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(54) VARIABLE DEPTH GROOVED DRILL STRING MEMBER

Bohrstrangelement mit einer Nut von variabler Tiefe

ELEMENT DE TIGE DE SONDAGE COMPORTANT DES RAINURES A PROFONDEUR VARIABLE

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Description

This invention relates in general to drill string members used in the rotary drilling art of the oil and gas industry. In particular the invention relates to an intermediate weight member adapted for placement between relatively lighter weight drill pipe and heavier weight drill collars.

Intermediate weight members have been used in the art of rotary drilling as a transition member between stiff drilling collars and standard drill pipe. Such intermediate weight members reduce fatigue in the stress-susceptible transition zone between drill pipe and drilling collars.

A prior art intermediate weight member sold by OMSCO Industries, includes a relatively heavy weight tubular member having upper and lower sections separated by a short center wear pad. The member has a constant inner diameter along its entire length. The upper and lower sections are of constant outer diameter. The wear pad has an outer diameter which is slightly less than about 13 millimetres larger than the outer diameter of the upper and lower sections. The outer diameter of the upper section is small enough to enable handling by standard slips and elevators of a drilling rig. The cross-section moment of inertia of the OMSCO intermediate weight member is significantly greater at the center wear pad from that at the upper and lower constant outer diameter sections. Accordingly, the OMSCO intermediate weight member, because of its construction, can be characterised by upper and lower relatively limber sections separated by a relatively stiff center section.

Another intermediate weight drill string member is described in US-4,460,202 to Chance et al. The Chance drill string member includes an upper relatively short slip and elevator section and a lower grooved section which extends substantially the remaining length of the member. The grooved section is of an outer diameter which is larger than the outer diameter of the slip and elevator section, but has spiral grooves formed therein of a number and depth such that the bending moment of inertia along the entire length of the member is susbstantially constant. In other words, the cross-section moment of inertia anywhere along the spiral section is substantially equal to the cross-section moment of inertia in the slip and elevator area. As a consequence, the Chance member can be characterized as having a single bending pattern which is substantially constant from one end of the member to the other. In addition, the spiralled grooved section provides advantages, like other spiralled members, of reduced potential for differential sticking in the hole, aiding in the removal of drilling chips up the annulus between the drill string and the borehole, and possible forward thrusting effect during drilling.

FR-A-2517357 discloses a drill string member possessing three distinct zones longitudinally; a central zone defined by a smooth cylindrical surface hardened to limit wear, and two zones extending to either side of the central zone defined by greater transversal flexibility obtained by grooves formed spirally therein, the three zones having the same external diameter. The depth of the grooves is constant along the length of the grooved zones, such that the cross section moment of inertia along the length of the grooved zones does not vary and is approximately equal to the cross-section moment of inertia of reduced diameter portions defined between each respective grooved zone and the adjacent drill string member end couplings. The features of the pre-characterizing portion of claim 1 herein are common with this disclosure.

It is a primary object of the invention to provide certain advantages of the prior art intermediate weight members described above with a unique mechanical structure.

It is another object of the invention to provide an intermediate weight member which includes not only a slip and elevator section and spiralled sections, but may also include a center wear pad section.

It is still another object of the invention to provide a drill string member of intermediate weight having a structure such that the cross-section moment of inertia of the member gradually changes a significant amount as a function of length along the member so as to reduce bending stresses inherent in regions where bending moments abruptly change.

The objects identified above as well as other advantages and features of the invention are incorporated in a drill string member in accordance with the characterizing part of claim 1. This is an integral elongate tubular member having tool joints placed at each end for screwing to other drill string members above and below. Typically a plurality of the members constructed according to the invention are screwed end to end and form an intermediate weight assembly between drill pipe above and drill collars below. The member, of substantially constant inner diameter along its entire length, includes an upper slip and elevator section of a first outer diameter of a dimension substantially the same as the outer diameter of drill pipe for which it is adpated to connect.

In the invention, the member includes a partially grooved section placed downwardly of the slip and elevator 5 section. The outer diameter of the grooved section is greater than the outer diameter of the slip and elevator section. The grooved section includes first and second grooved sections separated by an ungrooved section.

The ungrooved section is a relatively short section which may include hardbanding rings. Such rings are typically welded on strips that include granulated tungsten carbide particles which inhibit wear. The first and second grooved sections include grooves which vary in depth as a function of the length of the respective section. The first grooved section between the slip and elevator section and the ungrooved section is characterised by spiral grooves which are cut deeply into the outer diameter of the section at its slip and elevator end. Such

grooves are cut progressively less deeply as the length of the first section approaches the ungrooved section.

The second grooved section between the ungrooved section and the lower end of the member likewise has grooves cut into the outer diameter. The depth of such grooves also varies as a function of length. Such grooves are shallow at the ungrooved section end of the second grooved section and are progressively deeper as the length of the section approaches the lower end of the member.

As a result of the grooved sections which have groove depths which vary as a function of length of the member, the bending or cross-section moment of inertia of the member makes a relatively smooth transition from the slip and elevator section to the first grooved section as the length of the member increases from top to bottom. The term "bending moment" as used in the specification and claims shall be interpreted as the moment of inertia of a cross-section where the deflection is calculated. With the depth of the grooves being cut progressively shallower, and then progressively deeper as a function of length along the member, the bending moment of inertia as a function of length increases approximately linearly from the slip and elevator section to the ungrooved section and thence decreases approximately linearly from the ungrooved section toward the lower end of the member. A relatively short reduced diameter section is preferably provided at the lower end of the member. Tool joints are attached e.g., by welding to the top and bottom ends of the member.

The shape of the cross-section moment of inertia as a function of length along the member provides an intermediate heavy wall tool which is relatively more stiff at a short center section, yet is relatively more flexible at its ends. Such characteristics are advantageous in horizontal and directional drilling where the member is likely to be put under compression and a central, relatively more stiff and rugged region provides enhanced life and drilling performance. The spiralled sections of the first and second grooved sections not only provide the advantages of a smoothly varying cross-section moment of inertia of the member as a function of length, but also provide advantages of reducing possible differential sticking problems in the borehole. The novel structure also results in an intermediate weight drill string member of greater weight of the entire member as compared with prior art members. Such greater weight is advantageous in providing more weight on the drilling bit below. The novel structure also provides a greater wear surface toward the center of the member as compared with prior art members.

The objects, advantages and features of the invention will become more apparent by reference to the drawings which are appended hereto and wherein like numerals indicate like parts and wherein an illustrative embodiment of the invention is shown, of which:

Figure 1 is an illustration of the intermediate weight member of the invention with a graphical illustration of its bending moment of inertia as a function of length along the member;

Figure 2 is a more detailed illustration of the intermediate weight member of the invention showing tool joints provided at its upper and lower ends and grooved sections having grooves of varying depth provided below a slip and elevator section; and

Figures 3, 4 and 5 are cross-section illustrations taken along section lines 3-3, 4-4, and 5-5 of Figure 2, which show the depth of grooves varying as a function of length along the member.

A preferred embodiment of the invention is illustrated in Figures 1 through 5 below. Figures 1 and 2 5 illustrate the elongated integral drill string member 10 having tool joints 11 and 12 provided (as by welding) to its upper and lower ends. The tool joint 11 is provided with box threads to releasably join member 10 with other members 10 or with a string of drill pipe above. The tool joint 12 is provided with pin threads to releasably join member 10 or with a bottom hole assembly including drill collars below.

The drill string member 10 has an internal bore of a substantially constant inside diameter along its entire length. It includes a slip and elevator section 14 having a diameter small enough to accommodate slip and elevator equipment of the drilling rig. Such diameter is typically matched to the outside diameter of drill pipe to which it is adapted to connect. The purpose of the drill string member 10 is to provide a thick or heavy wall drill pipe which can tolerate compression and tension forces between the thinner walled drill pipe above and the thicker walled drill collars below. A larger diameter for almost the entire remainder of drill string member 10 is advantageous.

Accordingly, the partially grooved section 16 is characterized by a diameter D which may be about 140mm for a 76mm inner diameter and a 127mm outer diameter for slip and elevator section 14. These dimensions for other sizes of intermediate weight members are scaled depending on the drill pipe size, drill collars, and particular drilling application.

The partially grooved section 16 extends from the lower end of slip and elevator section 14 to a relatively short reduced diameter section 24 of a diameter d_2. For example, for 127mm drill pipe diameter d_2 of reduced diameter section 24 is preferably 130mm for an outside diameter D of about 140mm of a partially grooved section 16. Diameter d_2 could of course be a smaller diameter. For example, it could match the diameter of the slip and elevator section. Diameter d_1 is the size typically used to describe the drill string member, e.g., 127mm pipe. Alternatively, it need not be reduced in diameter from the diameter of partially grooved section 16, but providing a reduced diameter for section 24 increases

the flexibility at the lower end of the drill string member 10, and as a consequence, reduces the bending stress of the drill string member 10.

The partially grooved section 16 includes first grooved section 18 disposed between slip and elevator section 14 and ungrooved section 22. A second grooved section 20 is provided between ungrooved section 22 and reduced diameter section 24 at the lower end of drill string member 10.

The first grooved section 18 preferably includes three right hand spiral grooves 30A, 30B, 30C, the depth of each of which varies progressively with increasing length from the lower end of slip and elevator section 14 to the upper end of ungrooved section 22. Figures 3, 4 and 5 taken at upper, middle and lower section lines 3-3, 4-4, and 5-5 of upper grooved section 18 illustrate that grooves 30A, 30B, and 30C become more and more shallow toward the ungrooved section 22 end, and yet are relatively deep at the upper end of grooved section 18. The depth of the grooves 30A, 30B, 30C at the slip and elevator section is such that the bending moment of inertia at the upper end of first grooved section 18 is approximately the same as that of the slip and elevator section 14.

To illustrate such feature, the graph of Figure 1 below the illustration of drill string member 10 shows that the cross-section moment of inertia at P_1, where grooves 30A, 30B, 30C begin in first grooved section 18, makes a relatively smooth transition from the slip and elevator section 14 to the first grooved section 18. This graph depicts typical values for a 127mm size intermediate weight member. The grooves 30A, 30B, and 30C are progressively shallower with increasing length along grooved section 18 until such grooves vanish at the lower or ungrooved section end of first grooved section 18.

As illustrated by the region I_{22} of the graph of Figure 1, the bending moment of inertia of the ungrooved section 22 is approximately fifty percent greater than that of the slip and elevator section 14.

The grooves 30A, 30B, 30C of second grooved section 20 are shallow cut at the upper or ungrooved section end and are cut progressively more deeply with increasing length as illustrated in Figures 1 and 2 and especially in Figures 5, 4 and 3. Preferably such grooves have a depth at the lower end of second grooved section 20 such that the bending moment of inertia at point P_2 approximately matches that of reduced diameter section 24.

The drill string member 10 of the invention may also include one or more hardbanding rings 26 and 28 about ungrooved section 22. Such rings enhance the wear characteristics of the member where the ungrooved section 22 scrapes against the borehole.

The drill string member 10 of the invention may also include one or more regions of the member which are cold worked to increase fatigue resistance at highly stressed areas. Regions L_8 and L_9 where the upper and lower tool joints 11 and 12 are joined with drill string member 10 are such high stress areas where cold working of the steel material may be beneficial.

The drill string member 10 including upper and lower tool joints 11 and 12 produces advantages of relatively flexible ends with a relatively stiff center section. The center section 22 also functions as a wear region which may be hardbanded.

An integral slip and elevator section 14 provides flexibility at one end. Varying depth grooves 30A, 30B, 30C in first grooved section 18 and second grooved section 20 allow gradual transition of flexibility or cross-section moment of inertia as a function of length over a magnitude ratio of one to about one and one-half.

One of ordinary skill in the drilling art will preferably use the drill string member 10 as an intermediate weight member between drill pipe and drill collars.

A modification of the structure of Figures 1 and 2 may be advantageous where hardbanding between grooved section 18 and grooved section 20 is not necessary. For such a case, the length of ungrooved section 22 may be reduced to zero such that the grooves of grooved section 18 become very shallow at its lower end and actually become continuous with the shallow grooves of grooved section 20. In other words, the shallow grooves of grooved section 18 at its lower end can be continuous with shallow grooves of grooved section 20 at its upper end.

Still another modification of the structure of Figures 1 and 2 may be advantageous, like that above, where the length of ungrooved section 22 may be reduced to zero. Rather than the shallow grooves of grooved section 18 being continuous with the shallow grooves of grooved section 20, such grooves may simply vanish in an alternating or interleaving manner at the point along the length of member 10 where the two grooved sections 18 and 20 come together. In other words, the two sets of groove patterns are not continuous at the intersection point, but rather are spaced from each other at sixty degree intervals, for example, about the periphery of the member 10 at the intersection of grooved section 18 and grooved section 20.

The drill string member 10 is manufactured from a steel bar or tube of outside diameter D. A bore of diameter d_o is formed in the bar or tube. Slip and elevator section 14, reduced diameter section 24, and first and second grooved sections 18 and 20 are formed by conventional machining techniques. Grooves 30A, 30B and 30C are formed with a grooving machine having a flat bottomed cutter. Other groove shapes may be used by those of skill in the machining art without varying from the scope of the invention as defined by the appended claims. Any grooves formed as a function of length in first and second grooved sections 18 and 20 which produce a cross-section moment of inertia versus length profile similar to that of Figure 1 is within the scope of the invention as defined by the appended claims.

Claims

1. A drill string member (10) adapted for placement between a drill collar and a drill pipe comprising,

   an integral elongate tubular member having first and second tool joints (11,12) respectively placed at each end,

   said integral member having a slip and elevator section (14) of a first generally uniform outer diameter (d_1) at one of its ends adjacent the first tool joint (11),

   said integral member having a partially grooved section (16) of a second generally uniform outer diameter (D) which is greater than said first outer diameter (d_1) of said slip and elevator section (14),

   said partially grooved section (16) having an ungrooved intermediate section (22) having opposite ends, a first grooved end section (18) disposed between said slip and elevator section (14) and an end of said ungrooved intermediate section (22), and a second grooved end section (20) disposed between said second tool joint (12) and the other end of said ungrooved intermediate section (22), **characterized in that** the cross-section moments of inertia of the first and second grooved end sections (18, 20) vary as a function of their length such that

   a cross-section moment of inertia of a first end of said first grooved end section (18) adjacent the slip and elevator section (14) approximately matches a cross-section moment of inertia of said slip and elevator section, and a cross-section moment of inertia of a second end of the first grooved end section (18) approximately matches a cross-section moment of inertia of said ungrooved intermediate section (22), and

   a cross-section moment of inertia of a first end of said second grooved end section (20) approximately matches the cross-section moment of inertia of said ungrooved intermediate section (22) and a cross-section moment of inertia of a second end of said second grooved end section (20) matches approximately the cross-section moment of inertia of said slip and elevator section (14).

2. A member according to claim 1 wherein said first and second grooved end sections (18, 20) each have at least one spiral groove disposed therein.

3. A member according to claim 1 or claim 2 wherein said first and second grooved end sections (18, 20) each have three right hand wound spiral grooves (30A, 30B, 30C).

4. A member according to any of claims 1 to 3 wherein said ungrooved intermediate section (22) includes at least one ring of hardbanding (26, 28) secured thereto.

5. A member according to any of claims 1 to 4 wherein said first and second grooved end sections (18, 20) each have three right hand wound spiral grooves of depth in said second outer diameter (D) as a function of length such that said cross-section moment of inertia of said first grooved end section (18) varies approximately linearly with length from its first end to its second end and said cross-section moment of inertia of said second grooved end section (20) varies approximately linearly with length from its first end to its second end.

6. A member according to any of claims 1 to 5 wherein the cross-section moment of inertia of said ungrooved section (22) is approximately fifty percent greater than said cross-section moment of inertia of said slip and elevator section (14).

7. A member according to any of claims 1 to 6 wherein said tool joints (11, 12) are welded to said tubular member at each of its ends.

8. A member according to any of claims 1 to 7 further comprising a reduced diameter section (24) disposed between said second end of said second grooved end section (20) and said other of said tool joints (12), said reduced diameter section (24) being short in length relative to the length of said second grooved end section (20).

Patentansprüche

1. Bohrstrangelement (10), das zwischen eine Schwerstange und ein Gestängerohr eingesetzt werden kann, umfassend:

   ein einstückiges, langgestrecktes rohrförmiges Element mit einem an jedem Ende angebrachten ersten und zweiten Bohrstangenschloß (11, 12),

   wobei das einstückige Element einen Abfangkeilheberabschnitt (14) mit einem ersten im allgemeinen einheitlichen Außendurchmesser (d_1) an einem seiner Enden im Bereich des ersten Bohrstangenschlosses (11) aufweist,

wobei das einstückige Element einen teilweise gerieften Abschnitt (16) mit einem zweiten im allgemeinen einheitlichen Außendurchmesser (D) besitzt, der größer ist als der erste Außendurchmesser (d_1) des Abfangkeilheberabschnitts (14),

wobei der teilweise geriefte Abschnitt (16) einen ungerieften mittleren Abschnitt (22) mit einander entgegengesetzten Enden aufweist, wobei ein erster geriefter Endabschnitt (18) zwischen dem Abfangkeilheberabschnitt (14) und einem Ende des ungerieften mittleren Abschnitts (22) angeordnet ist, und ein zweiter geriefter Endabschnitt (20) zwischen dem zweiten Bohrstangenschloß (12) und dem anderen Ende des ungerieften mittleren Abschnitts (22) angeordnet ist, dadurch gekennzeichnet, daß sich das Querschnittsträgheitsmoment des ersten und des zweiten gerieften Endabschnitts (18, 20) je nach dessen Länge ändert, so daß

ein Querschnittsträgheitsmoment eines ersten Endes des ersten gerieften Endabschnitts (18) im Bereich des Abfangkeilheberabschnitts (14) ungefähr einem Querschnittsträgheitsmoment des Abfangkeilheberabschnitts entspricht, und ein Querschnittsträgheitsmoment eines zweiten Endes des ersten gerieften Endabschnitts (18) ungefähr einem Querschnittsträgheitsmoment des ungerieften mittleren Abschnitts (22) entspricht, und

ein Querschnittsträgheitsmoment eines ersten Endes des zweiten gerieften Endabschnitts (20) ungefähr dem Querschnittsträgheitsmoment des ungerieften mittleren Abschnitts (22) entspricht, und ein Querschnittsträgheitsmoment eines zweiten Endes des zweiten gerieften Endabschnitts (20) ungefähr dem Querschnittsträgheitsmoment des Abfangkeilheberabschnitts (14) entspricht.

2. Element nach Anspruch 1, bei dem der erste und der zweite geriefte Endabschnitt (18, 20) jeweils mindestens eine spiralförmige Nut aufweisen.

3. Element nach Anspruch 1 oder Anspruch 2, bei dem der erste und der zweite geriefte Endabschnitt (18, 20) jeweils drei rechtsgängige Spiralnuten (30A, 30B, 30C) aufweisen.

4. Element nach einem der Ansprüche 1 bis 3, bei dem an dem ungerieften mittleren Abschnitt (22) mindestens ein harter Versteifungsring (26, 28) befestigt ist.

5. Element nach einem der Ansprüche 1 bis 4, bei dem der erste und der zweite geriefte Endabschnitt (18, 20) jeweils drei rechtsgängige Spiralnuten aufweist, deren Tiefe in dem zweiten Außendurchmesser von der jeweiligen Länge abhängt, so daß das Querschnittsträgheitsmoment des ersten gerieften Endabschnitts (18) ungefähr linear mit der Länge von dem ersten Ende zu dem zweite Ende variiert, und das Querschnittsträgheitsmoment des zweiten gerieften Endabschnitts (20) ungefähr linear mit der Länge von dem ersten Ende zu dem zweiten Ende variiert.

6. Element nach einem der Ansprüche 1 bis 5, bei dem das Querschnittsträgheitsmoment des ungerieften Abschnitts (22) ungefähr fünfzig Prozent größer ist als das Querschnittsträgheitsmoment des Abfangkeilheberabschnitts (14).

7. Element nach einem der Ansprüche 1 bis 6, bei dem die Bohrstangenschlösser (11, 12) an jedem Ende des rohrförmigen Elements mit diesem verschweißt sind.

8. Element nach einem der Ansprüche 1 bis 7, des weiteren umfassend einen Abschnitt (24) mit vermindertem Durchmesser, der zwischen dem zweiten Ende des zweiten gerieften Endabschnitts (20) und dem anderen der Bohrstangenschlösser (12) angeordnet ist, wobei der Abschnitt (24) mit vermindertem Durchmesser kurz ist im Verhältnis zur Länge des zweiten gerieften Endabschnitts (20).

Revendications

1. Elément (10) de train de tiges de forage destiné à être placé entre une masse-tige et une tige de forage, comprenant :

un organe tubulaire allongé en une seule pièce comprenant un premier et un second raccord (11, 12) d'outil placés respectivement à ses extrémités,
l'organe en une seule pièce ayant un tronçon (14) de coopération avec des coins de retenue, ayant un premier diamètre externe (d_1) uniforme de façon générale à une première extrémité près du premier raccord (11) d'outil,
l'organe en une seule pièce ayant un tronçon (16) à gorge partielle ayant un second diamètre externe (D) uniforme de façon générale qui est supérieur au premier diamètre externe (d_1) du tronçon (14) de coopération avec des coins de retenue,
le tronçon (16) à gorge partielle ayant un tronçon intermédiaire (22) sans gorge comportant, à ses extrémités opposées, un premier tronçon (18) d'extrémité à gorge placé entre le tronçon

(14) de coopération avec des coins de retenue et une extrémité du tronçon intermédiaire (22) sans gorge, et un second tronçon (20) d'extrémité à gorge placé entre le second raccord (12) d'outil et l'autre extrémité du tronçon intermédiaire (22) sans gorge, caractérisé en ce que les moments d'inertie des sections du premier et du second tronçon (18, 20) d'extrémité à gorge varient en fonction de la longueur de manière que le moment d'inertie de la section d'une première extrémité du premier tronçon (18) d'extrémité à gorge adjacente au tronçon (14) de coopération avec des coins de retenue corresponde approximativement au moment d'inertie de la section du tronçon de coopération avec les coins de retenue, et que le moment d'inertie de la section d'une seconde extrémité du premier tronçon (18) d'extrémité à gorge corresponde approximativement au moment d'inertie de la section du tronçon intermédiaire (22) sans gorge, et que
le moment d'inertie de la section de la première extrémité du second tronçon (20) d'extrémité à gorge corresponde approximativement au moment d'inertie de la section du tronçon intermédiaire (22) sans gorge, et que le moment d'inertie de la section d'une seconde extrémité du second tronçon (20) d'extrémité à gorge corresponde approximativement au moment d'inertie de la section du tronçon (14) de coopération avec des coins de retenue.

2. Elément selon la revendication 1, dans lequel le premier et le second tronçon (18, 20) d'extrémité à gorge possèdent chacun au moins une gorge spiralée disposée vers l'intérieur.

3. Elément selon la revendication 1 ou 2, dans lequel le premier et le second tronçon (18, 20) d'extrémité à gorge possèdent chacun trois gorges spiralées (30A, 30B, 30C) à pas à droite.

4. Elément selon l'une quelconque des revendications 1 à 3, dans lequel le tronçon intermédiaire (22) sans gorge comporte au moins un anneau (26, 28) de bandage dur qui lui est fixé.

5. Elément selon l'une quelconque des revendications 1 à 4, dans lequel le premier et le second tronçon (18, 20) d'extrémité à gorge possèdent chacun trois gorges spiralées à pas à droite dont la profondeur par rapport au second diamètre externe (D) est fonction de la longueur afin que le moment d'inertie de la section du premier tronçon (18) d'extrémité à gorge varie de façon approximativement linéaire avec la longueur de sa première extrémité à sa seconde extrémité et que le moment d'inertie de la section du second tronçon (20) d'extrémité à gorge varie approximativement de manière linéaire avec la longueur de sa première extrémité à sa seconde extrémités

6. Elément selon l'une quelconque des revendications 1 à 5, dans lequel le moment d'inertie de la section du tronçon (22) sans gorge est supérieur d'environ 50 % au moment d'inertie de la section du tronçon (14) de coopération avec des coins de retenue.

7. Elément selon l'une quelconque des revendications 1 à 6, dans lequel des raccords (11, 12) d'outil sont soudés à l'organe tubulaire à chacune de ses extrémités.

8. Elément selon l'une quelconque des revendications 1 à 7, comprenant en outre un tronçon (24) de diamètre réduit disposé entre la seconde extrémité du second tronçon (20) d'extrémité à gorge et l'autre des raccords (12) d'outil, le tronçon (24) de diamètre réduit ayant une faible longueur par rapport au second tronçon (20) d'extrémité à gorge.

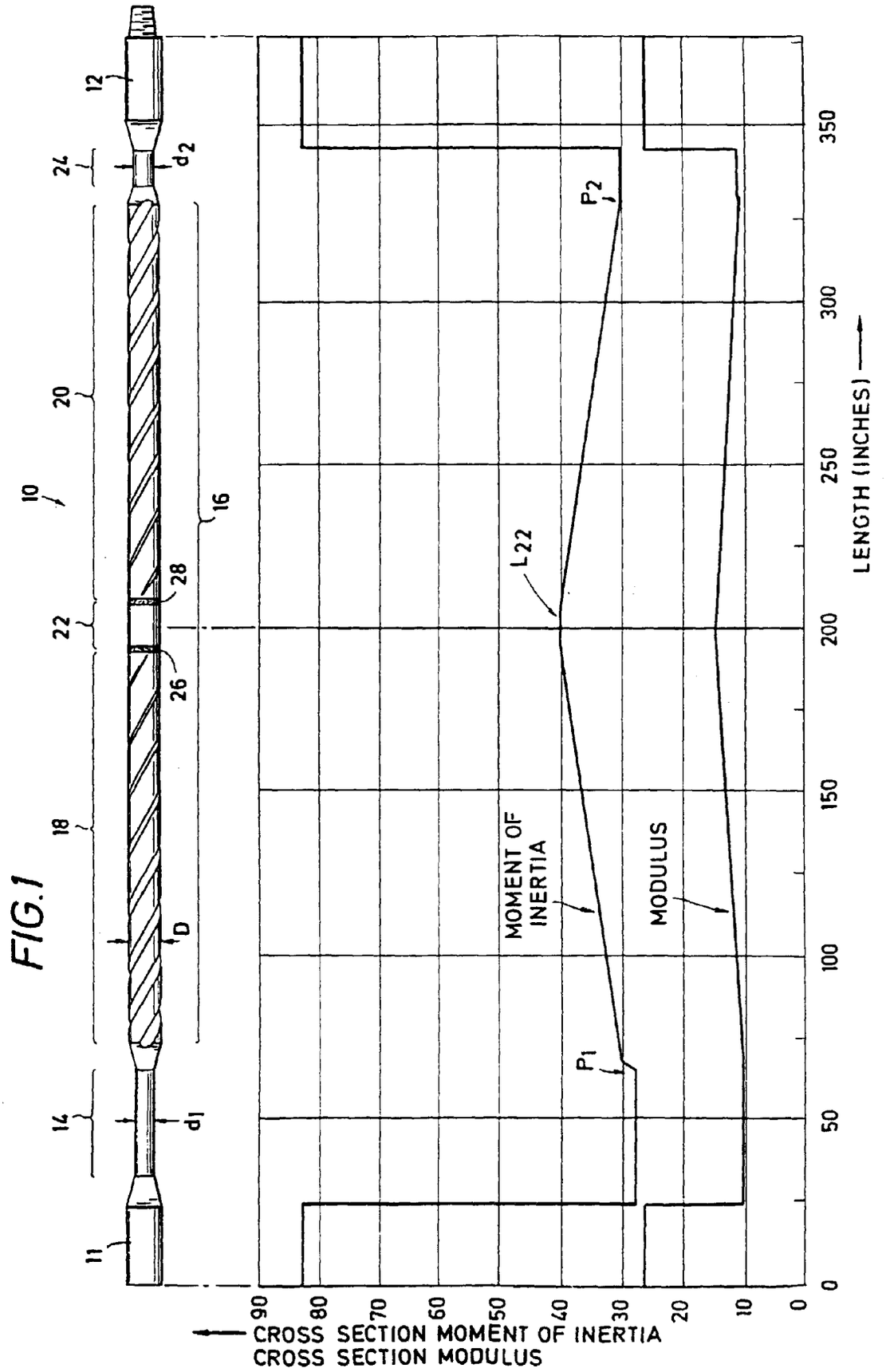

10
11
12
14
16
18
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22
24
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28
D
d1
d2
L22
P1
P2
MOMENT OF INERTIA
MODULUS
LENGTH (INCHES)
CROSS SECTION MOMENT OF INERTIA
CROSS SECTION MODULUS
0
50
100
150
200
250
300
350
10
20
30
40
50
60
70
80
90

FIG.1

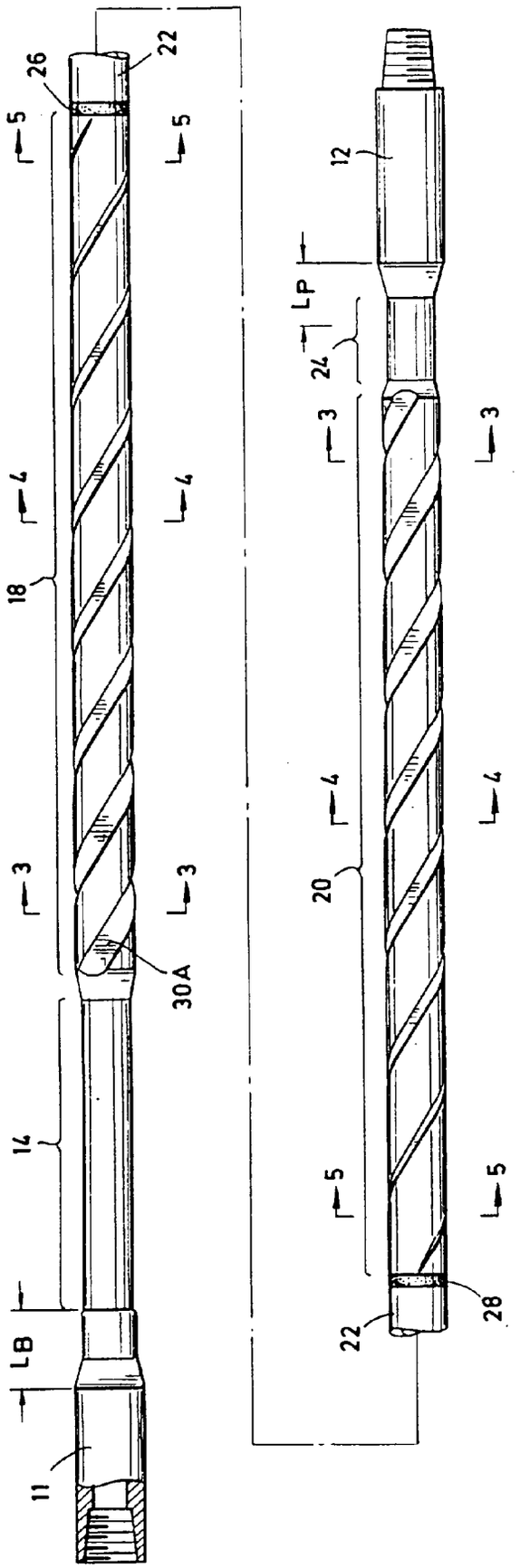


FIG. 2

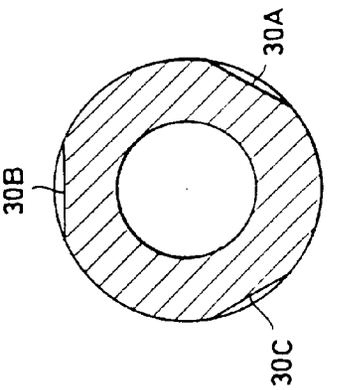


FIG. 5

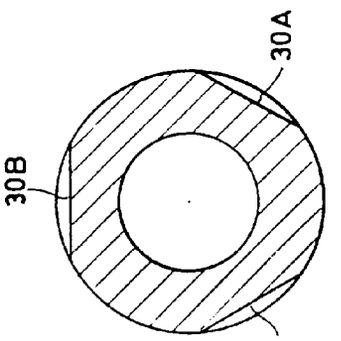


FIG. 4

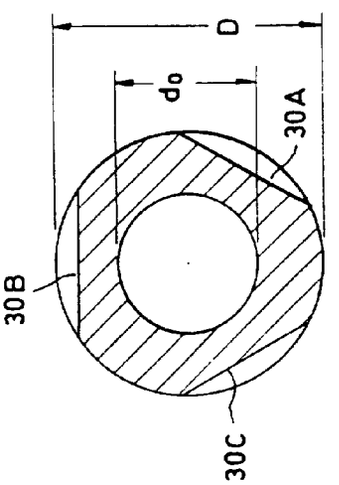


FIG. 3