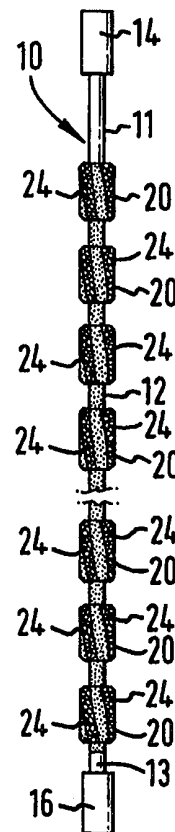




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(21) International Application Number: PCT/GB99/00668 (22) International Filing Date: 2 March 1999 (02.03.99) (30) Priority Data: 09/033,970 3 March 1998 (03.03.98) US (71) Applicants: WEATHERFORD/LAMB, INC. [US/US]; c/o CSC – The United States Corporation Company, 1013 Centre Road, Wilmington, DE 19805 (US). LUCAS, Brian, Ronald [GB/GB]; Lucas & Co., 135 Westhall Road, Warlingham, Surrey CR6 9HJ (GB). (72) Inventors: ROBERTSON, Robert; 16606 Chewton Glen, Tomball, TX 77375 (US). BLIZZARD, William, Alan, Jr.; 4314 Island Hills Drive, Houston, TX 77059 (US). WILSON, Timothy, Lee; 1927 Haddon, Houston, TX 77019 (US). CARTER, Thurman, B.; Beamer, 2901 Roseheath Lane, Houston, TX 77073 (US). JOHANTGES, Paul, Jeffrey; 1802 Wynridge, Deer Park, TX 77536 (US). MCCLUNG, Guy, LaMont, III; 8130 Vintage Creek, Spring, TX 77379 (US). (74) Agent: MARKS & CLERK; 4220 Nash Court, Oxford Business Park South, Oxford OX4 2RU (GB).		(81) Designated States: AU, CA, CN, JP, NO, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>
(54) Title: A MILL AND A METHOD FOR MILLING (57) Abstract A mill comprising a body (12) and milling material (20), characterised in that said body (12) is flexible. A method of milling using said mill, the method comprising the step of lowering said mill into tubulars in a wellbore across an offset portion thereof, operating said mill to mill at least a portion of said tubulars.		



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A Mill and a Method for Milling

This invention relates to a mill and a method for milling. The invention more particularly, but not exclusively, relates to a mill for milling casing in a wellbore which has been deformed or broken due to external effects such as subsidence.

In the construction of an oil or gas well, a string of casing is lowered into a wellbore and cemented in place. The string of casing provides a substantially sealed tube which will carry oil or gas from an underground reservoir to the surface.

It has been observed that due to external effects such as subsidence in the formation surrounding the string of casing, a lower part of the string may become offset from a top part of the string. This creates a deformed, bent, partially collapsed or pinched casing in the string. It then becomes difficult or impossible to pass tools through this section of the string.

Accordingly, the invention provides a mill comprising a body and milling material, characterised in that said body is flexible. The term milling material includes, but is not limited to, any known matrix milling material and any known milling inserts applied in any known way in any known pattern, array, or combination. The body may be essentially solid.

Preferably, the body is provided with a flow bore therethrough.

Advantageously, the body comprises a cable.

Preferably, the cable comprises multiple strands.

Advantageously, the milling material is arranged directly on the cable.

Preferably, the body is provided with at least one sleeve, the milling material arranged thereon. The sleeves may be crimped or welded on.

Advantageously, there is provided a plurality of

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sleeves spaced apart along said body.

Preferably, said body comprises a series of interconnected tubular members.

Advantageously, said body is provided with a member
5 therein.

Preferably, said member is flexible or articulable. In one particular aspect, said member comprises a metal tubular having a series of spaced-apart cuts made by a suitable cutter or by a laser that renders the tubular
10 sufficiently articulable to traverse a wellbore casing or tubing offset or to enter such an offset to mill away portions thereof. In another aspect, the member comprises a series of tubulars one on top of the other positioned in a bore in a cable. Any suitable member which flexes
15 either due to its material and dimensions and/or flexes due to recesses, grooves, cut, dimples and/or indentations thereon, therein, and/or therethrough may be used.

Advantageously, a sealing tube surrounds the member.
20 The sealing tube may be made for example of plastic or flexible metal so that fluid under pressure can flow through the mill. Fluid circulation through a bore of an articulable member or through a sealing tubular within an articulable member or members provides for circulation
25 from the mill into the wellbore annulus to circulate cuttings and debris away from the mill and/or to cool the mill. Any suitable wellbore or drilling fluid may be used, including, but not limited to, clean brine.

Preferably, the member is a tube.

Advantageously, a weight is disposed on a lower end
30 of the mill.

Preferably, wherein the mill is at least partly hollow for accommodating a stinger. In one aspect the stinger is sufficiently long to facilitate positioning of
35 the mill with respect to a previously milled-out portion

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of an offset.

Advantageously, the mill comprises a stinger and a shear pin arranged therebetween. Shearing of the shear pin releases the stinger for movement up into the bore of the mill body during milling by the wellbore mill.

Preferably, the body is provided with a fishing member.

Advantageously, the mill further comprises a guide mill. The guide mill or guide mill portion may be provided with one, two, three, four or more helices of milling matrix material therearound and an upper laced collar portion with a single, double, triple, or quadruple helix of matrix milling material therearound. Use of a single helix on the laced collar portion facilitates emplacement of a tong around the milling portions.

Preferably, the mill further comprises a top sub and a bottom sub connected to the body.

Advantageously, the body includes a tapered portion to facilitate passage of the mill through a wellbore.

Preferably, the milling material is replaceable.

The invention also provides a method of milling using a mill in accordance with the present invention, the method comprising the step of lowering the mill into tubulars in a wellbore across an offset portion thereof, operating the mill to mill at least a portion of the tubulars.

Preferably, the method further comprises the step of introducing a secondary mill into the tubulars in a wellbore across an offset portion thereof, operating the secondary mill to mill at least a portion of the tubulars and/or formation external to the wellbore.

Advantageously, the secondary mill comprises a stinger shear pinned thereto, the method further comprising the step of shearing the shear pin during

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operation of the mill, whereupon the stinger is released from the mill, or is swallowed by the mill. The stinger is used for positioning and stabilising a mill or mills of the system adjacent an area milled out by the flexible
5 mill for enlargement thereof.

Preferably, the method comprises the step of lowering a liner across the milled out section of tubular.

Advantageously, the liner is sealed to the tubular.
10 The liner is generally not at as extreme an angle as was the original casing offset, thus facilitating the passage therethrough of wellbore devices and tubulars.

Preferably, the method comprises the step of rotating the mill to facilitate the milling.

15 Advantageously, the method comprises the step of reciprocating the mill to facilitate the milling.

The invention also provides a method comprising the steps of inserting a liner over an offset portion of said tubulars in a wellbore, for facilitating the passage of
20 tools therethrough.

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For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1A is a front view of a first embodiment of a
5 primary mill in accordance with the present invention;

Figure 1B is a front view of the primary mill of Figure 1A provided with an additional member;

Figure 1C is a cross-sectional view of the primary mill of Figure 1A;

10 Figure 1D is a cross-sectional view of a second embodiment of a primary mill in accordance with the present invention;

Figure 2 is a front view of a first embodiment of a secondary mill in accordance with the present invention;

15 Figure 3 is an unwrapped side view of part of a part of the mill of Figures 1A, 1C or 2;

Figure 4A is a side cross-sectional view of a string of casing in a wellbore, the string of casing offset by subsidence;

20 Figure 4B shows a primary mill according to the present invention in the string of casing of Figure 4A;

Figure 4C shows the string of casing of Figure 4A after milling with the primary mill;

25 Figure 5A shows a secondary mill in accordance with the present invention in the string of casing of Figure 4A;

Figure 5B shows the string of casing of Figure 4A after milling with the secondary mill;

30 Figure 5C shows a liner installed in the string of casing of Figure 4A;

Figure 6 is a side-perspective view, partially in cross section, of a further embodiment of a mill according to the present invention;

35 Figure 7 is side view of a series of generally cylindrical members for use in a mill according to the

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present invention with hidden parts shown with broken lines;

Figure 8 is a side view of a generally cylindrical flexible member for use in a mill according to the present invention with hidden parts shown with broken lines;

Figure 9 is a side view of a further embodiment of a mill according to the present invention with hidden parts shown with broken lines; and

Figure 10 is a side view of a further embodiment of a mill according to the present invention with with hidden parts shown with broken lines.

Referring to Figures 1A and 1C, there is shown a primary mill 10 having a body 12 that is flexible. The main body 12 comprises a flexible metal cable including a plurality of large diameter metal strands 17 surrounding a plurality of smaller diameter metal strands 19. A top sub 14 is connected by, for example, welding or epoxy, to a top end 11 of the body 12 and a bottom sub 16 is connected to a bottom end 13 of the body 12. The subs may have appropriate threads for connection to tubulars, strings, or other apparatuses.

The body 12 may be sufficiently small in outer diameter to serve as a fishing member or fishing neck. Alternatively, a separate fishing member may be used on top of the body 12.

A plurality of milling structures 20 are secured, for example by welding, to sleeves 22 which are secured to the main body 12, for example by crimping, friction fit or welding. Matrix milling material 24 is applied to the exterior surface of the milling structures 20, in one aspect spirally about the structures 20 as shown. If desired milling blades may be used on the milling structures 20 with or without milling matrix material and/or milling inserts. Alternatively substantially all

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of the exterior surface of the milling structures 20 is covered with milling matrix material and/or milling inserts.

5 An articuable member 26 extends from top to bottom in the main body 12 and is provided with a fluid flow bore 28 therethrough. An optional tubular 30, for example made of plastic (or suitable flexible metal, composite, or fiberglass, for example) encases the articuable member 26. The articuable member 26 has cuts
10 therein or therethrough, the tubular 30 seals such cuts so that fluid flow through the bore 28 is passible without leakage through the cuts.

Referring to Figure 1B there is shown a primary mill 10 provided with a weight member 38 connected to the bottom sub 16 (or alternatively, the weight member 38 is
15 connected directly to the bottom end 13 of the body 12).

The break in the body 12 in Figs. 1A and 1B indicates that it may be any desired length and that any desired number of structures 20 may be used.

20 In one embodiment the sleeves 22 are slipped over the cable and then crimped in place (they may also be welded to the cable or only welded). The mill structures 20 are then slid over the sleeves 22 and welded in place. Alternatively a sleeve which is originally open is wrapped
25 onto the cable and crimped in place.

Referring to Figures 1D there is shown a second embodiment of a secondary mill 40 comprising a cable 41 made of individual strands 42 and 44. A bendable central tubular member 46 extends through the secondary mill 40
30 from top to bottom and, optionally, is surrounded sealingly by a tubular member 48. Matrix milling material 50 is applied to the strands of the cable 41 either spirally as in Figure 1A or vertically (or in any other desired configuration). In certain embodiments as
35 shown, the matrix milling material 50 flows between

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strands of the cable 41. Alternatively the entire exterior cable surface may be covered with matrix milling material and/or milling inserts and/or any combination thereof; or such milling structure may be applied in a spaced-apart manner to the cable's exterior (spaced-apart, for example, as are the structures 20, Figure 1A). Optionally, a fluid flow bore 49 extends through the secondary mill 40 from top to bottom.

Figure 2 illustrates a secondary mill 60 with a body 61, a lower guide mill 62 secured on or formed of the mill body 61, an upper laced collar 63 secured to or formed of the body 61, a top sub 65, and a stinger 64 initially secured to the body 61 with a shear pin 69. The lower guide mill 62 and the upper laced collar 63 are hollow, each with a bore 71, 72 therethrough, respectively, from top to bottom suitable for receiving the stinger 64 during milling following shearing of the shear pin 69. The mill system 60 is suited, among other things, for movement into an offset that has previously been milled by a mill such as that of Figure 1A. The stinger 64 can be moved through the offset so that at least a portion of the stinger 64 extends into a non-offset portion of the tubulars. In this way the mill system 60 is correctly located; the tendency of a mill to engage stub ends created in the previous milling is inhibited or eliminated; and the secondary mill 60 is stabilized at the desired location. During milling the stinger 64 acts as a stabilizer and it maintains desired system position. In one particular embodiment, the stinger 64 has an outside diameter of about 5cm (2 inches) and its length a is about 9m (30 feet); the guide mill 62 has an outer diameter of about 15cm (6 1/16 inches) and its length b is about 46cm (18 inches); and the laced collar 63 has an outer diameter of about 15cm (6 1/16 inches) and its length c is about 4.5m (15 feet);

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and such a mill is useful in a casing with an inner diameter of about 16cm (6.25 inches).

In one aspect the laced collar 63 is a drill collar to which is applied matrix milling material 66 (and/or milling inserts). Such material 68 is also applied to the guide mill 62.

Figure 3 shows the articuable member 26 of the mill 10, Figure 1A. Figure 3 depicts a portion of the articuable member 26 that is cut and flattened out. Cuts 27 through the member provide a series of interlocking lobes 33 and corresponding recesses 35 which are movable with respect to each other and which render the member flexible.

Figs. 4A - 4C depict a method of milling according to the present invention using the primary mill 10. Figure 4A shows a wellbore W in the earth cased with casing C and cemented in place with cement D. As originally drilled, the wellbore W was substantially vertical. As shown in Figure 4A, subsidence zone S has been created in an earth formation F, resulting in the pinching of casing C creating offset portion O of the casing. As shown in Figure 4B a mill 10 on a tubular (for example drill pipe which is part of a drill string) T has been introduced into the wellbore W and positioned with its milling structures adjacent the offset portion O. Known locating techniques and/or devices may be used for such locating (such a mill may be used on a cable or wireline). The primary mill 10 is then rotated by rotating the tubular string and portions of the offset casing are milled away as shown in Figure 4C which shows that the primary mill 10 has been removed from the wellbore W.

As shown in Figure 5A a secondary mill 60 has been run into the wellbore W and positioned with respect to the offset O with its stinger 64 extending down in the

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casing C past the offset O. Rotation of the mill system 60 (for example by a hydraulic or power swivel) removes more of the offset casing. The mill system 60 is then removed from the wellbore (see Figure 5B). Then a liner 67 (see Figure 5C) connected for example to a setting tool and/or to an entire string of casing is moved into the casing C and positioned across the milled off portion of the offset. The liner 67 is secured in place by any known suitable liner securement device or apparatus and is, in one aspect, sealed at either end by any known suitable seal mechanism or device. Movement of apparatuses and/or tubulars through offset is thus facilitated.

A fishing member or member with a fish neck may be located above or below a top sub of a mill according to the present invention; for example as (see mill 10 of Figure 1A), in one aspect, the top sub 14 is releasably connected to the top 11 of the main body 12 by one or more shear pins and the top 11 acts as a fishing member.

Figure 6 shows a further embodiment of a mill 70 according to the present invention, which may form part of a primary or secondary mill. The mill 70 is provided with a plurality of wire cables 72 surrounding a plurality of individual cylindrical inner members 74, each with an optimal fluid flow bore 76 therethrough from top to bottom. As shown the individual cylindrical members 74 may be held in position by the cable and/or secured to or adhered to the cable, for example with epoxy and/or fasteners so they remain in a spaced-apart configuration. Alternatively, they may be placed one on top of the other. The cables 72 extend from the top of the mill 70 to its bottom. They may be wound around the members 74 in any desired fashion, for example but not limited to, helically or they may be substantially straight up and down. Milling material 79 may be applied

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as shown around the cables 72 or, alternatively, may be applied helically in any desired member helices of any desired wraith. In another aspect, sleeves or other tubulars are secured around the cables and milling material and/or inserts are applied thereto in any known way. The cables are flexible and the use of individual separate inner members also provides flexibility. In one aspect, the inner members between the top and bottom inner member have an outer diameter slightly less than that of the top and bottom inner members for added flexibility. To provide a sealed fluid flow path, as with the various embodiments described above, an inner sealing tube 99 may be used within the inner members 74. Alternatively, a tube may be used on the exterior of the inner members, encompassing all of them.

Figure 7 shows an alternative embodiment of the inner members 77 and 78 useful with a mill 70. Inner members 78 have a curved surface 75 and inner members 77 have a curved surface 73. Optionally, the inner members 77 and 78 may have fluid flow bores 97, 96 respectively therethrough from top to bottom. Any member 77, 78 may be used in place of any member 74 in the mill 70 of Figure 6.

Figure 8 shows an alternative inner member 80 with an optional fluid flow bore 82 therethrough from top to bottom and a series of cuts 84 which render the inner member 80 flexible (or more flexible if a relatively flexible material is used for the inner member 80). The cuts 84 may be any suitable length and width. Such an inner member 80 may be used as a single inner member for an entire mill or a plurality of inner members 80 of appropriate size may be used within a mill. Alternatively an inner member 80 may be used for any inner member such as the inner members 74 of the mill 70. It is to be understood that a mill 70 may have any

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desired member of inner members and be any desired length.

Figure 9 shows a further embodiment of a mill 86 according to the present invention. The mill 86 includes a plurality of movably interconnected articulable members 89 and an end 88. Optionally fluid flow bores 87 extend through each member 89 and the end 88. Milling material 85 is applied around each member 69. Alternatively, such material can be applied helically. As shown, the milling material on the two lowest members 89 is shaped as at 94 to taper inwardly from top to bottom to facilitate entry of the mill into tubulars and to facilitate passage therethrough. Such a tapering configuration can be used with any mill and any milling material disclosed herein, including but not limited to on the structures 20 of the mill of Figure 1A.

Figure 10 shows a starting mill 200 useful with the mill system for forming an initial window, for example in casing in which the system is positioned. The starting mill 200 has a body 202 with a fluid flow channel 204 therethrough (shown in dotted lines). Three sets of cutting blades 210, 220, and 230 with, respectively, a plurality of blades 211, 221, and 231 are spaced apart on the body 202. Jet ports 239 are in fluid communication with the channel 204. A nose 240 projects down from the body 202 and has a tapered end 241, a tapered ramped portion 242, a tapered portion 243, and a cylindrical portion 244. In one aspect the nose is made of readily millable material and is releasably secured to the body 202; for example so that it can be twisted off by shearing a shearable member that holds the nose to the body. Then the released nose may be milled by the mill. The nose 240 may have a fluid flow channel therethrough and a flow controlling valve therein.

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CLAIMS:

1. A mill comprising a body (12) and milling material (20), characterised in that said body (12) is flexible.
2. A mill as claimed in Claim 1, wherein said body (12)
5 is provided with a flow bore (28) therethrough.
3. A mill as claimed in Claim 1 or 2, wherein said body (12) comprises a cable (17,19;40).
4. A mill as claimed in Claim 3, wherein said cable comprises multiple strands (17,19).
- 10 5. A mill as claimed in Claim 3 or 4, wherein said milling material (20) is arranged directly on said cable (17,19;40).
6. A mill as claimed in any preceding Claim, wherein said body (12) is provided with at least one sleeve (22),
15 said milling material (20) arranged thereon.
7. A mill as claimed in Claim 6, wherein there is provided a plurality of sleeves (22) spaced apart along said body (12).
8. A mill as claimed in any preceding Claim, wherein
20 said body (12) is provided with a member therein.
9. A mill as claimed in Claim 7 or 8, wherein said body (12) comprises a series of interconnected tubular members (46).
10. A mill as claimed in Claim 8 or 9, wherein said
25 member (46) is flexible or articulable.
11. A mill as claimed in Claim 8, 9 or 10, wherein a sealing tube (48) surrounds said member (46).
12. A mill as claimed in Claim 8, 9, 10 or 11, wherein said member (46) is a tube.
- 30 13. A mill as claimed in any preceding Claim, wherein a weight (38) is disposed on a lower end of said mill.
14. A mill as claimed in any preceding Claim, wherein said mill is at least partly hollow for accommodating a stinger (64).
- 35 15. A mill as claimed in Claim 14, wherein said mill

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comprises a stinger (64) and a shear pin (69) arranged therebetween.

16. A mill as claimed in any preceding Claim, wherein said body (12) is provided with a fishing member.

5 17. A mill as claimed in any preceding Claim further comprising a guide mill.

18. A mill as claimed in any preceding Claim, further comprising a top sub (14) and a bottom sub (16) connected to said body (12).

10 19. A mill as claimed in any preceding claim, wherein said body (12) includes a tapered portion (89) to facilitate passage of said mill through a wellbore.

20. A mill as claimed in any preceding claim, wherein said milling material (20) is replaceable.

15 21. A method of milling using the mill as claimed in any preceding claim, the method comprising the step of lowering said mill into tubulars in a wellbore across an offset portion thereof, operating said mill to mill at least a portion of said tubulars.

20 23. A method according to Claim 21 or 22, further comprising the step of introducing a secondary mill into said tubulars in a wellbore across an offset portion thereof, operating said secondary mill to mill at least a portion of said tubulars and/or formation external to
25 said wellbore.

24. A method according to Claim 23, wherein said secondary mill comprises a stinger shear pinned thereto, the method further comprising the step of shearing said shear pin during operation of said mill, whereupon said
30 stinger is released from said mill, or is swallowed by said mill.

25. A method according to Claim 24, comprising the step of lowering a liner across the milled out section of tubular.

35 26. A method according to Claim 25, wherein said liner

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is sealed to said tubular.

27. A method according to any of Claims 21 to 26,
wherein said mill is rotated to facilitate said milling.

28. A method according to any of Claims 21 to 27,
5 wherein said mill is reciprocated to facilitate said
milling.

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FIG. 1A

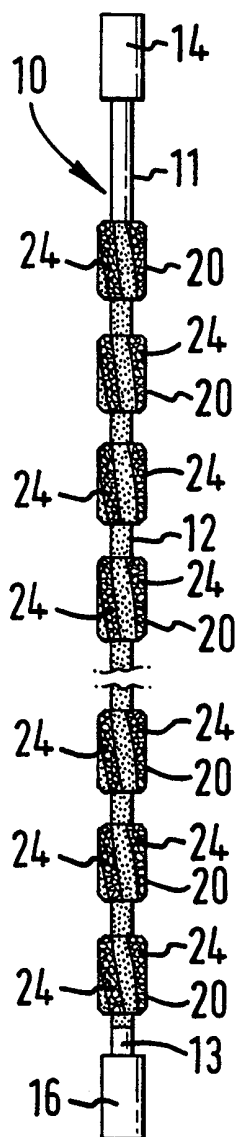


FIG. 1B

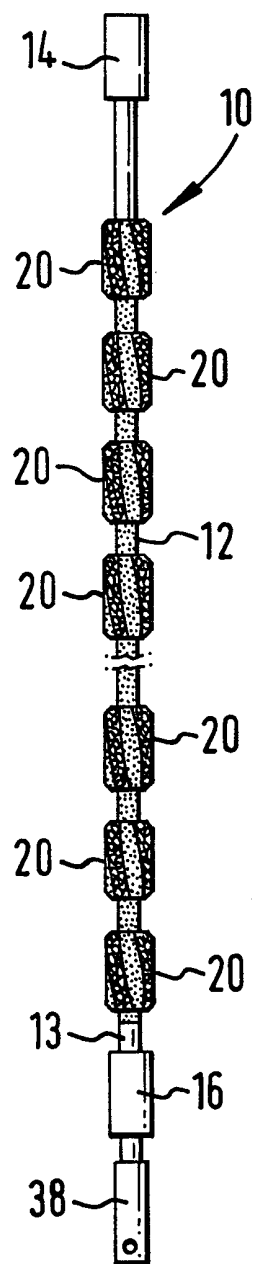


FIG. 2

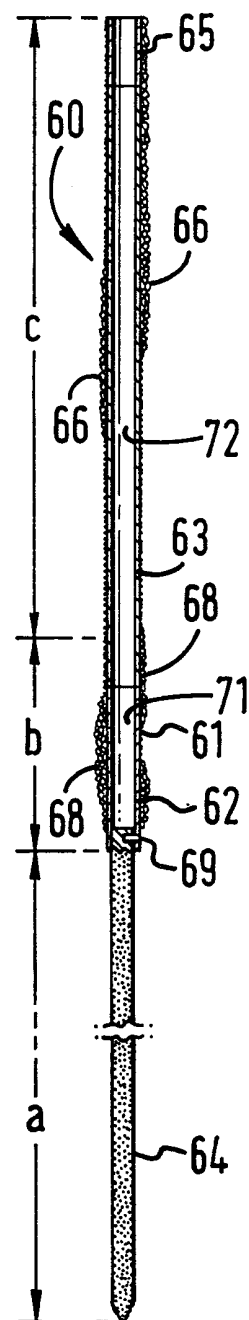
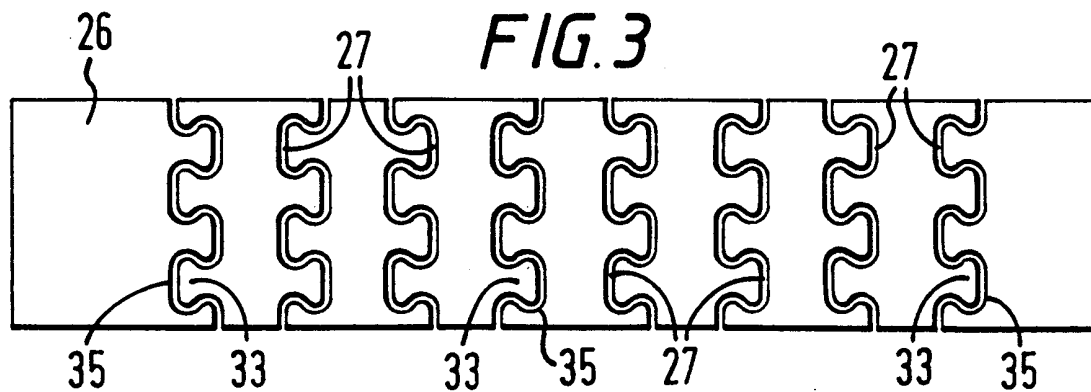
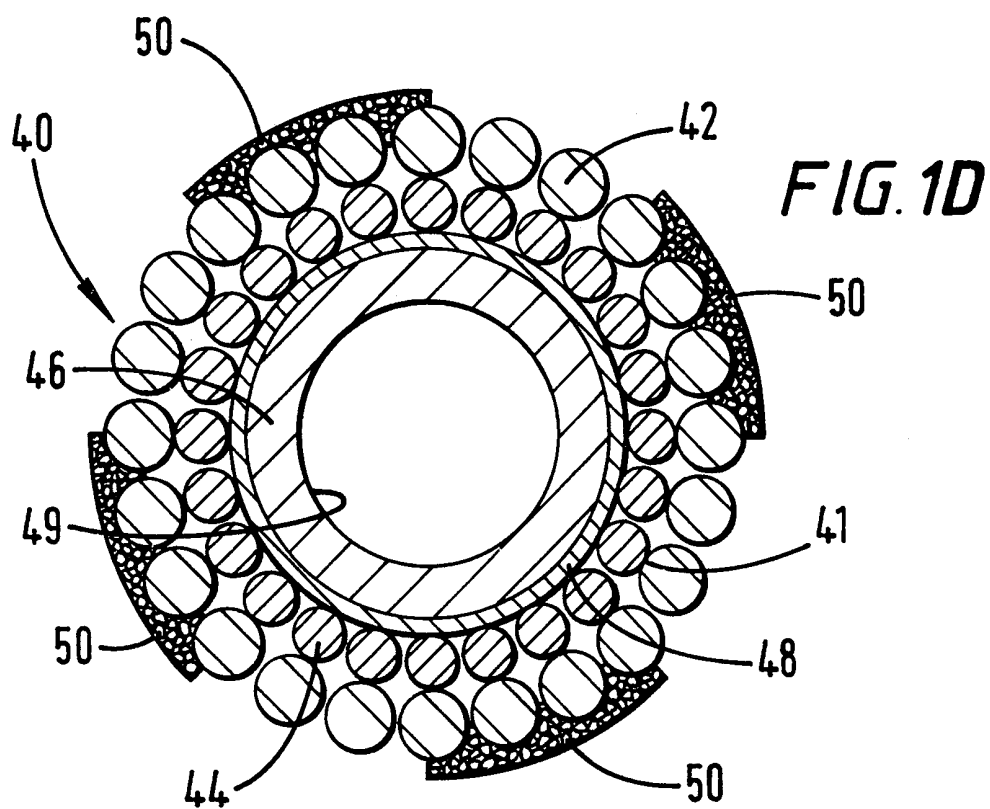
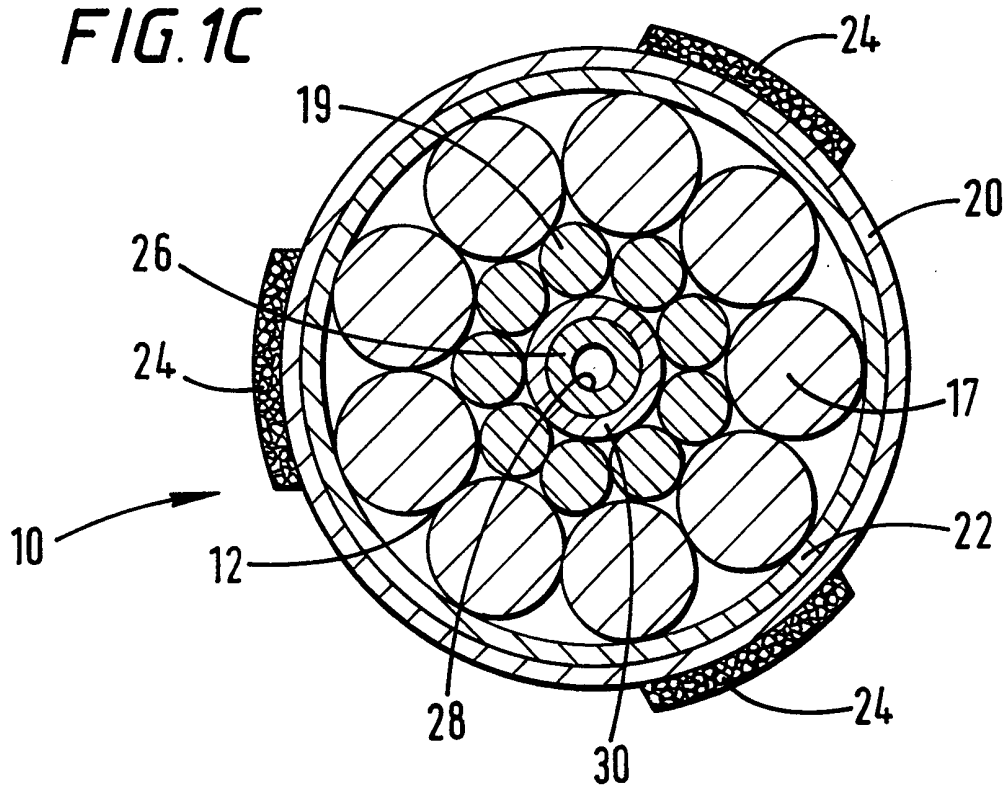


FIG. 3



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FIG. 1C

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FIG. 4C

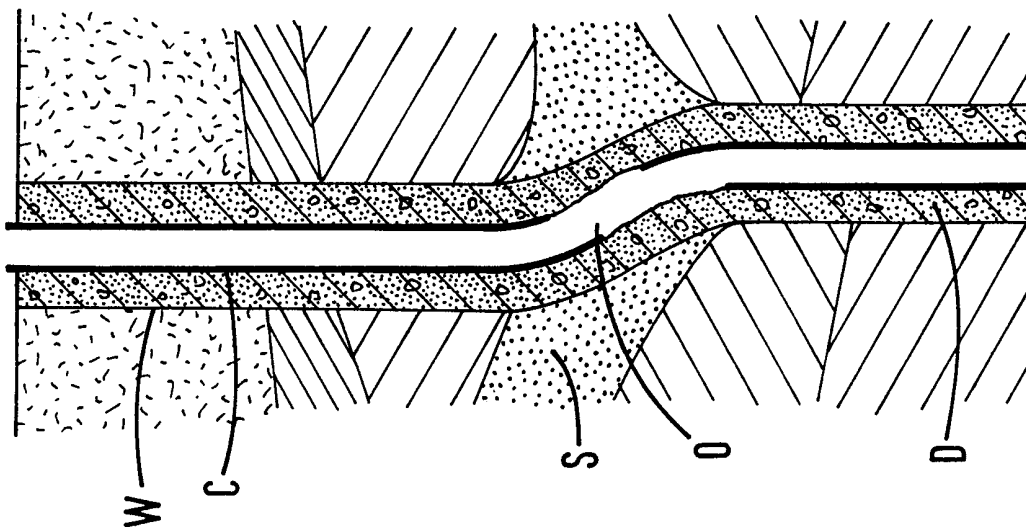


FIG. 4B

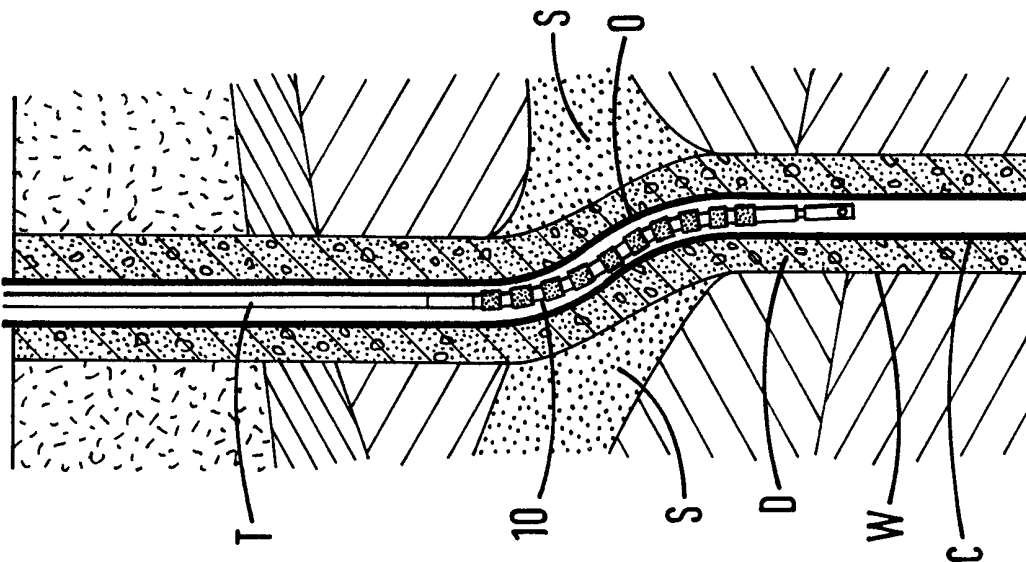
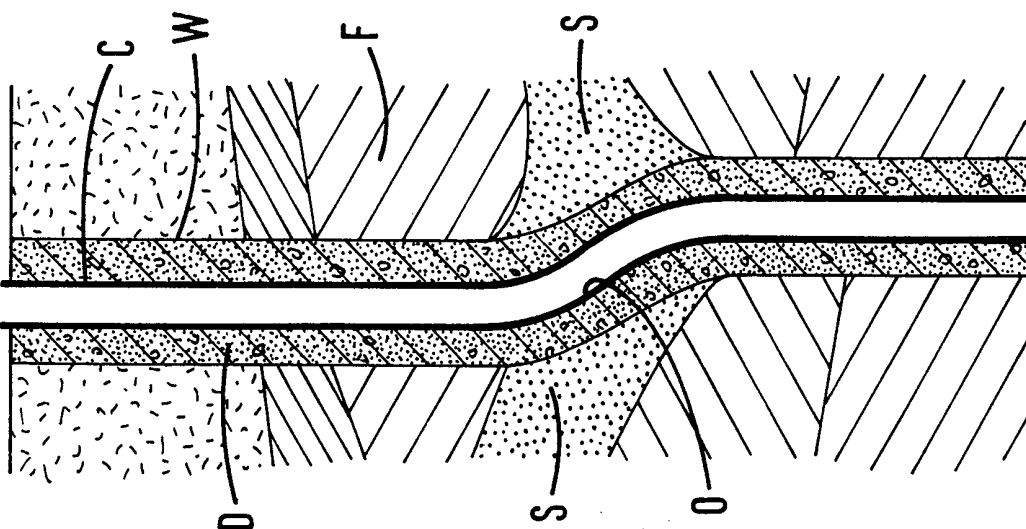


FIG. 4A



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FIG. 5C

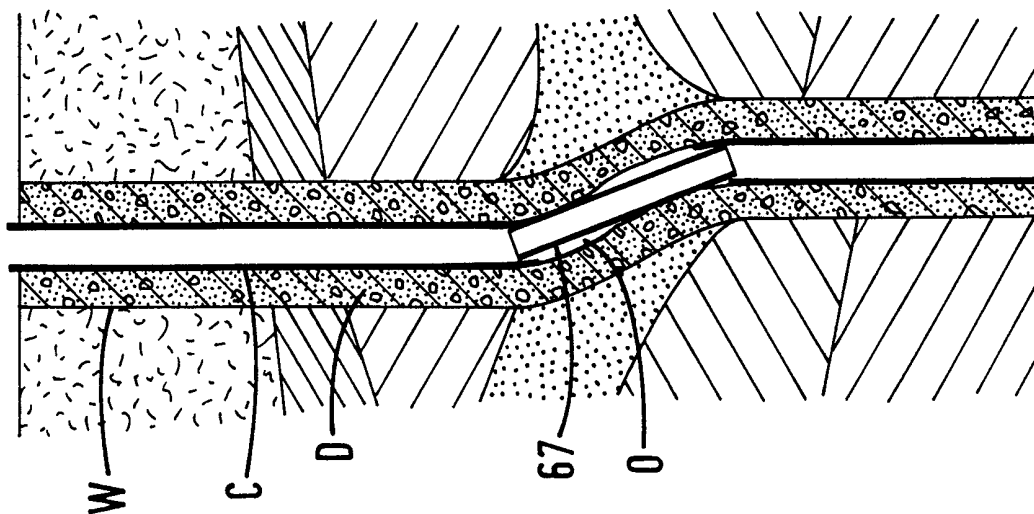


FIG. 5B

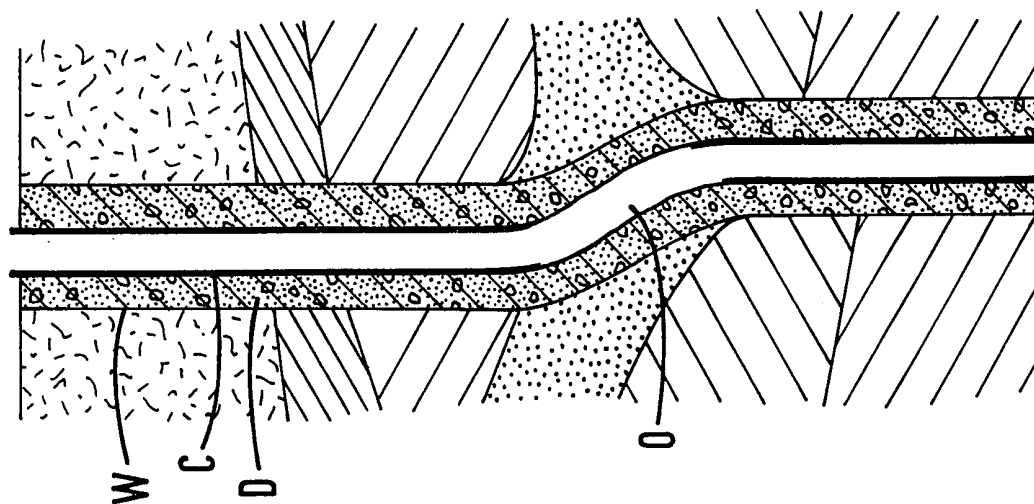
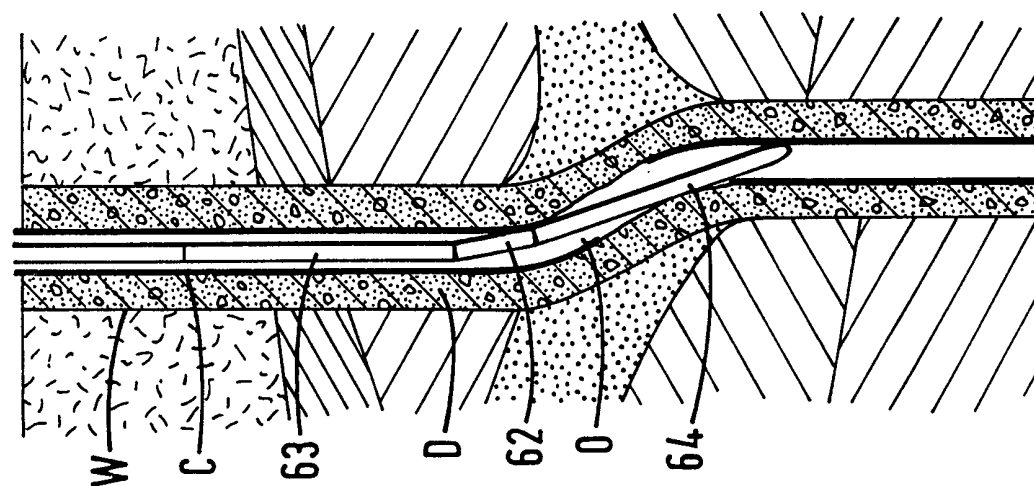


FIG. 5A



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FIG. 10

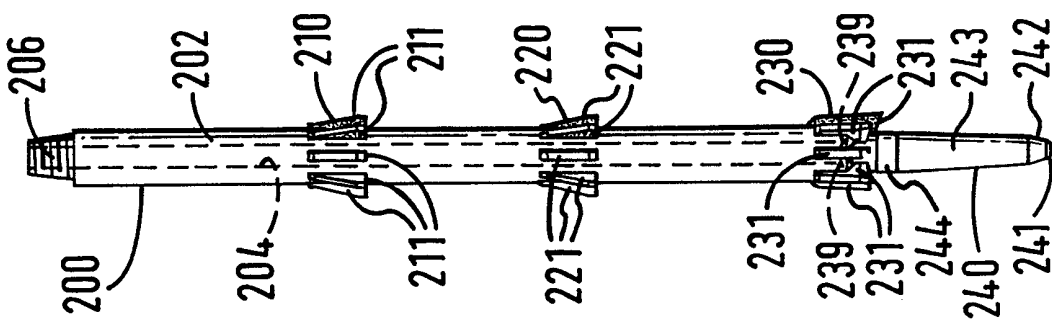


FIG. 9

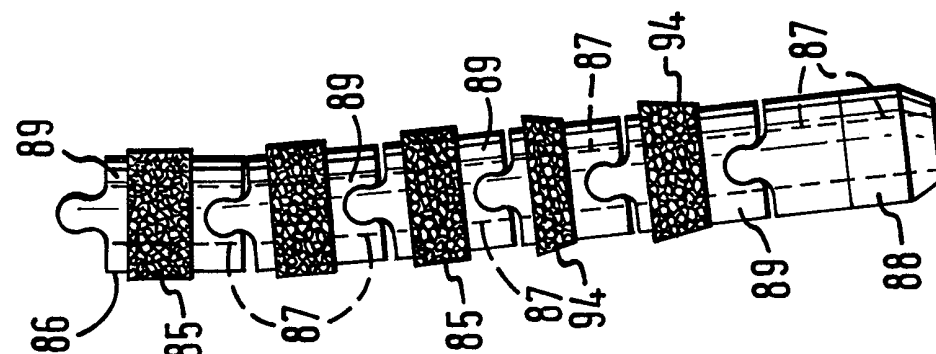


FIG. 8

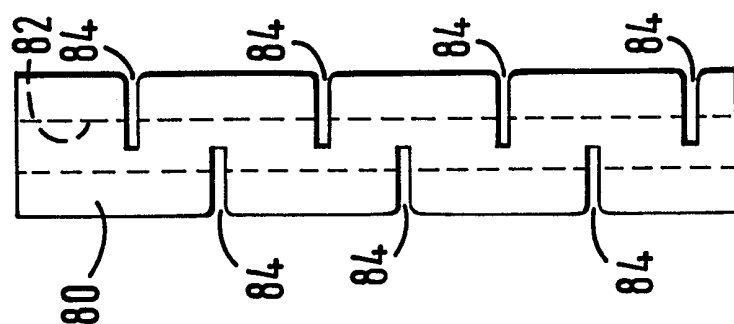


FIG. 7

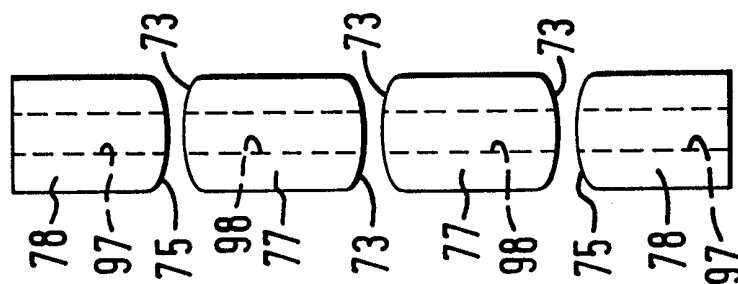
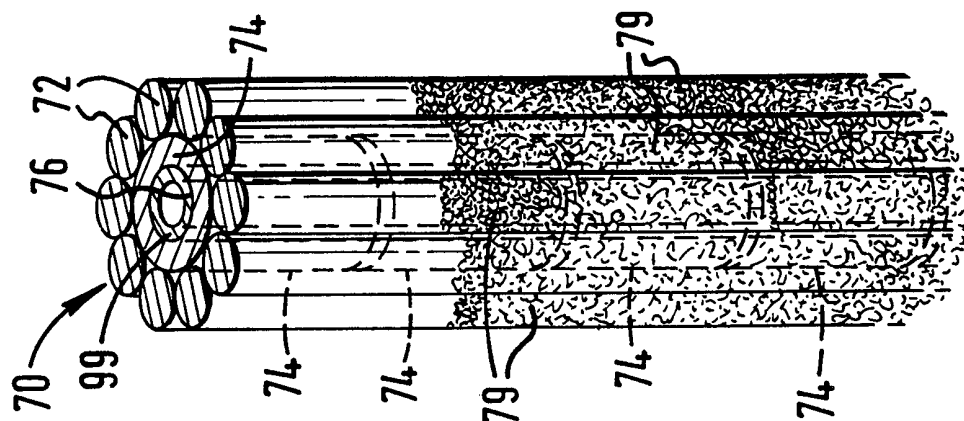


FIG. 6



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00668

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 E21B29/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 E21B A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 109 924 A (KREHL DIETMAR ET AL) 5 May 1992	1,2,8, 17-19, 21,23, 27,28
Y	see column 3, line 5 - line 12 see column 2, line 47 - line 49	3,4,9, 10, 13-15, 20,24 25,26
A	see figure 2 ---	
X	EP 0 338 965 A (PAPANTONAKOS APOSTOLOS DR) 25 October 1989 see column 2, line 18 - line 20 see column 4, line 41 - line 45 --- -/--	1



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search

4 June 1999

Date of mailing of the international search report

21/06/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Bellingacci, F

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PCT/GB 99/00668

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 4 397 360 A (SCHMIDT JERRY W) 9 August 1983 see figure 3 ---	9,10
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Y	EP 0 397 417 A (SMITH INTERNATIONAL) 14 November 1990 see column 2, line 27 - line 30 ---	20
A	SMITH H G: "PATCHES CURE LEAKY CASING PROBLEMS IN INDONESIA" OIL AND GAS JOURNAL, vol. 88, no. 22, 28 May 1990, page 99, 102/103 XP000121198 see page 103, column 3, line 1 - column 4, line 1 -----	25,26

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