modified adaptation of the principles of the invention;

FIG. 10 is a longitudinal sectional view, in larger scale, of a mandrel structure of a type similar to that of FIG. 9, featuring retracting spring provisions and expanding plugs arranged in vertically spaced relation to one another;

FIGS. 11 and 12 are, respectively, views in horizontal section on lines 11—11 and 12—12 of FIG. 10;

FIG. 13 is a view in longitudinal section, similar to FIG. 10, of a further modification;

FIG. 14 is a view in horizontal section on line 14—14 of FIG. 13;

FIG. 15 is a view in longitudinal section and in enlarged scale further showing details of structure of a mandrel of the type appearing in FIGS. 13 and 14;

FIG. 16 is a fragmentary view in axial section through a still further embodiment of the mandrel, the fluid pressure expanding members being omitted; and

FIGS. 17 and 18 are views in horizontal section on lines 17—17 and 18—18, respectively, of FIG. 16.

The essential components of the improved pile driving mandrel 10 of the invention, in its embodiment illustrated in FIGS. 1 and 2, are an external driving core 11; a plurality of sets of shell-gripping plug assemblies, generally designated 12, arranged in circumferentially and axially spaced relation to one another around and along the circumference of the core 11, in a manner to be described; an internal, box-like column 13 of rectangular section; and a number of axially elongated inflatable envelopes or bladders 14 which act radially outwardly between abutting surfaces furnished by the column 13 and the respective plug assemblies 12. These assemblies are carried in

apertures 15 formed in the otherwise longitudinally and circumferentially continuous, cylindrical wall of the core 11. It will be understood that, as thus urged outwardly under heavy force by the inflatable members, the plug elements (to be described) of the plug assemblies 12 strongly grip the corrugations of the conventional pile shell 17 (FIGS. 4, 5 and 6), so that blows imparted to the mandrel will drive the shell into the earth.

The driving core 11, as embodied in the mandrel of FIGS. 1 and 2, is longitudinally and coextensive in length with the pile shell to be driven, or may even be of greater length, being provided with a driving head 19 at its top, projecting above the top of the shell 17, to which the driving hammer blows are applied and by which they are transmitted to core 11. Head 19 may be suitably fitted in any manner to the top of the core 11, as by telescoping a reduced diameter lower extension 20 thereof within the bore of the core, and by fitting a further and smaller extension 21 of rectangular outline within the top of the rectangular column 13. Thus the core 11 and column 13 are well piloted, in radially spaced relation to one another, at their respective upper ends. If desired, they may be welded or otherwise rigidly secured in this relationship, as by bolts 22 connecting the core 11 to head 19 and welded means connecting the core to column 13, as hereinafter described.

A similar arrangement is made for securing a bottom driving plate or foot 23 on the lower end of the mandrel core and internal bracing column, features thereof being best shown in FIGS. 7 and 8, taken in connection with FIGS. 1 and 2, as well as in connection with FIG. 3, to a modified embodiment of the mandrel. Thus, the bottom driving plate 23 has a circular lower flange 24 of the external diameter of the core 11, an axially extending circular shoulder 25 of the internal diameter of the core, adapted to nest within and pilot the latter, and an axially extending further pilot 26 of rectangular cross section, which fits within and pilots the bottom end of column 13. The flange may be suitably formed at 27 to receive bolts anchoring plate 23 in place; and it is seen that the structure in regard to this member substantially duplicates that characterizing the upper driving plate 19.

The plug assemblies 12 of the mandrel 10 are preferably carried in the sets of radial openings or apertures 15 of the latter at zones or planes spaced equally from one another along the axial length of the mandrel, for example in spacings of three feet from one another in the case of a mandrel of about 30 feet overall length. In the illustrated embodiment, employing an internal bracing column 13 of square or rectangular cross section, there are four of the openings and associated plug assemblies 12 arranged in 90° angular spacing relative to one another. It will be understood that this spacing and number of plug assemblies will, of course, accord with the number of flat wall surfaces of the core 13, in the event that the latter is other than rectangular in cross section. The inflating members 14 may typically be formed of lengths of fire hose or equivalent strong and wear resistant material.

As best shown in FIGS. 4, 5 and 6, the plug assemblies 12 are identical, each comprising a radially outer retaining ring 30 which is threadedly engaged in the outer end of the corresponding core opening 15 and taken up tightly in the latter. As will appear, when the ring 30 is loosened and removed, all of the remaining parts of the plug assembly 12 may be withdrawn radially outwardly through the opening 15, for inspection, repair or replacement.

The plug assembly further comprises a gripping plug 31 which acts radially in the opening 15 to grip and release the corrugated surface of the pile shell 17. Although shown in a special form, hollow in cross section (FIG. 4) and provided with a semi-spherical gripping nose 32, and integral cylindrical, radially inwardly ex-

tending body portion or extension 33, it is to be understood that the plugs 31 may be of other outline, square or rectangular, that the facing thereof may be either smooth or roughened, as by corrugating the latter, to increase the frictional resistance between the plug and the corrugated shell 17 being driven, or that this increased grip may be accomplished by simply surface roughening a plug of circular or rectangular cross section, though rounded at its area of engagement with the interior of the pile shell 17.

Whatever its outline, the gripping plug 31 of the assembly 12 is preferably provided at its radially inner end or extension 33 with a radially outwardly extending annular flange or shoulder 35; and a coil type retracting spring 36 acts in the axial direction of the plug (radially of the core 11) between the retaining ring 30 and the shoulder 35 to normally urge the plug 31 radially inwardly, and thus out of gripping engagement with the shell 17. A further coil spring 38, of lesser strength than the spring 36, also acts against the shoulder or flange 35, in a manner and for a purpose to be described. It will be understood that the flange 35 is of adequately small external diameter to enable the action of plug 31 in opening 15, including radial removal or replacement of the plug assembly 12, as described above.

The inflating bladders or envelopes 14, one disposed longitudinally against each of the vertically extending walls 40 of the mandrel column 13, as illustrated in FIGS. 4 and 5, are shown in FIGS. 1 and 2, as well as in the modification of FIG. 3, as being of substantially the full axial length of the mandrel 10, although it is to be understood that bladders of partial length, spaced from one another along this axial direction may be alternatively employed, as illustrated and described in my copending application, Serial No. 570,881, identified above. Members 14 are liquid and gas tight, being preferably of a width, when collapsed radially as in FIG. 4, approximating the horizontal width of the column wall 40, and having a substantial area of engagement with the latter even when inflated, as shown in FIG. 5.

Inflatable members, envelopes or bladders 14 are each provided with a tubular fitting 41 (FIGS. 1 and 2) extending through the adjacent column wall 40 and in communication with the interior of the column, at the upper end of the latter. This upper zone of the column is sealed from the remainder of the latter by a welded cross plate 42, and the enclosed space serves as a fluid manifold for the respective fittings 41 and bladders 14, by which each is equally inflated under like pressure applied to the manifold space through a connector tube 43, which extends radially through one of the column walls and through the core 11, where it is connected with a suitably valved source of pneumatic or hydraulic pressure (not shown).

The respective bladders or envelopes 14 act radially outwardly against the inner ends of the holding springs 38 on the four sides of the column 40, and upon the abutment shoulder or flange 35 of the plug 31 there-adjacent (i.e., through the fully collapsed spring 38) when the associated bladder or envelope 14 is inflated, as illustrated in FIGS. 5 and 6 of the drawings. This urges the gripping plugs 31 of the respective, axially spaced sets of plug assemblies 12 radially outwardly into gripping engagement with corrugations of the shell 17, as explained above.

As pointed out above, the retracting spring 36 of the assembly 12 is stronger than the holding spring 38, so that the plugs 31 are normally held in their retracted position of FIG. 4 when the inflating means described above are deflated. It is simply the function of the springs 38, in this condition of the mandrel, to hold the plugs 31 from falling radially inwardly and downwardly of the plugs receiving openings 15, thus insuring that the mandrel 10 is at all times in condition for action.

As illustrated in FIGS. 1, 2 and 3, the mandrel core 10 is provided, adjacent its upper end, with fixed, radially projecting ears 45, by which the mandrel may be engaged to pull the same from the shell 17.

A mandrel of the foregoing description will, when its inflating members are inflated and its plug assemblies radially outwardly projected, grip the corrugations of the shell 17 at a sufficient number of zones and under sufficient expansive force to enable downward driving of the shell by this means of engagement, alone, and without requiring the application of any force to the bottom plate or foot 23 (other than its engagement by the core 11) such as would tend to tear out the plate.

FIG. 3 of the drawings illustrates an alternative embodiment of the mandrel, here designated generally by the reference numeral 48, which is in all essential respects similar to the mandrel 10 in that it is in a continuous solid circumferentialy and axial section as distinguished from a split type. Accordingly, corresponding parts in the embodiment of FIG. 3 are indicated by corresponding reference numerals, and further description thereof will be dispensed with.

Mandrel 48 is built up of a desired number of axially successive core lengths or section 49, which are rigidly secured to one another at axially adjacent and overlapped ends thereof, as at 50 (FIG. 3), by axially and circumferentially spaced bolts 51. These lengths or sections are provided with radial openings receiving the gripping plug assemblies 12, as in the first described embodiment.

Thus, by bolting together a desired number of the lengths, sections or segments 49 it is possible to accomplish the driving of piles to different lengths. Furthermore, the respective successive lengths 49 may be of equal external diameter, as in the embodiment of FIGS 1 and 2, or they may be assembled in lengths of differing or progressively smaller diameter, so as to conform to any design criterion elected by the designer of a foundation, as to the shape of the piles employed therein.

Furthermore, successive lengths of the internal bracing column of the mandrel 48, here designated 58, may be assembled in endwise overlap and suitably united, such component lengths being designated 54. As in the first embodiment, the thus constituted column serves as a centralizing and reaction support for the expansible bladders or envelopes 14, as well as performing the function of a fluid pressure manifold or chamber.

Referring again to FIGS. 4 and 5, in the interest of neededly stiffening and rigidifying either of the mandrels 10 or 48, radially extending ribs 56, of a suitably heavy gage plate stock and co-extensive in length with the mandrel, are welded at opposite radial ends thereof to the corners of the column 13 and to the inner surface of the core wall, respectively. This affords a braced column and core structure which is of great rigidity and strength, indeed, not subject in any axial zone thereof to yielding to bending stress in the radial sense, such as is constantly set up in the use of pile driving mandrels.

FIGS. 9 through 12 illustrate a further alternative type of mandrel contemplated by the invention, which may be fabricated in assembled telescoped and bolted sections, similar to the adaptation of FIG. 3, this type, as shown in FIG. 9, being generally designated 60, or may be in a uniform external diameter throughout the length of the mandrel, this type being shown in FIGS. 10, 11 and 12 and generally designated 61.

In these embodiments, the structural features of the respective cores 62, 63, the reaction column and bracing provisions therefor, the inflatable members and provisions to supply the same with pneumatic or hydraulic inflating fluid, and certain other features, correspond with what is shown and described in FIGS. 1 through 8, hence corresponding reference numerals are employed to designate corresponding parts, and further description thereof is dispensed with.

In the forms of FIGS. 9 through 12, the respective mandrels 60, 61 carry sets of radially acting expanding plugs or fingers 65 at axially spaced zones thereof which

are in the form of plate-like members contoured on their radially outermost surfaces **66** in a corrugated outline suitable for mating engagement with the corrugations of the pile shell to be driven; and alternating with these fingers are sets of spring assemblies, designated **68**, as distinguished from the coaxial assemblies **12** of gripping plugs and spring provisions characteristic of the embodiments of FIGS 1 through 8.

For the reception of the sets of pile gripping plate plugs **65**, the wall of the mandrel **60** or **61** is provided with axially elongated radial openings **67** therethrough, rounded at their top and bottom edges and the portion **65'** of the plug **65** receivable in these openings is correspondingly contoured, but, of course, in slightly smaller cross sectional area. As best shown in FIG. 11, the plug portion **65'** is, at its inner edge, secured by a pair of axially spaced bolts **69** to a channel member **70** which backs it along its axial length; and each of these channel members has its flanges directed inwardly and welded within the outwardly directed flanges of an elongated pressure plate **71** of channel-shaped cross section. This pressure plate is substantially co-extensive in length with the mandrel inflating member **14**, which bears radially outwardly against the inner surface thereof, and thus urges the sets of plugs along one side of the reaction column **13** radially outwardly for gripping engagement with the mandrel.

The spring assemblies **68** (FIG. 12) which retract the plugs **65** are, like the latter, arranged in longitudinally or axially spaced horizontal sets, alternating with the plug sets, as mentioned above. Each such assembly includes a coil spring **73** bearing radially inwardly against the outer surface of the elongated pressure plate **71**, the spring being centered on the stem of a stud **74** whose head **75** threads into a radial opening **76** in the wall of the mandrel core **60** or **61**, the outer end of the spring being received in this hole and bearing against the stud head **75**. The latter is formed at **77** for the reception of a suitable wrench, as of the Allen type, enabling an adjustment of the force of spring **73**, or the removal of the latter through hole **76**, if desired.

Thus, it is seen that the spring assemblies **68** act at a plurality of longitudinally spaced points against the pressure plate **71** to urge the plugs **65** radially inwardly, upon deflation of the associated inflatable member **14**. Suitable further provisions may be made, as will suggest themselves to those skilled in the art, for sustaining the weight of the elongated pressure plate **71**, if this is found desirable.

As in the first described embodiments, radial bracing ribs, designated **79**, may be provided along the corner zones of the reaction column **13**, acting between the latter and the core to stabilize and centralize the parts relative to one another. If desired, these ribs may be welded only to the column corners, having simple abutting engagement at their outer edges with the inner wall of the core **60** or **61**, through which it is desired to transmit the hammer blows, rather than through the reaction column.

FIGS. 13, 14 and 15 show a further alternative adaptation of the mandrel, generally designated **82**, FIG. 15 in particular illustrating structural details of the plug mounting provisions, such as have been described in connection with FIGS. 9 through 12, hence designated by corresponding reference numerals.

In this embodiment, and as indicated in FIG. 13, it is contemplated that the mandrel **82** incorporate pressure plate provisions for the inflatable members **14** in the form of sets of pressure plate lengths **84** of outwardly flanged, channel-shaped cross section, and to employ elongated inwardly flanged plug mounting members **85** which are each formed of an extended length of channel stock, substantially equaling the length of the associated inflatable member **14**. The plug portions **65'** of the gripping plugs or fingers **65**, are secured by bolts **69** at axially spaced points, as in the form of FIGS. 9–12, and the flanges of the members **85** which fit within those of the pressure plates **84** are suitably secured in fixed relation to the latter, as by welding.

It is seen that the embodiments of FIGS. 9–12 and FIGS. 13 and 14 resemble one another closely, save for the fact that in the former the pressure plates engaged by the inflatable members **14** are of the substantially full length of the latter, whereas in the form of the latter each plug mounting channel member **85** is of full length. Suitable centralizing and stabilizing ribs **79** may be provided in the embodiments of FIGS. 13 and 14, as in the preceding one, it being noted that in this embodiment there is a slight spacing of these ribs from the inner wall of the core of mandrel **82**, permitting some radial equalizing play.

Retracting spring provisions are made in the embodiment of FIGS. 13 and 14, similar to what is shown in FIGS. 9 through 12, hence not requiring specific illustration and further description.

The invention provides, in any of the illustrated embodiments thereof, a mandrel made up of a core which is substantially continuous in a circumferential sense, whether of a straight cylindrical and one-piece construction or jointed and/or stepped to different diameters at conveniently placed locations, which core is of great strength, rigidity and ability to resist lateral flexure. If made up of individual segments, mounted and bolted at their end connections, there is nevertheless a good sturdy joint capable of bearing and transmitting tremendous bending stresses to the next succeeding portion of section of the mandrel core.

The expanding and gripping plugs **31** or **65** will, under relatively moderate fluid pressure applied to the inflatable members **14**, grip the shell **17** at multiple points and with great expansive force to enable the shell to be driven properly into the ground.

After the driving has been completed and the fluid pressure released, the plugs are quickly retracted by the spring mechanism, whether in the form of coaxial assemblies **12** (FIGS. 1 through 8) or axially spaced assemblies **68** (FIGS. 9 through 15), these assemblies being in each case uniformly distributed around the circumference of the mandrel core. In each instance, the spring assemblies may be easily and quickly withdrawn from the core. Parenthetically, it may be noted that in the embodiments of FIGS. 9 through 15 there is no need for provisions such as the secondary springs **38** of FIGS. 1 through 8, to hold the plugs against dropping out of their core openings, since the plug portions **68** and associated mounting means are of sufficient radial extent to prevent such occurrence.

In all embodiments the driving head end of the interior square column **13** serves as an air chamber or manifold, into which the respective inflatable members **14** communicate for a common source of fluid pressure supply. Tremendous expansion forces may be applied to the expanding plugs under this mode of operation, and the mandrel can be made to operate with great success under even the most severe driving conditions. Maintenance of the improved mandrel is simple, the number of parts is small, and in any of its embodiments it gives excellent overall performance.

FIGS. 16, 17 and 18 of the drawings show an improvement and refinement over the embodiments of FIGS. 9–15, in which the plugs **65** are secured or yoked on elongated pressure plates or members **71** or **84** extending lengthwise of the mandrel. In accordance with FIGS. 16–18, the plugs have a floating, rather than a fixed, mount on such members, which allows for wear on the slots **67** in the mandrel (designated **88** in FIGS. 16–18), wear of the plugs themselves and wear on the elongated pressure members or plates, designated **89**. An extended life time of the mandrel is the result. Structural features common to those of FIGS. 9–15 are designated by the same reference numerals, and further description is unnecessary.

As best shown in FIG. 17, the pressure plates **89**, of

substantially full mandrel length in the manner of FIGS. 9–12, although the alternate proportioning of FIGS. 13 and 14 may be employed, if desired, differ from the respective pressure plates **71**, **84** in that they are of generally box-like horizontal cross section and have inturned flanges **90** at their outer sides. A floating plug-guide **91** of block-like, generally T-shaped cross section, one for each of the expanding plugs **92**, is internally received in these box-like pressure plates, and the plug is bolted or otherwise secured to the outer face of the plug-guide **91** which floats or slides within the flanges **90**. Otherwise, the plug **92** may be of any desired cross sectional contour, generally similar to what is shown in FIGS. 9 through 15, and is urged outwardly by the inflating members **14** bearing against the pressure plates **89** in the fashion previously described. This floating arrangement contributes to diminished wear and increased life of the mandrel **88**, in the respects referred to above.

Retracting spring assemblies **94** (FIG. 18) are provided for the pressure plates **89**. Sprockets **95** mounted between the flanges **90** of the pressure plates receive the inner ends of compression springs **96** which act inwardly against the pressure plate. Each spring **96** acts outwardly against an abutment screw element **97** threaded into the body of the mandrel **88** so as not to project beyond its outer periphery.

In all other respects, the mandrel of FIGS. 16, 17 and 18 is substantially the same as the embodiments previously described, and has all the advantages set forth in the description thereof.

What I claim as my invention is:

1. A fluid pressure operated, expanding mandrel structure for the driving of corrugated pile shells and like elongated forms, comprising an external tubular core of length of the order of that of the form, a driving head engaged with one end of said core to receive and transmit heavy blows axially thereto, internal reaction means fixedly mounted within said core in radially inwardly spaced relation thereto at certain zones spaced angularly about the axis thereof, said core having radial apertures through the same, sets of gripping plugs received in said apertures for radial movement into and out of gripping engagement with the form to be driven, said plugs being radially inwardly sustained within said core by pressure plate members extending longitudinally within the core, spring means acting to normally urge said plugs radially inwardly in their respective apertures, fluid pressure inflatable means acting on said plugs, when inflated, to urge the latter outwardly for said gripping engagement with the form, comprising individual inflatable members mounted within and extending axially of said core, said inflatable members radially inwardly engaging and being sustained by said internal reaction means, said reaction means comprising an elongated hollow column of non-circular flat-sided cross section, said respective inflatable members inwardly engaging different sides of said column and acting in different radial directions between said column and said respective pressure plate members to urge said plugs outwardly, and means extending through said plugs from the outer ends thereof for removably mounting the same on said pressure plate members.

2. A fluid pressure operated, expanding mandrel structure for the driving of corrugated pile shells and like elongated forms, comprising an external tubular core of length of an order of that of the form, a driving head engaged with one end of said core to receive and transmit heavy blows axially thereto, an elongated internal bracing and reaction column of non-circular cross section fixedly mounted within and extending longitudinally of said core, being in radially inwardly spaced relation to the latter thereto at column surfaces arranged angularly about the axis thereof, said core having radial apertures through the same in opposed relation to said respective column surfaces, each of said apertures receiving a gripping plug for radial movement into and out of gripping engagement with the form to be driven, fluid pressure inflatable means acting on said plugs, when inflated, to urge the latter outwardly for said gripping engagement with the form, comprising individual inflatable members mounted within and extending axially of said core, said inflatable members being radially inwardly sustained by said surfaces of said internal reaction column, an elongated pressure plate for each of said inflatable members, means providing a non-rigid connection with radially outward force transmitting characteristics between said pressure members and said plugs, and means connecting said inflatable members with a source of fluid pressure.

3. A fluid pressure operated, expanding mandrel structure for the driving of corrugated pile shells and like elongated forms, comprising an external tubular core of length of an order of that of the form, a driving head engaged with one end of said core to receive and transmit heavy blows axially thereto, an elongated internal bracing and reaction column of hollow, non-circular cross section fixedly mounted within and extending longitudinally of said core, being in radially inwardly spaced relation to the latter thereto at column surfaces arranged angularly about the axis thereof, said core having radial apertures through the same in opposed relation to said respective column surfaces, each of said apertures receiving a gripping plug for radial movement into and out of gripping engagement with the form to be driven, fluid pressure inflatable means acting on said plugs, when inflated, to urge the latter outwardly for said gripping engagement with the form, comprising individual inflatable members mounted within and extending axially of said core, said inflatable members being radially inwardly sustained by said surfaces of said internal reaction column, an elongated pressure plate for each of said inflatable members which is of length substantially coextensive with said column, individual pressure members for said plugs in force transmitting engagement with said pressure plate, said pressure plates being directly engaged radially by said respective inflatable members and said pressure plates being directly engaged radially by said plugs, and means connecting said inflatable members through said column with a source of fluid pressure.

4. A fluid pressure operated, expanding mandrel structure for the driving of corrugated pile shells and like elongated forms, comprising an external tubular core insertable within the form and having radial apertures through the same, a driving head engaged with one end of said core to receive and transmit heavy blows axially thereto, gripping plugs received in said apertures for radial movement into and out of gripping engagement with said form, fluid pressure inflatable means acting radially of said plugs to urge the same outwardly for said gripping engagement, an elongated pressure member disposed between said inflatable means and said plugs to transmit force from the former to the latter, and floating connection means between said plugs and said member whereby said plugs are guided individually for independent floating movement in relation to said pressure member while being urged by the latter for said gripping engagement.

5. A fluid pressure operated, expanding mandrel structure for the driving of corrugated pile shells and like elongated forms, comprising an external tubular core insertable within said form and of length of an order of that of the latter, a driving head engaged with one end of said core to receive and transmit heavy blows axially thereto, an elongated internal bracing and reaction column fixedly mounted within and extending longitudinally of said core in radially spaced relation thereto, said core having radial apertures through the same, gripping plugs received in said apertures for radial movement into and out of gripping engagement with said form, fluid pressure inflatable means acting between said column and plugs to urge the latter outwardly for said gripping engagement, an elongated pressure member disposed be-

tween said inflatable means and said plugs to transmit force from the former to the latter, floating connection means between said plug and said member whereby said plugs are guided individually for independent floating movement in relation to said pressure member while being urged by the latter for said gripping engagement, and spring means acting between said core and pressure member to urge said plugs radially inwardly out of said gripping engagement.

6. A driving mandrel insertable axially in a pile shell or like elongated tubular form and adapted to radially outwardly engage and grip such form, comprising an external elongated and rigidly unitary tubular core of a sufficient thickness of wall to enable said core to receive and sustain heavy blows imparted to one end thereof, the wall of said core being provided with openings therethrough which are spaced from one another peripherally and axially of the core, an elongated reaction member mounted in fixed relation to and within said core to extend axially thereof, said reaction member having portions spaced radially inwardly from the core wall and being provided at said portions with flat outer axially extending surfaces, gripping elements mounted for radial movement in said core wall openings into and out of gripping engagement with said form for the axial transmission to the latter of the force of blows imparted to said end of the core, and fluid pressure expanding means sustained radially inwardly by said reaction member and acting in the radial space between said core wall and said reaction member to expand said gripping elements radially into gripping engagement with said form, said last named means comprising elongated, fluid pressure inflatable members sustained radially inwardly by said surfaces of said reaction member and acting radially outwardly on said gripping elements when said inflatable members are inflated, and means engaged between said respective inflatable members and the gripping elements and movable radially relative to said reaction member to transmit expanding force from said inflatable members to the gripping elements, including pressure members, and radial thrust transmitting connections between said gripping elements and said pressure members, said connections including means restraining relative movement between said elements and said members radially of the core while permitting relative movement axially of the core.

7. A driving mandrel insertable axially in a pile shell or like elongated tubular form and adapted to radially outwardly engage and grip such form, comprising an external elongated and rigidly unitary tubular core of a sufficient thickness of wall to enable said core to receive and sustain heavy blows imparted to one end thereof, the wall of said core being provided with openings therethrough which are spaced from one another peripherally and axially of the core, an elongated tubular reaction member mounted in fixed relation to and within said core to extend axially thereof, said reaction member having portions spaced radially inwardly from the core wall and being provided at said portions with flat outer axially extending surfaces, gripping elements mounted for radial movement in said core wall openings into and out of gripping engagement with said form for the axial transmission to the latter of the force of blows imparted to said end of the core, and fluid pressure expanding means sustained radially inwardly by said reaction member and acting in the radial space between said core wall and said reaction member to expand said gripping elements radially into gripping engagement with said form, said last named means comprising elongated, fluid pressure inflatable members sustained radially inwardly by said surfaces of said reaction member and acting radially outwardly on said gripping elements when said inflatable members are inflated, and means engaged between said respective inflatable members and the gripping elements and movable radially relative to said reaction member to transmit expanding force from said inflatable members to the gripping elements, including pressure members, and radial thrust transmitting connections between said gripping elements and said pressure members, said connections including means restraining relative movement between said elements and said members radially of the core while permitting relative movement axially of the core, and means to inflate said inflatable members, including fluid pressure transmitting passage means in communication therewith and constituted at least in part by the interior of said tubular reaction member.

8. An expanding mandrel for lengthwise driving of pile shells and like elongate forms, comprising: an elongate rigid tubular core wall, a driving head on one end of said core wall for transmitting the forces of heavy blows in compression axially to the wall, said wall having at least one row of axially spaced radial apertures therethrough, a plurality of individually movable gripping plugs slidably engaging in said apertures for radial movement into and out of engagement with said form, whereby the forces transmitted axially to the wall are transmitted thereby to the gripping plugs, radial thrust producing means within the core wall for urging the plugs outwardly for gripping engagement with said form, radial thrust transmitting connections providing relative movement between said radial thrust producing means and the inner ends of said plugs.

9. An expanding mandrel for lengthwise driving of pile shells and the like forms, comprising: an elongate rigid tubular core wall; a driving head overlying said core wall at one end for transmitting the forces of heavy blows to the core wall, said wall having lengthwise rows of axially spaced radial apertures therethrough; individually movable gripping plugs slidably engaging in said apertures for radial movement into and out of engagement with said form; an elongate force transmitting member disposed inwardly of each row of apertures, said force transmitting members having lengthwise slideway means thereon; slides on the inner ends of said plugs engaging in said slideway means; and fluid pressure expansible means engaging said force transmitting members for forcing the same outwardly.

10. A mandrel as claimed in claim 9, said force transmitting members each comprising an outwardly facing channel, said slides comprising nuts engaging in said channel and to which nuts the inner ends of said plugs are removably attached.

11. In an expanding mandrel for axial driving of elongate hollow forms, an elongate core having a cylindrical side wall with at least one lengthwise row of radial apertures spaced along the length thereof, gripping plugs engaging in said apertures and being slidable radially inward and outward therein, a force transmitting member disposed in said core behind said row, said member being radially movable in said core, radial force transmitting connections between the inner ends of said plugs and said member, said connections restraining relative radial movement between said plugs and member and providing freedom of movement between said plugs and member axially of said core, and means for moving said member radially in said core.

12. An expanding mandrel for lengthwise driving of pile shells and like elongate forms, comprising an elongate rigid core having a generally cylindrical wall, a driving head on one end of said core for transmitting the forces of heavy blows axially of the wall, an axial column rigidly affixed within said core and having a plurality of radially outwardly facing surface portions disposed at angularly spaced intervals thereon, said core wall having a plurality of angularly spaced openings therethrough disposed radially outward of the surface portions on the column, a plurality of thrust transmitting members having channels therein, said thrust transmitting members being respectively disposed radially outward of said surface portions and being movable radially inwardly

and outwardly with respect thereto, fluid inflatable means between the surface portions of said column and said thrust transmitting members for forcing the latter radially outwardly from the column, means engaged between said wall and said thrust transmitting members for retracting the latter radially inwardly towards the column, a plurality of gripping elements slidable radially inward and outward in said openings, and radial thrust bearing means movably mounted in said channels for connecting inner sides of said gripping elements to said thrust transmitting members.

13. An expanding mandrel for lengthwise driving of pile shells and like elongate forms, comprising an elongate rigid core having a generally cylindrical hollow wall, a driving head on one end of said core for transmitting the forces of heavy blows axially of the wall, an axial column rigidly affixed within said core and having a plurality of radially outwardly facing surface portions disposed at angularly spaced intervals thereon, said core wall having a plurality of angularly spaced openings therethrough disposed radially outward of the surface portions on the column, a plurality of thrust transmitting members having outwardly open channels extending axially of the core, said thrust transmitting members being respectively disposed radially outwardly of said surface portions and being movable radially inwardly and outwardly with respect thereto, fluid inflatable means between the surface portions of said column and said thrust transmitting members for forcing the latter radially outwardly away from the column, means engaged between said wall and said thrust transmitting members for retracting the latter radially inwardly towards the column, a plurality of gripping elements slidable radially inward and outward in said openings, radial thrust bearing means slidably mounted in said channels, and means for connecting inner sides of said gripping elements to said radial thrust bearing means.

14. An expanding mandrel for lengthwise driving of pile shells and like elongate forms, comprising an elongate rigid hollow core having a generally cylindrical outer wall, a driving head on one end of said core for transmitting the forces of heavy blows axially of the wall, an axial column rigidly affixed within said core and having a plurality of radially outwardly facing surface portions disposed at angularly spaced intervals thereon, said core wall having a plurality of angularly spaced openings therethrough disposed radially outward of the surface portions on the column, a plurality of thrust transmitting members having outwardly open channels therein, said channels being elongate in the axial direction of the core,

said thrust transmitting members being respectively disposed between said surface portions and the wall of the core and being movable radially inwardly and outwardly with respect to said wall, fluid inflatable means between the surface portions of said column and said thrust transmitting members for forcing the latter radially outwardly away from the column and towards the wall, means engaged between said wall and said thrust transmitting members for retracting the latter radially inwardly towards the column and away from the wall, a plurality of gripping elements slidable radially inward and outward in said openings, radial thrust bearing means movably mounted in said channels, and means extending through said gripping elements from the outer sides thereof for removably mounting the same on said thrust bearing means for connecting inner sides of said gripping elements to said radial thrust bearing means.

15. An expanding mandrel for lengthwise driving of pile shells and like elongate forms, comprising: an elongate rigid tubular core wall, a driving head on one end of said core wall for transmitting the forces of heavy blows in compression axially to the wall, said wall having at least one row of axially spaced radial apertures therethrough, a plurality of individually movable gripping plugs slidably engaging in said apertures for radial movement into and out of engagement with said form, whereby the forces transmitted axially to the wall are transmitted thereby to the gripping plugs, and means within the core wall for urging the plugs outwardly for gripping engagement with said form, said means comprising elongate pressure transmitting means disposed lengthwise within said core wall, abutting connections between the inner ends of said plugs and said pressure transmitting means, said connections providing freedom of movement between the plugs and the pressure transmitting means, said connections providing freedom of movement between the plugs and the pressure transmitting means in the axial direction of the core wall, and elongate fluid pressure expansible means engaging said pressure transmitting means for forcing the same outwardly.

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