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DEDICATED PERFORATABLE NIPPLE

WITH INTEGRAL ISOLATION SLEEVE

5 This invention relates generally to apparatus
for completing downhole wells, and in particular to flow
conductors for conveying inflowing formation fluid in
water, oil, gas and recovery wells.

10 In the course of completing an oil and/or gas
well, it is common practice to run a string of protective
casing or liner into the well bore and then to run
production tubing inside the casing. The annulus between
the liner or casing and the surrounding formation is
sealed with a deposit of cement to prevent fluid flow
15 through the external annulus from one formation zone to
another. The cement is pumped through a work string
suspended within the casing or liner into the annular
space between the liner or casing and the surrounding
well bore.

20 If the lining or casing traverses a hydrocarbon-
bearing formation, the lining is perforated to create
flow apertures through the casing and cement so that the
formation fluids can flow into the well. The liner
and/or well casing is perforated by a perforating gun
25 which is suspended within the well. Shaped explosive
charges carried by the gun blast openings through the
metal lining, the cement deposit and the surrounding
formation.

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In some completions, however, the well bore is uncased, and an open face is established across the oil or gas bearing zone. Open bore hole (uncased) arrangements may be utilized, for example, in water wells, test wells and horizontal/deviated well completions.

Some open bore hole (uncased) installations are known as "slimhole" or "monobore" completions in which a protective liner or casing is not installed across the productive zone. In such completions, a small diameter flow conductor is suspended within the uncased bore hole and cement is pumped through the flow conductor into the annulus between the flow conductor and the surrounding earth formation. After cement residue is cleaned from the flow conductor, the flow conductor and the surrounding cement deposit are perforated to admit formation fluid into the well.

Because of the economies associated with slimhole/monobore completions, there is a continuing interest in improving the flow conductors used in such completions. There is a need for a small diameter production nipple which can be used in vertical as well as deviated uncased well bores, wherein the production nipple can be used to spot an annular deposit of cement across the face of the uncased well bore, with the nipple and protective cement deposit thereafter being perforated reliably by a small diameter perforating gun. There is also a need for a production nipple of the character



described which can be closed and reopened in response to changing conditions in the producing zone.

The present invention is concerned with the provision of a method and apparatus for locating a
5 perforating gun within a production nipple in a slimhole/monobore completion, and with a production nipple for use in slimhole/monobore completions, in particular with a production nipple in which improved puncture of the nipple sidewall and penetration into the
10 formation are realised.

The present invention is also concerned with the provision of production nipples having a reduced resistance to perforation by a shaped explosive charge, and which can be opened for production or selectively
15 closed for isolating a zone which may be producing an excessive amount of gas or water.

In one form of the invention a production nipple, designed for suspension from a flow conductor within an uncased well bore, includes a tubular mandrel
20 having a longitudinal production bore. The tubular mandrel includes first and second longitudinally spaced sidewall sections, with one of the sidewall sections being dedicated for perforation by a perforating gun. The dedicated sidewall section is characterised by having
25 a lower resistance to perforation by a shaped charge as compared to the perforation resistance of the other sidewall section. Preferably, the tubular mandrel is intersected by a longitudinal counterbore along the



dedicated sidewall section of the mandrel, with the radial thickness of the dedicated sidewall section being less than the radial thickness of the production bore mandrel section. An isolation sleeve is received in
5 slidable, sealing engagement against the production bore of the nipple mandrel, and is shiftable from a first position in which the dedicated sidewall section is covered by the isolation sleeve to a second position in which the dedicated sidewall section is uncovered.

10 In a preferred embodiment, the nipple is suspended within the well bore on a tubular coupling sub. The coupling sub is radially intersected by an internal, annular locator slot. A resilient latch arm carried on a perforating gun is movable from a retracted, non-
15 interfering position to a radially extended, latched position in which the latch arm is received within the locator slot. According to this arrangement, the perforating gun is located precisely in shoot alignment with the dedicated sidewall section of the production
20 nipple. Because of the reduced radial thickness of the dedicated sidewall section, reliable puncture and penetration through the nipple, cement deposit and earth formation can be obtained with a smaller, less powerful explosive charge.

25 Other features and advantages of the present invention will be appreciated by those skilled in the art upon reading the detailed description which follows with reference to the attached drawings. In the drawings:

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Fig. 1 is a simplified schematic diagram showing a vertical section through two producing formations which are intersected by an uncased well bore which has been completed with two production nipples suspended from a retrievable packer;

Fig. 2 is a simplified, sectional view which illustrates perforation of the production nipple, cement deposit and formation in a slimhole/monobore completion;

Fig. 3 is a longitudinal sectional view of the production nipple of Fig. 1 showing the isolation sleeve in its uncovered position with the dedicated section of the production nipple being exposed for perforation;

Fig. 4 is a view similar to Fig. 3 in which the isolation sleeve is in its covered position in which the dedicated sidewall of the production nipple is sealed;

Fig. 5 is a longitudinal sectional view of the slimhole/monobore completion showing the production of formation fluid through the perforated nipple;

Fig. 6 is a view similar to Fig. 3 in which fluid flow through the production nipple has been terminated by an isolation sleeve; and,

Fig. 7 is a simplified, sectional view which illustrates a horizontal well completion in an uncased bore hole in which multiple production nipples are positioned in registration with multiple producing zones.

In the description which follows, like parts are indicated throughout the specification and drawings with the same reference numerals, respectively. The drawings



are not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details of the invention.

Referring now to Fig. 1, a first hydrocarbon formation 10 and a second hydrocarbon formation 12 are intersected by an uncased well bore 14. The uncased well bore 14 is sealed from the surface by a primary casing string 16, having an 11 inch diameter, which is secured to the wellhead assembly. Intermediate zones of the uncased well bore 14, are isolated by an intermediate casing string 18, having a 7 $\frac{1}{2}$ inch (194mm) diameter, and a final casing string 20, having a 5 $\frac{1}{2}$ inch (140mm) casing diameter.

The well 14 is completed by multiple nipple sections 22,24 which are connected by a threaded union T in flow communication by flow conductors 26,28. The flow conductor 28 is suspended from a retrievable packer 30 which is releasably set in engagement against the bore of the lowermost casing 20. The retrievable production packer 30 includes a mandrel 32 having a longitudinal production bore 34 for conveying formation fluid to the surface. The packer mandrel bore is coupled in fluid communication with a string of 3 $\frac{1}{2}$ inch (89mm) production tubing 36 by a full bore landing nipple 38. Production flow through the production tubing string 36 is controlled by a tubing retrievable safety valve 40.

Before the production tubing 36 is installed in the full bore landing nipple 38, a work string is coupled



to the landing nipple and a predetermined volume of cement is pumped through the packer bore, the flow conductors 26,28 and the production nipples 22,24. The annulus surrounding the suspended flow conductors and production nipples is filled with a cement deposit 42 which prevents vertical flow of formation fluid between the hydrocarbon formation 10 and the hydrocarbon formation 12. A seal plug is introduced into the bore of the work string to separate the cement from the displacing fluid and to wipe the cement from the packer bore, the flow conductor bores and the nipple bores as the cement is displaced out of the tubing and into the surrounding annular space.

After the seal plug has been removed and the production bores have been cleared of debris, a perforating gun 44 is positioned within the bore of each nipple. The perforating gun 44 is suspended and run into the well on a tubing string. Preferably, the tubing string is a length of coil tubing having a firing line inside. The perforating gun assembly 44 is equipped with a mandrel 46 which includes an array of explosive, jet-type perforating charges 48. The perforating gun 44 is coupled to the flow conductor 28 by a locator sub 50.

Upon detonation, each explosive charge 48 produces a high temperature, high pressure plasma jet 52 which penetrates the sidewall of the nipple 22, the protective cement layer 42 and the surrounding formation 12. The high temperature, high pressure plasma jet 52

penetrates the metal sidewall of the nipple, thus producing a clean perforation 54 through the nipple sidewall and an irregular fracture 56 through the surrounding concrete layer and earth formation.

5 Preferably, the shoot is performed with the well in an underbalanced pressure condition relative to the surrounding formation. With a sufficiently high pressure differential, the pressure surge from the surrounding formation will break up any compacted material and sweep
10 it back in the well bore where it will be flowed to the surface. As compacted fragments are swept away, the nipple sidewall perforations 54 are cleaned and cleared for maximum inflow. After the perforating gun 44 is removed from the well, the well is then ready for
15 immediate production.

Referring now to Fig. 3 and Fig. 4, the production nipple 22 includes a tubular mandrel 58 which includes first and second longitudinally spaced sidewall sections 58A, 58B. According to one aspect of the present
20 invention, one of the mandrel sidewall sections, in this instance section 58A, is dedicated for perforation by a perforating gun, and is characterised by a lower resistance to perforation in response to the explosive force of a shaped charge as compared to the perforation
25 resistance of the other sidewall section 58B. The differential resistance to perforation is obtained, according to one aspect of the present invention, by forming the dedicated sidewall section 58A with a reduced



radial thickness as compared to the sidewall thickness of the nipple section 58B.

The mandrel section 58B is intersected by a longitudinal production bore 60, and the dedicated
5 sidewall section 58A is intersected by a longitudinal counterbore 62 which extends along the length of the dedicated sidewall section 58A. According to this arrangement, the main production bore 60 is enlarged by the counterbore 62 along the length of the dedicated
10 sidewall section. The radial thickness of the dedicated sidewall section 58A is reduced substantially with respect to the thickness of the nipple sidewall section 58B, as shown in Fig. 4. In those illustrations where the nipples support very little hang weight, the radial
15 thickness of the dedicated sidewall section 58A can be reduced substantially relative to the thickness of the nipple sidewall section 58B.

According to another aspect of the present invention, an isolation sleeve 64 is incorporated within
20 the production nipple 22 for the purpose of selectively isolating a particular production zone at any time during the life of the well. That is, the isolation sleeve 64 is shifted to a non-interfering position, as shown in Fig. 2, in which the dedicated sidewall section 58A is
25 exposed to the perforating gun 44. The isolation sleeve 64 is also movable to a closed position, as shown in Fig. 4, in which the perforated, dedicated sidewall section is sealed for the purpose of isolating the zone which may be



producing an excessive amount of gas or water.

The isolation sleeve 64 is received in slidable, sealing engagement against the production bore 60 of the nipple mandrel. The isolation sleeve 64 is provided with
5 shifting shoulders 64A, 64B which are engagable by a shifting tool supported on a wire line or by a coiled tubing string. Although the exemplary embodiment shows that the dedicated nipple sidewall section 58A is arranged for exposure by downshifting the isolation
10 sleeve 64, it will be appreciated that the respective positions of the dedicated nipple section 58A and nipple section 58B could be reversed, with the isolation sleeve 64 being shifted upwardly for exposure of the dedicated sidewall section.

15 As can best be seen in Fig. 4, the isolation sleeve 64 spans the complete length of the dedicated sidewall section 58A, with the counterbore 62 being sealed with respect to the production bore 60 by first and second annular seal members 68, 70, respectively. The
20 annular seal members 68, 70 are curved, molded seals which are carried in annular slots formed in the shifting shoulders 66A, 66B, respectively.

Referring to Fig. 5, the isolation sleeve 64 is received within the production bore 60 of the nipple
25 mandrel 58 in a non-interfering position in which the dedicated sidewall section 58A of the nipple is uncovered, thus permitting the flow of formation fluid through the nipple perforations 56, as indicated by the



arrows 72. As shown in Fig. 6, the dedicated section 58A is completely covered by the isolation sleeve 64, and the counterbore 62 is sealed by the annular seals 68,70, thus preventing the inflow of formation fluid through the nipple perforations 56.

In some installations, the flow conductor 28 is suspended directly from the wellhead, with one or more production nipples 22,24 being suspended within an uncased well bore, typically in a shallow slimhole/ monobore well completion. In such installations, the perforating gun 44 may be located accurately when the depth of the production nipple is known. The operator runs the perforating tool until the length of the coiled tubing corresponds with the known depth of the production nipple. However, that method becomes less accurate for deep wells, in particular for wells which may have lateral deviations.

Referring now to Fig. 2, accurate positioning of the perforating gun 44 is provided by an annular locator slot 74 formed on the flow conductor 28, and a resilient, deflectable latch arm 76 carried on the locator sub 50. The resilient, deflectable latch arm 76 is movable from a retracted, non-interfering position which permits travel of the perforating gun 44 through the production bore, to a radially extended, latched position, as shown in Fig. 2, in which it is received within the locator slot 74. According to this arrangement, the perforating gun 44 is located precisely in shoot alignment with the dedicated



sidewall section 58A of the production nipple 22. The longitudinal distance of the dedicated nipple sidewall section 58A relative to the locator slot 74 is known, and the length of the perforating gun 46 relative to the latch arm 76 is adjusted with a coupling sub 78 so that the explosive charges 48 are centered in shoot alignment along the length of the dedicated nipple sidewall section 58A when the latch arm 76 is received in detented engagement with the locator slot 74.

It will be appreciated that because of the reduced radial thickness of the dedicated nipple sidewall section 58A, reliable puncture and penetration through the nipple 22, cement deposit 42 and earth formation 10 can be obtained with a smaller, less powerful explosive charge. Since a less powerful explosive charge is required, the perforating gun 46 can be physically smaller in diameter, and can be run through the small diameter production tubing ($3\frac{1}{4}$ inch or smaller) utilized in slimhole/monobore completions. Because of the reduced sizing provided by the production nipple, the well may be drilled with a smaller rig, less well control material is required during drilling of the bore hole, the quantity of cement required is reduced, and the size and quantity of casing and tubing required to complete the well are reduced. Moreover, the well may be completed on coiled tubing, thus further reducing the cost of the completion string and reducing the overall time required for installation. Since coiled tubing may be utilized, the



well may be completed or recompleted without the necessity of killing the well, thereby reducing the potential for damage to the reservoir. Moreover, in multizone completions, the production nipples may be
5 opened and closed as desired, either sequentially or selectively, for isolating a zone which may be producing too much water or gas. The production nipples of the present invention may also be used in uncased, horizontal completions as shown in Fig. 7.

10 Although the invention has been described with reference to an oil well completion, and with reference to particular preferred embodiments, the foregoing description is not intended to be construed in a limiting sense. The production nipple of the present invention
15 may be used to good advantage in alternative applications, for example, in gas wells, environmental wells, including monitoring wells, recovery wells and disposal wells. It is therefore contemplated that the invention includes any such applications which
20 incorporate the production nipple disclosed.



CLAIMS

1. A production nipple for completing a well comprising:

5 a tubular mandrel having an internal longitudinal production bore, said tubular mandrel having first and second longitudinally spaced sidewall sections, one of said sidewall sections being dedicated for perforation by a perforating gun, said dedicated sidewall
10 section being characterised by having a lower resistance to perforation by a shaped charge as compared to the perforation resistance of said other sidewall section.

2. A production nipple for completing a well comprising:

15 a tubular mandrel having a first sidewall section intersected by a longitudinal production bore and having a second sidewall section intersected by a longitudinal counterbore along a dedicated sidewall
20 section of said mandrel, wherein the radial thickness of the dedicated sidewall section is less than the radial thickness of said first sidewall section.

3. A well completion apparatus comprising, in combination:

25 a tubular flow conduit adapted for suspension within a well; and

a nipple coupled to said flow conduit, said





nipple having a tubular mandrel and a longitudinal production bore, said tubular mandrel having a dedicated sidewall section characterised by having a lower resistance to perforation by a shaped charge as compared
5 to the perforation resistance of said mandrel.

4. Well completion apparatus as defined in claim 3, including:

latch apparatus mounted on said flow conduit for
10 locating a perforating gun at a predetermined service position adjacent to the dedicated sidewall section of said nipple.

5. Well completion apparatus as defined in claim 4,
15 said flow conductor having a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus including a resilient latch arm carried by said perforating gun, said latch arm being movable from a radially retracted, non-interfering
20 position to a radially extended, latched position in which said latch arm is received within said locator slot.

6. A production nipple as defined in claim 1 or
25 claim 2 or well completion apparatus as defined in any one of claims 3 to 5, including:

an isolation sleeve disposed in slidable, sealing engagement against the internal bore of said





tubular mandrel or nipple, said isolation sleeve being shiftable along the longitudinal axis of internal bore between alternative positions covering and uncovering the dedicated sidewall section of said mandrel or nipple.

5

7. Well completion apparatus comprising, in combination:

a packer having means for engaging a well casing and having a longitudinal bore for passing a service tool
10 to and from a well location below the packer;

a tubular flow conduit coupled to said packer for suspension within the well;

a tubular nipple having an internal bore coupled to said flow conduit; and

15 coacting latch apparatus coupled to said flow conduit and to the service tool for locating the service tool at a predetermined service position within the bore of the tubular nipple.

20 8. Well completion apparatus as defined in claim 7, including:

an isolation sleeve disposed in slidable, sealing engagement against the internal bore of said tubular nipple, said isolation sleeve being shiftable
25 along the longitudinal axis of internal bore between alternative positions covering and uncovering a sidewall section of said nipple.





9. A production nipple as defined in claim 1 or claim 2 or well completion apparatus as defined in any one of claims 6 to 8, including:

first and second longitudinally spaced annular
5 seal members disposed in slidable, sealing engagement between said isolation sleeve and said bore of the nipple, said nipple and first and second annular seal members engaging said bore when said sleeve is in the covered position.

10

10. Well completion apparatus as defined in claim 7, said nipple having a tubular sidewall and a longitudinal production bore, said tubular sidewall being intersected by a longitudinal counterbore along a
15 dedicated sidewall section of said nipple,

an isolation sleeve disposed in slidable, sealing engagement against the internal bore of said tubular nipple, said isolation sleeve being shiftable along the longitudinal axis of internal bore between
20 alternative positions covering and uncovering the dedicated sidewall section of said mandrel or nipple.

11. Well completion apparatus comprising, in combination:

25 a packer having anchor slips for engaging a well casing and having a longitudinal bore for passing a perforating gun to and from a well location below the packer;





production tubing coupled to said packer for suspension within the well;

a nipple coupled to said production tubing for suspension within the well, said nipple having a tubular
5 sidewall and a longitudinal production bore, said tubular sidewall being intersected by a longitudinal counterbore along a dedicated sidewall section of said nipple, wherein said production bore and counterbore together define a service chamber;

10 an isolation sleeve disposed in slidable, sealing engagement against the production bore of said tubular nipple, said isolation sleeve being shiftable along the longitudinal axis of the tubular nipple from a first position in which said dedicated sidewall section
15 of the tubular nipple is uncovered and exposed for perforation by a perforating gun, to a second position in which said dedicated sidewall section is covered by said isolation sleeve; and

coacting latch apparatus coupled to the
20 production tubing and to the perforating gun for locating said perforating gun within the service chamber of the tubular nipple.

12. Well completion apparatus as defined in claim
25 11, the tubular sidewall of said nipple having first and second end portions, said dedicated sidewall section being disposed intermediate said first and second sidewall end portions, said first and second sidewall end





portions being adapted for sealing engagement with said isolation sleeve when it is in the fully extended position.

5 13. Well completion apparatus as defined in claim 11 or claim 12, the tubular sidewall of said nipple having first and second end portions, said dedicated section being disposed intermediate said first and second sidewall end portions, wherein the radial thickness of
10 said dedicated sidewall section is less than the radial thickness of said first and second sidewall end portions.

14. Well completion apparatus as defined in any one of claims 11 to 13 including first and second
15 longitudinally spaced annular seal members disposed in slidable, sealing engagement between said isolation sleeve and the production bore of said nipple, said isolation sleeve spanning said sidewall section of said nipple and sealing said sidewall section when the sleeve
20 is in said covered position.

15. Well completion apparatus as defined in any one of claims 7, 8 or 11 to 14, including a coupling sub connecting said tubular nipple to said packer, said
25 coupling sub having a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus including a resilient latch arm mounted on said service tool, said latch arm being





movable from a retracted, non-interfering position to a radially extended, latched position in which said latch arm is received within said locator slot.

- 5 16. A method for completing a well comprising:
 suspending a flow conductor and a production
 nipple within a well casing;
 pumping cement into the annulus between the
 production nipple and the well bore;
10 removing residual cement from the bore of the
 production nipple; and
 perforating the production nipple and the
 annular cement deposit with a perforating gun.
- 15 17. A method for completing a well as defined in
 claim 16, including the step of locating the perforating
 gun in registration with a dedicated section of the
 production nipple by latching the perforating gun onto
 the flow conductor at a predetermined latching location
20 relative to the production nipple.
18. A method for completing a well as defined in
 claim 16 or claim 17, including the step of isolating the
 production nipple by covering the dedicated sidewall
25 section with a tubular sleeve.
19. A production nipple constructed and arranged for
 use and operation substantially as described herein with





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reference to the accompanying drawings.

20. Well completion apparatus constructed and
arranged for use and operation substantially as described
5 herein with reference to the accompanying drawings.

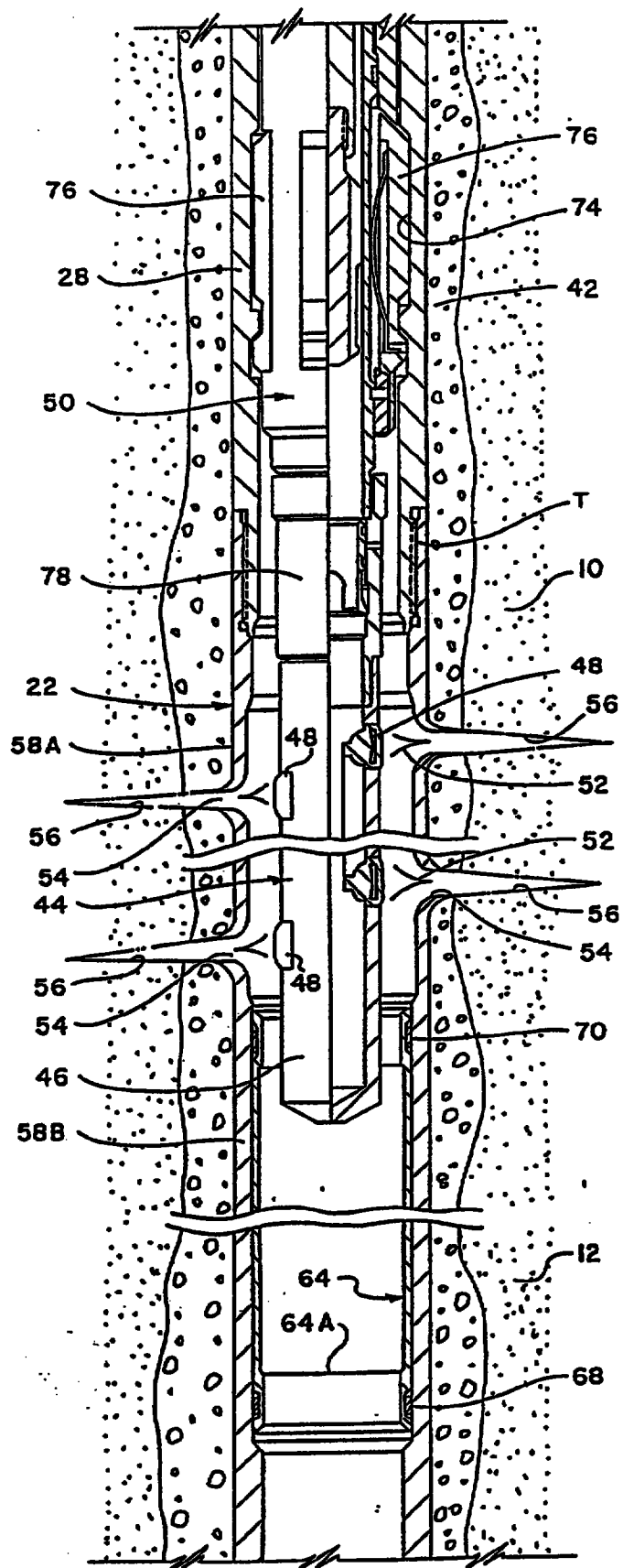
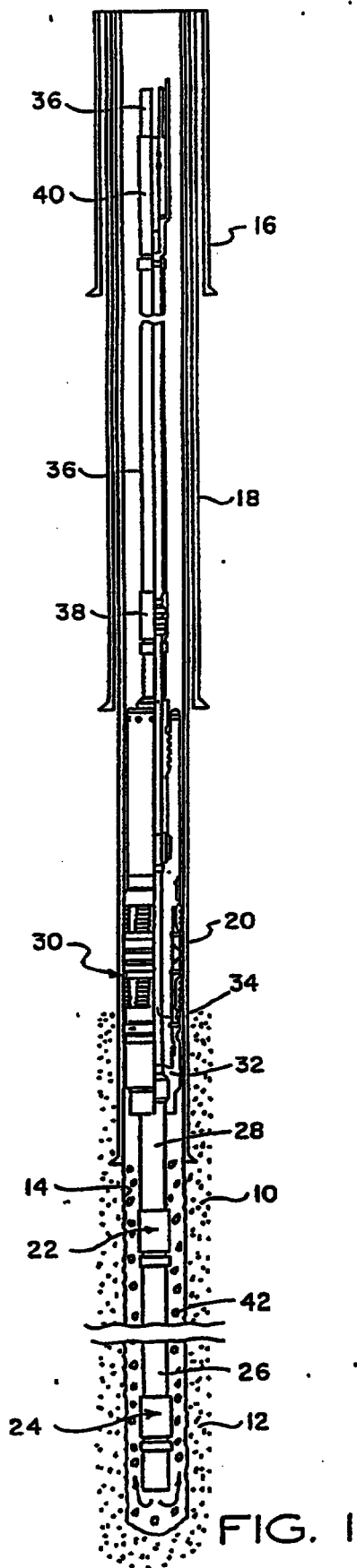
21. A method of completing a well substantially as
described herein with reference to the accompanying
drawings.

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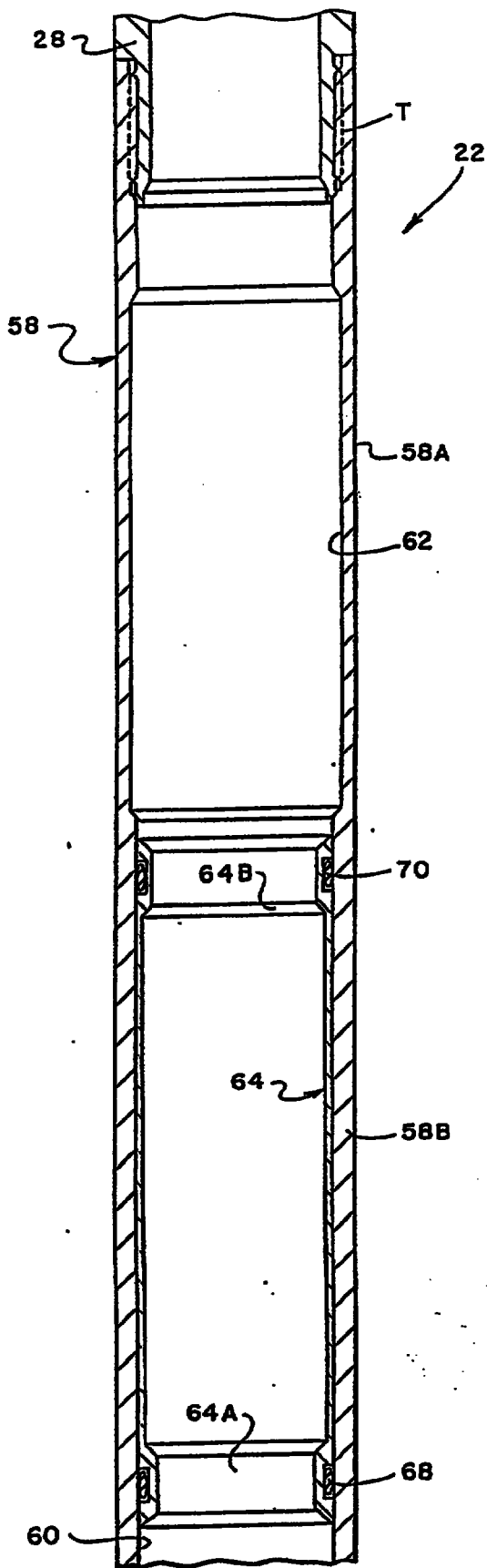


FIG. 3

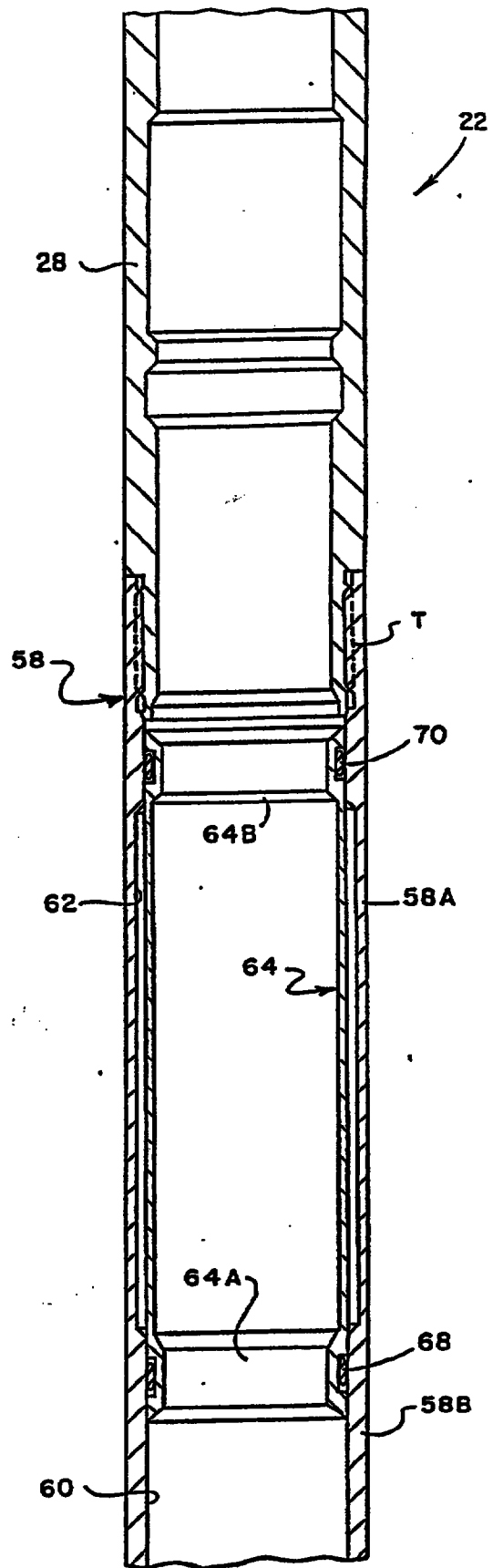


FIG. 4

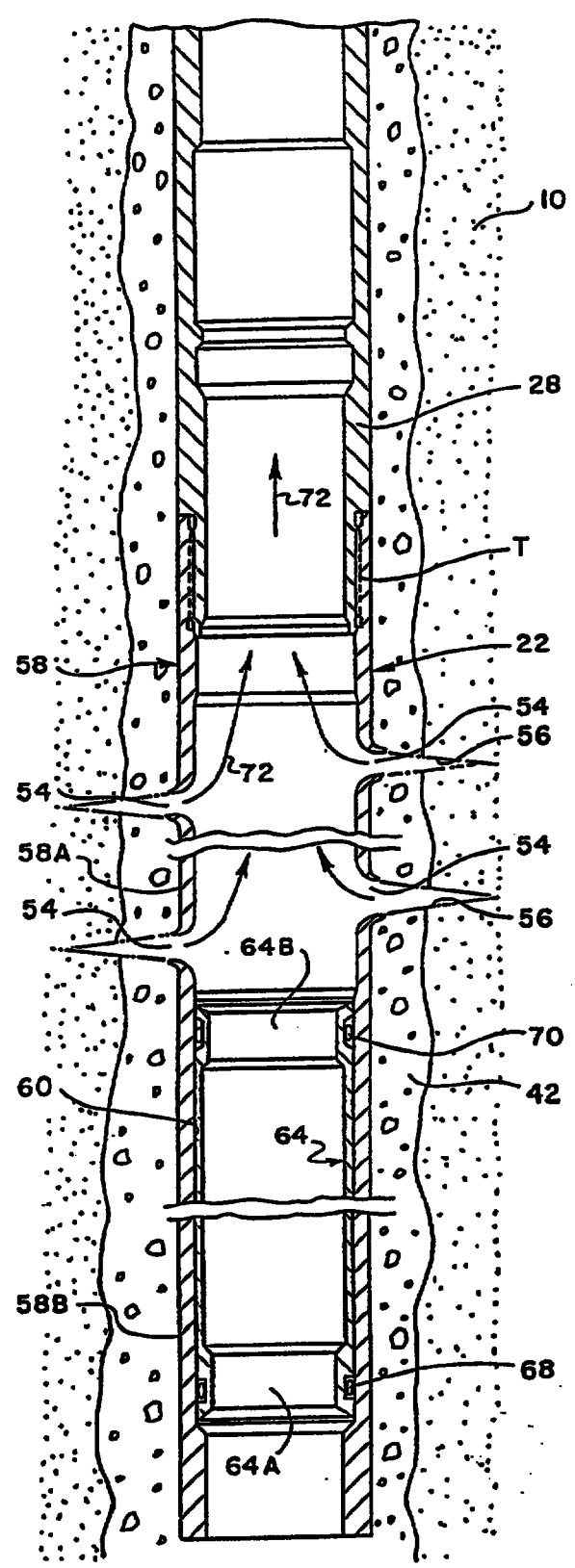


FIG. 5

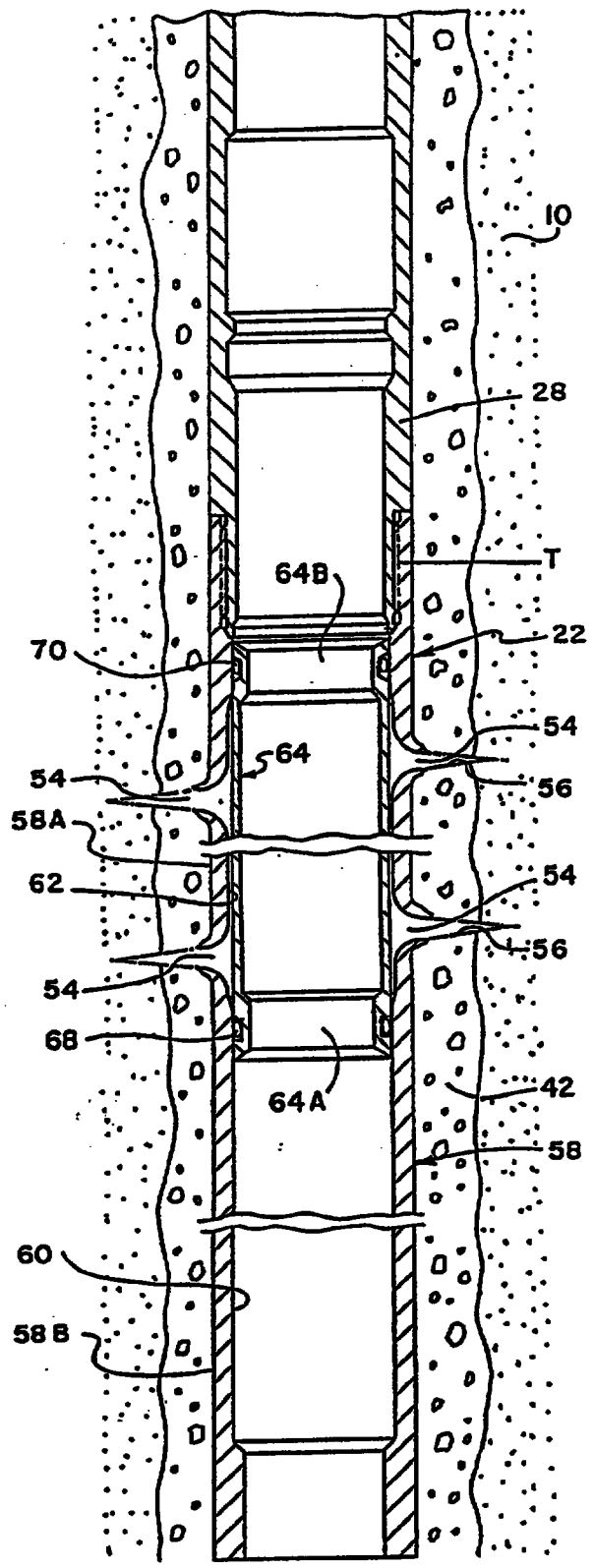


FIG. 6



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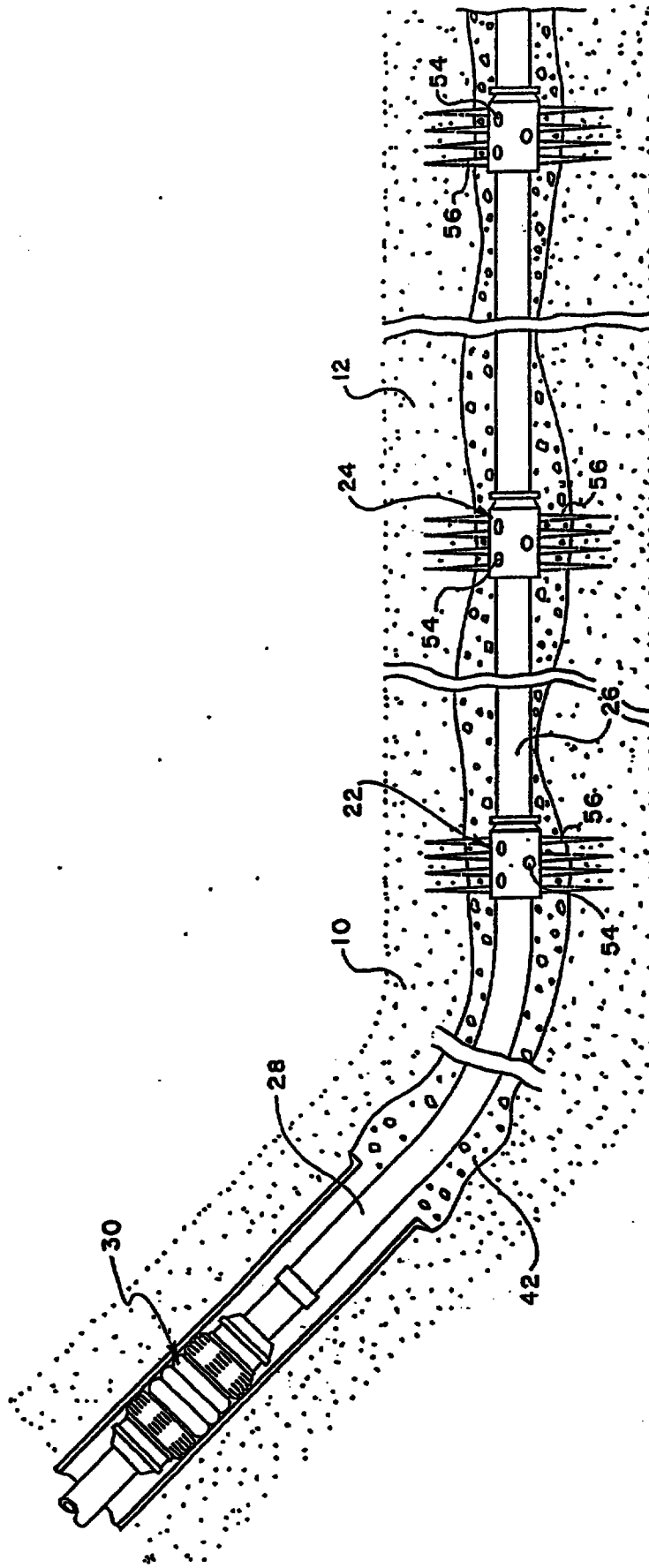


FIG. 7

Figure (a) to accompany abstract
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DEDICATED PERFORATED NIPPLE
WITH INTEGRAL ISOLATION SLEEVE

5 ABSTRACT

A production nipple (22) is suspended within an uncased bore hole (14) in a slimhole/monobore completion. A deposit of cement is conveyed through the nipple and is spotted in the annulus across the face of the uncased well bore, with the nipple and cement deposit thereafter being perforated by a small diameter perforating gun (44). The production nipple has a thin walled section (58A) which is characterised by reduced resistance to perforation by a shaped explosive charge. The perforating gun is accurately positioned in registration with the dedicated nipple section by an annular locator slot (74) formed on a coupling sub, which is engageable by a resilient latch arm (76) carried by the perforating gun.

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(Fig. 2)

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DEDICATED PERFORABLE NIPPLEWITH INTEGRAL ISOLATION SLEEVE

5 This invention relates generally to apparatus for completing downhole wells, and in particular to flow conductors for conveying inflowing formation fluid in water, oil, gas and recovery wells.

10 In the course of completing an oil and/or gas well, it is common practice to run a string of protective casing or liner into the well bore and then to run production tubing inside the casing. The annulus between the liner or casing and the surrounding formation is sealed with a deposit of cement to prevent fluid flow
15 through the external annulus from one formation zone to another. The cement is pumped through a work string suspended within the casing or liner into the annular space between the liner or casing and the surrounding well bore.

20 If the lining or casing traverses a hydrocarbon-bearing formation, the lining is perforated to create flow apertures through the casing and cement so that the formation fluids can flow into the well. The liner and/or well casing is perforated by a perforating gun
25 which is suspended within the well. Shaped explosive charges carried by the gun blast openings through the metal lining, the cement deposit and the surrounding formation.

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In some completions, however, the well bore is uncased, and an open face is established across the oil or gas bearing zone. Open bore hole (uncased) arrangements may be utilized, for example, in water wells, test wells and horizontal/deviated well completions.

Some open bore hole (uncased) installations are known as "slimhole" or "monobore" completions in which a protective liner or casing is not installed across the productive zone. In such completions, a small diameter flow conductor is suspended within the uncased bore hole and cement is pumped through the flow conductor into the annulus between the flow conductor and the surrounding earth formation. After cement residue is cleaned from the flow conductor, the flow conductor and the surrounding cement deposit are perforated to admit formation fluid into the well.

Because of the economies associated with slimhole/monobore completions, there is a continuing interest in improving the flow conductors used in such completions. There is a need for a small diameter production nipple which can be used in vertical as well as deviated uncased well bores, wherein the production nipple can be used to spot an annular deposit of cement across the face of the uncased well bore, with the nipple and protective cement deposit thereafter being perforated reliably by a small diameter perforating gun. There is also a need for a production nipple of the character

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described which can be closed and reopened in response to changing conditions in the producing zone.

According to one aspect of the invention there is provided a method for completing a well comprising: suspending a flow conductor and a production nipple having a tubular mandrel within a well bore; pumping cement into the annulus between the production nipple and the well bore; removing residual cement from the bore of the production nipple; perforating the tubular mandrel of the production nipple and the annular cement deposit with a perforating gun; and isolating the production nipple by covering the perforated sidewall section with a tubular sleeve.

In one embodiment, the perforating gun may be located in registration with a dedicated section of the tubular mandrel of the production nipple by latching the perforating gun onto the flow conductor at a predetermined latching location relative to the production nipple. The dedicated section of the production nipple may have a lower resistance to shaped charge as compared to the perforation resistance of said mandrel.

In another embodiment, the nipple may have a longitudinal production bore, said tubular mandrel may have a dedicated sidewall section by having a lower resistance to perforation by a shaped charge as compared to the perforation resistance of said mandrel, and said tubular sleeve may be disposed in slidable, sealing engagement against the internal bore of said tubular mandrel or nipple, said tubular sleeve being shiftable along the longitudinal axis of the internal bore between alternative positions covering and uncovering the dedicated sidewall section of said mandrel or nipple.

According to this arrangement, the perforating gun is located precisely in shoot alignment with the dedicated sidewall section of the production nipple.

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Latch apparatus may be mounted on said flow conductor for locating a perforating gun at a predetermined service position adjacent to the dedicated sidewall section of said nipple.

The flow conductor may have a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus may include a resilient latch arm carried by said perforating gun, said latch arm being movable from a radially retracted, non-interfering position to a radially extended, latched position in which said latch arm is received within said locator slot.

First and second longitudinally spaced annular seal means may be disposed in slidable, sealing engagement between said tubular sleeve and said bore of the nipple, said nipple and first and second annular seal members engaging said bore when said sleeve is in the covered position.

In another embodiment a packer may be provided having anchor slips for engaging a well casing and having a longitudinal bore for passing a perforating gun to and from a well location below the packer. In this embodiment, the flow conductor comprises production tubing coupled to said packer for suspension within the well; and the nipple is provided with a longitudinal production bore, said tubular mandrel being intersected by a longitudinal counterbore along a dedicated sidewall section of said nipple. Also, in this embodiment, the production bore and counterbore together define a service chamber, and the tubular sidewall of said nipple has first and second end portions, said dedicated section having disposed intermediate said first and second sidewall end portions, and the radial thickness of said dedicated sidewall section is less than the radial thickness of said first and second sidewall end portions. The tubular sleeve, in this embodiment, is disposed in slidable, sealing engagement against the production bore of said tubular nipple, said tubular sleeve being shiftable along the longitudinal axis of the tubular

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nipple from a first position in which said dedicated sidewall section of the tubular nipple is uncovered and exposed for perforation by the perforating gun to a second position in which said dedicated sidewall section is covered by said tubular sleeve.

Coacting latch apparatus may be coupled to the production tubing and to the perforating gun for locating said perforating gun within the service chamber of the tubular nipple.

The first and second sidewall end portions may be adapted for sealing engagement with said tubular sleeve when it is in the fully extended position.

First and second longitudinally spaced annular seal members may be disposed in slidable, sealing engagement between said isolation sleeve and the production bore of said nipple, said tubular sleeve spanning said sidewall section of said nipple and sealing said sidewall section when the sleeve is in said covered position.

A coupling sub may connect said tubular nipple to said packer, said coupling sub having a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus may include a resilient latch arm mounted on said perforating gun, said latch arm being movable from a retracted, non-interfering position to a radially extended, latch position in which said latch arm is received within said locator slot.

Because of the reduced radial thickness of the dedicated sidewall section, reliable puncture and penetration through the nipple, cement deposit and earth formation can be obtained with a smaller, less powerful explosive charge.

Reference is now made to the accompanying drawings in which:

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Fig. 1 is a simplified schematic diagram showing a vertical section through two producing formations which are intersected by an uncased well bore which has been completed with two production nipples suspended from a retrievable packer;

Fig. 2 is a simplified, sectional view which illustrates perforation of the production nipple, cement deposit and formation in a slimhole/monobore completion;

Fig. 3 is a longitudinal sectional view of the production nipple of Fig. 1 showing the isolation sleeve in its uncovered position with the dedicated section of the production nipple being exposed for perforation;

Fig. 4 is a view similar to Fig. 3 in which the isolation sleeve is in its covered position in which the dedicated sidewall of the production nipple is sealed;

Fig. 5 is a longitudinal sectional view of the slimhole/monobore completion showing the production of formation fluid through the perforated nipple;

Fig. 6 is a view similar to Fig. 3 in which fluid flow through the production nipple has been terminated by an isolation sleeve; and,

Fig. 7 is a simplified, sectional view which illustrates a horizontal well completion in an uncased bore hole in which multiple production nipples are positioned in registration with multiple producing zones.

In the description which follows, like parts are indicated throughout the specification and drawings with the same reference numerals, respectively. The drawings

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are not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details of the invention.

Referring now to Fig. 1, a first hydrocarbon formation 10 and a second hydrocarbon formation 12 are intersected by an uncased well bore 14. The uncased well bore 14 is sealed from the surface by a primary casing string 16, having an 11 inch diameter, which is secured to the wellhead assembly. Intermediate zones of the uncased well bore 14, are isolated by an intermediate casing string 18, having a 7 $\frac{1}{2}$ inch (194mm) diameter, and a final casing string 20, having a 5 $\frac{1}{2}$ inch (140mm) casing diameter.

The well 14 is completed by multiple nipple sections 22, 24 which are connected by a threaded union T in flow communication by flow conductors 26, 28. The flow conductor 28 is suspended from a retrievable packer 30 which is releasably set in engagement against the bore of the lowermost casing 20. The retrievable production packer 30 includes a mandrel 32 having a longitudinal production bore 34 for conveying formation fluid to the surface. The packer mandrel bore is coupled in fluid communication with a string of 3 $\frac{1}{2}$ inch (89mm) production tubing 36 by a full bore landing nipple 38. Production flow through the production tubing string 36 is controlled by a tubing retrievable safety valve 40.

Before the production tubing 36 is installed in the full bore landing nipple 38, a work string is coupled

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to the landing nipple and a predetermined volume of cement is pumped through the packer bore, the flow conductors 26,28 and the production nipples 22,24. The annulus surrounding the suspended flow conductors and production nipples is filled with a cement deposit 42 which prevents vertical flow of formation fluid between the hydrocarbon formation 10 and the hydrocarbon formation 12. A seal plug is introduced into the bore of the work string to separate the cement from the displacing fluid and to wipe the cement from the packer bore, the flow conductor bores and the nipple bores as the cement is displaced out of the tubing and into the surrounding annular space.

After the seal plug has been removed and the production bores have been cleared of debris, a perforating gun 44 is positioned within the bore of each nipple. The perforating gun 44 is suspended and run into the well on a tubing string. Preferably, the tubing string is a length of coil tubing having a firing line inside. The perforating gun assembly 44 is equipped with a mandrel 46 which includes an array of explosive, jet-type perforating charges 48. The perforating gun 44 is coupled to the flow conductor 28 by a locator sub 50.

Upon detonation, each explosive charge 48 produces a high temperature, high pressure plasma jet 52 which penetrates the sidewall of the nipple 22, the protective cement layer 42 and the surrounding formation 12. The high temperature, high pressure plasma jet 52

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penetrates the metal sidewall of the nipple, thus producing a clean perforation 54 through the nipple sidewall and an irregular fracture 56 through the surrounding concrete layer and earth formation.

5 Preferably, the shoot is performed with the well in an underbalanced pressure condition relative to the surrounding formation. With a sufficiently high pressure differential, the pressure surge from the surrounding formation will break up any compacted material and sweep
10 it back in the well bore where it will be flowed to the surface. As compacted fragments are swept away, the nipple sidewall perforations 54 are cleaned and cleared for maximum inflow. After the perforating gun 44 is removed from the well, the well is then ready for
15 immediate production.

Referring now to Fig. 3 and Fig. 4, the production nipple 22 includes a tubular mandrel 58 which includes first and second longitudinally spaced sidewall sections 58A, 58B. According to one aspect of the present
20 invention, one of the mandrel sidewall sections, in this instance section 58A, is dedicated for perforation by a perforating gun, and is characterised by a lower resistance to perforation in response to the explosive force of a shaped charge as compared to the perforation
25 resistance of the other sidewall section 58B. The differential resistance to perforation is obtained, according to one aspect of the present invention, by forming the dedicated sidewall section 58A with a reduced

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radial thickness as compared to the sidewall thickness of the nipple section 58B.

The mandrel section 58B is intersected by a longitudinal production bore 60, and the dedicated
5 sidewall section 58A is intersected by a longitudinal counterbore 62 which extends along the length of the dedicated sidewall section 58A. According to this arrangement, the main production bore 60 is enlarged by the counterbore 62 along the length of the dedicated
10 sidewall section. The radial thickness of the dedicated sidewall section 58A is reduced substantially with respect to the thickness of the nipple sidewall section 58B, as shown in Fig. 4. In those illustrations where the nipples support very little hang weight, the radial
15 thickness of the dedicated sidewall section 58A can be reduced substantially relative to the thickness of the nipple sidewall section 58B.

A tubular sleeve in the form of an isolation sleeve 64 is incorporated within the production nipple 22 for the purpose of selectively isolating a particular production zone at any time during the life of the well. That is, the isolation sleeve 64 is shifted to a non-interfering position, as shown in Fig. 2, in which the dedicated sidewall section 58A is exposed to the perforating gun 44. The isolation sleeve 64 is also movable to a closed position, as shown in Fig. 4, in which the perforated, dedicated sidewall section is sealed for the purpose of isolating the zone which may be _____

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producing an excessive amount of gas or water.

The isolation sleeve 64 is received in slidably, sealing engagement against the production bore 60 of the nipple mandrel. The isolation sleeve 64 is provided with
5 shifting shoulders 64A, 64B which are engagable by a shifting tool supported on a wire line or by a coiled tubing string. Although the exemplary embodiment shows that the dedicated nipple sidewall section 58A is arranged for exposure by downshifting the isolation
10 sleeve 64, it will be appreciated that the respective positions of the dedicated nipple section 58A and nipple section 58B could be reversed, with the isolation sleeve 64 being shifted upwardly for exposure of the dedicated sidewall section.

15 As can best be seen in Fig. 4, the isolation sleeve 64 spans the complete length of the dedicated sidewall section 58A, with the counterbore 62 being sealed with respect to the production bore 60 by first and second annular seal members 68, 70, respectively. The
20 annular seal members 68, 70 are curved, molded seals which are carried in annular slots formed in the shifting shoulders 66A, 66B, respectively.

Referring to Fig. 5, the isolation sleeve 64 is received within the production bore 60 of the nipple
25 mandrel 58 in a non-interfering position in which the dedicated sidewall section 58A of the nipple is uncovered, thus permitting the flow of formation fluid through the nipple perforations 56, as indicated by the

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arrows 72. As shown in Fig. 6, the dedicated section 58A is completely covered by the isolation sleeve 64, and the counterbore 62 is sealed by the annular seals 68,70, thus preventing the inflow of formation fluid through the
5 nipple perforations 56.

In some installations, the flow conductor 28 is suspended directly from the wellhead, with one or more production nipples 22,24 being suspended within an uncased well bore, typically in a shallow slimhole/
10 monobore well completion. In such installations, the perforating gun 44 may be located accurately when the depth of the production nipple is known. The operator runs the perforating tool until the length of the coiled tubing corresponds with the known depth of the production
15 nipple. However, that method becomes less accurate for deep wells, in particular for wells which may have lateral deviations.

Referring now to Fig. 2, accurate positioning of the perforating gun 44 is provided by an annular locator
20 slot 74 formed on the flow conductor 28, and a resilient, deflectable latch arm 76 carried on the locator sub 50. The resilient, deflectable latch arm 76 is movable from a retracted, non-interfering position which permits travel of the perforating gun 44 through the production bore, to
25 a radially extended, latched position, as shown in Fig. 2, in which it is received within the locator slot 74. According to this arrangement, the perforating gun 44 is located precisely in shoot alignment with the dedicated

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sidewall section 58A of the production nipple 22. The longitudinal distance of the dedicated nipple sidewall section 58A relative to the locator slot 74 is known, and the length of the perforating gun 46 relative to the latch arm 76 is adjusted with a coupling sub 78 so that the explosive charges 48 are centered in shoot alignment along the length of the dedicated nipple sidewall section 58A when the latch arm 76 is received in detented engagement with the locator slot 74.

It will be appreciated that because of the reduced radial thickness of the dedicated nipple sidewall section 58A, reliable puncture and penetration through the nipple 22, cement deposit 42 and earth formation 10 can be obtained with a smaller, less powerful explosive charge. Since a less powerful explosive charge is required, the perforating gun 46 can be physically smaller in diameter, and can be run through the small diameter production tubing (3½ inch or smaller) utilized in slimhole/monobore completions. Because of the reduced sizing provided by the production nipple, the well may be drilled with a smaller rig, less well control material is required during drilling of the bore hole, the quantity of cement required is reduced, and the size and quantity of casing and tubing required to complete the well are reduced. Moreover, the well may be completed on coiled tubing, thus further reducing the cost of the completion string and reducing the overall time required for installation. Since coiled tubing may be utilized, the

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well may be completed or recompleted without the necessity of killing the well, thereby reducing the potential for damage to the reservoir. Moreover, in multizone completions, the production nipples may be opened and closed as desired, either sequentially or selectively, for isolating a zone which may be producing too much water or gas. The production nipples of the present invention may also be used in uncased, horizontal completions as shown in Fig. 7.

Although the invention has been described with reference to an oil well completion, and with reference to particular preferred embodiments, the foregoing description is not intended to be construed in a limiting sense. The well completion method according to the present invention may be used to good advantage in alternative applications, for example, in gas wells, environmental wells, including monitoring wells, recovery wells and disposal wells. It is therefore contemplated that the invention includes any such applications which incorporate the well completion method disclosed.

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CLAIMS:

1. A method for completing a well comprising: suspending a flow conductor and a production nipple having a tubular mandrel within a well bore; pumping cement into the annulus between the production nipple and the well bore; removing residual cement from the bore of the production nipple; perforating the tubular mandrel of the production nipple and the annular cement deposit with a perforating gun; and isolating the production nipple by covering the perforated sidewall section with a tubular sleeve.
2. A method according to claim 1, further comprising locating the perforating gun in registration with a dedicated section of the tubular mandrel of the production nipple by latching the perforating gun onto the flow conductor at a predetermined latching location relative to the production nipple.
3. A method according to claim 2, wherein the dedicated section of the production nipple is characterised by having a lower resistance to shaped charge as compared to the perforation resistance of said mandrel.
4. A method according to claim 1, wherein the nipple has a longitudinal production bore, said tubular mandrel has a dedicated sidewall section characterised by having a lower resistance to perforation by a shaped charge as compared to the perforation resistance of said mandrel, and said tubular sleeve is disposed in slidable, sealing engagement against the internal bore of said tubular mandrel or nipple, said tubular sleeve being shiftable along the longitudinal axis of the internal bore between alternative positions covering and uncovering the dedicated sidewall section of said mandrel or nipple.

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5. A method according to claim 4, wherein latch apparatus is mounted on said flow conductor for locating a perforating gun at a predetermined service position adjacent to the dedicated sidewall section of said nipple.

6. A method according to claim 5, wherein the flow conductor has a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus includes a resilient latch arm carried by said perforating gun, said latch arm being movable from a radially retracted, non-interfering position to a radially extended, latched position in which said latch arm is received within said locator slot.

7. A method according to claim 4,5 or 6, wherein first and second longitudinally spaced annular seal means are disposed in slidable, sealing engagement between said tubular sleeve and said bore of the nipple, said nipple and first and second annular seal members engaging said bore when said sleeve is in the covered position.

8. A method according to claim 1, wherein a packer is provided having anchor slips for engaging a well casing and having a longitudinal bore for passing a perforating gun to and from a well location below the packer; the flow conductor comprises production tubing coupled to said packer for suspension within the well; the nipple is provided with a longitudinal production bore, said tubular mandrel being intersected by a longitudinal counterbore along a dedicated sidewall section of said nipple, wherein said production bore and counterbore together define a service chamber, and wherein the tubular sidewall of said nipple has first and second end portions, said dedicated section is disposed intermediate said first and second sidewall end portions, and the radial thickness of said dedicated sidewall section is

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less than the radial thickness of said first and second sidewall end portions; and said tubular sleeve is disposed in slidable, sealing engagement against the production bore of said tubular nipple, said tubular sleeve being shiftable along the longitudinal axis of the tubular nipple from a first position in which said dedicated sidewall section of the tubular nipple is uncovered and exposed for perforation by the perforating gun to a second position in which said dedicated sidewall section is covered by said tubular sleeve.

9. A method according to claim 8, wherein coacting latch apparatus is coupled to the production tubing and to the perforating gun for locating said perforating gun within the service chamber of the tubular nipple.

10. A method according to claim 9, wherein said first and second sidewall end portions are adapted for sealing engagement with said tubular sleeve when it is in the fully extended position.

11. A method according to claim 9 or 10, including first and second longitudinally spaced annular seal members disposed in slidable, sealing engagement between said isolation sleeve and the production bore of said nipple, said tubular sleeve spanning said sidewall section of said nipple and sealing said sidewall section when the sleeve is in said covered position.

12. A method according to claim 9, 10 or 11, including a coupling sub connecting said tubular nipple to said packer, said coupling sub having a tubular sidewall radially intersected by an internal, annular locator slot, and said latch apparatus includes a resilient latch arm mounted on said perforating gun, said latch arm being movable from a retracted, non-

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interfering position to a radially extended, latch position in which said latch arm is received within said locator slot.

13. A method of completing a well substantially as described herein with reference to the accompanying drawings.

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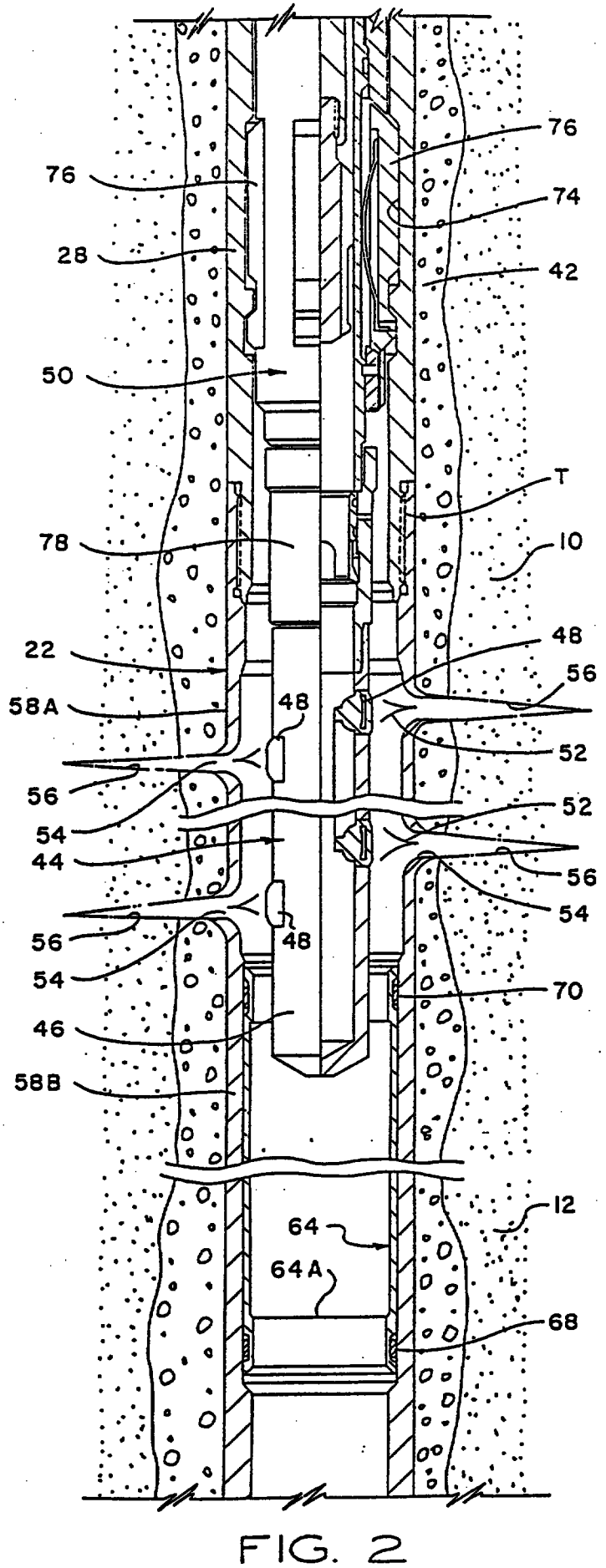
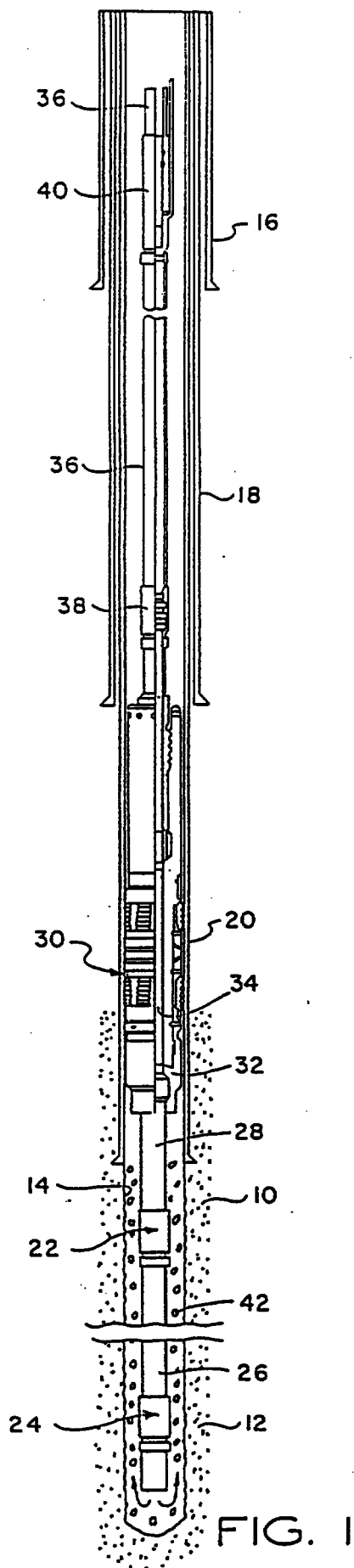
DEDICATED PERFORATED NIPPLE
WITH INTEGRAL ISOLATION SLEEVE

5 ABSTRACT

 A production nipple (22) is suspended within an uncased bore hole (14) in a slimhole/monobore completion. A deposit of cement is conveyed through the nipple and is spotted in the annulus across the face of the uncased
10 well bore, with the nipple and cement deposit thereafter being perforated by a small diameter perforating gun (44). The production nipple has a thin walled section (58A) which is characterised by reduced resistance to perforation by a shaped explosive charge. The
15 perforating gun is accurately positioned in registration with the dedicated nipple section by an annular locator slot (74) formed on a coupling sub, which is engageable by a resilient latch arm (76) carried by the perforating gun.

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Fig. 2



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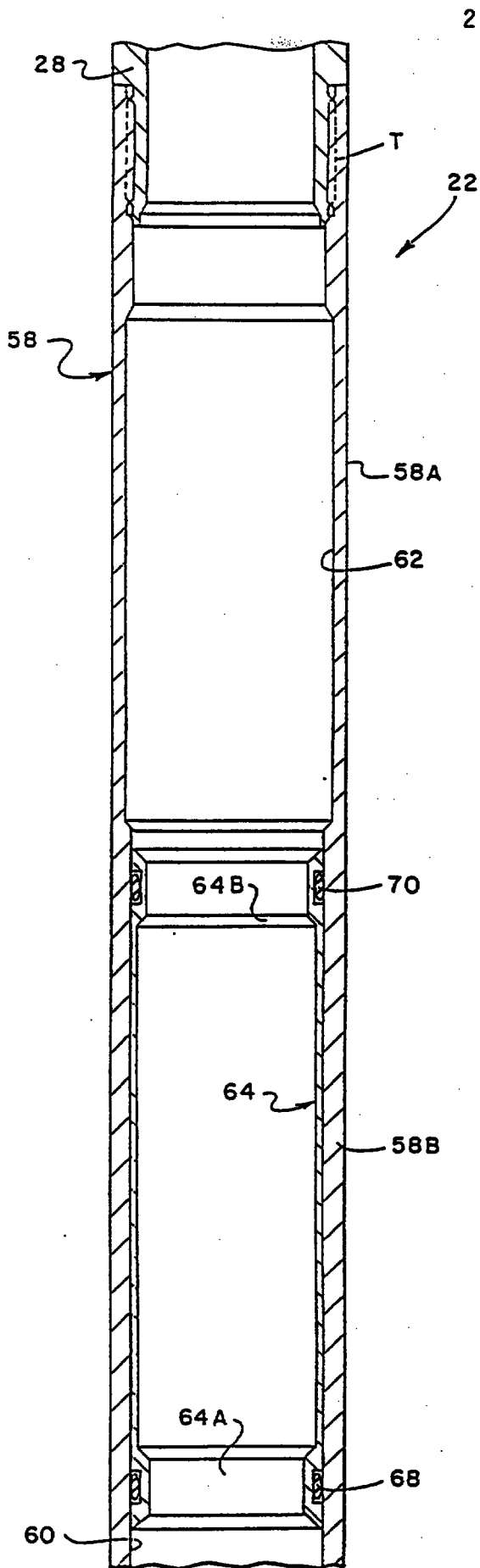


FIG. 3

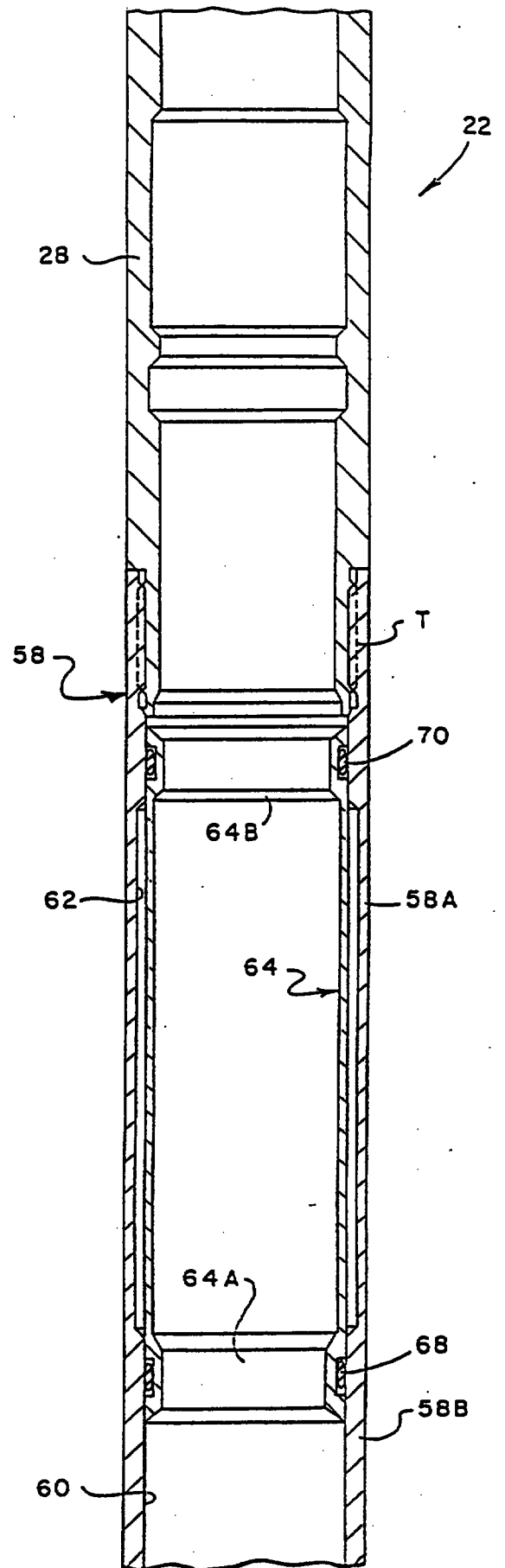


FIG. 4

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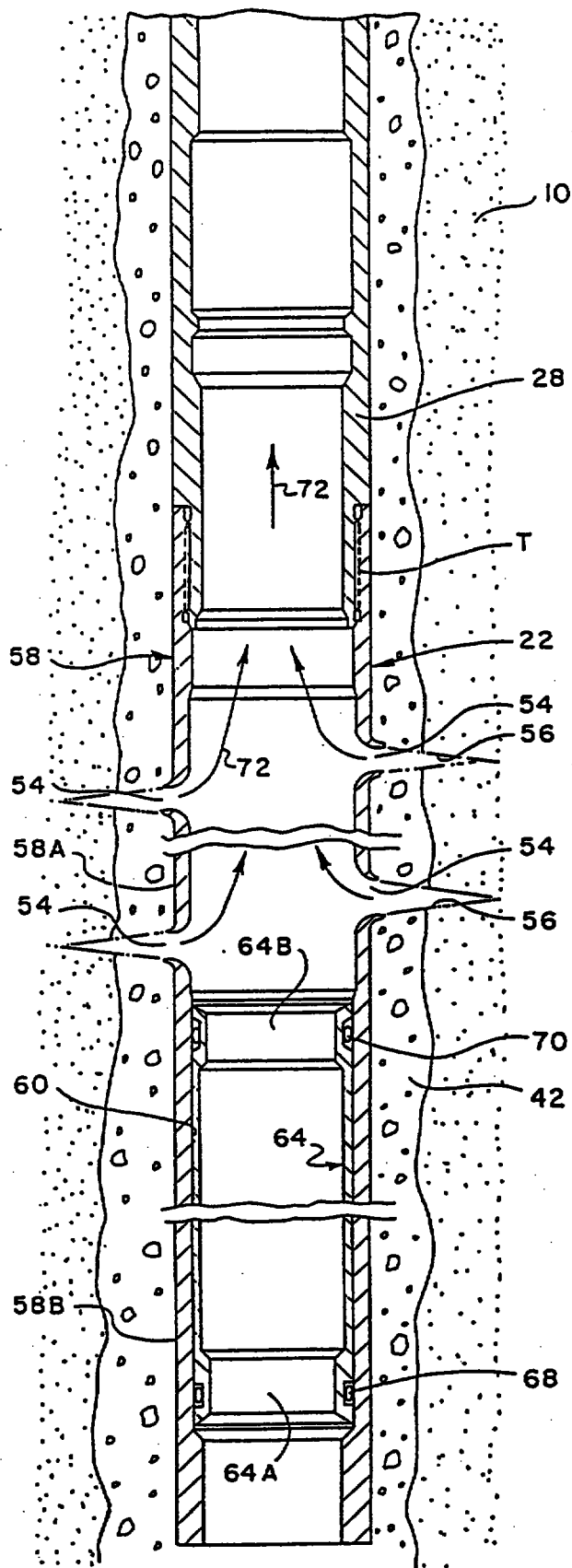


FIG. 5

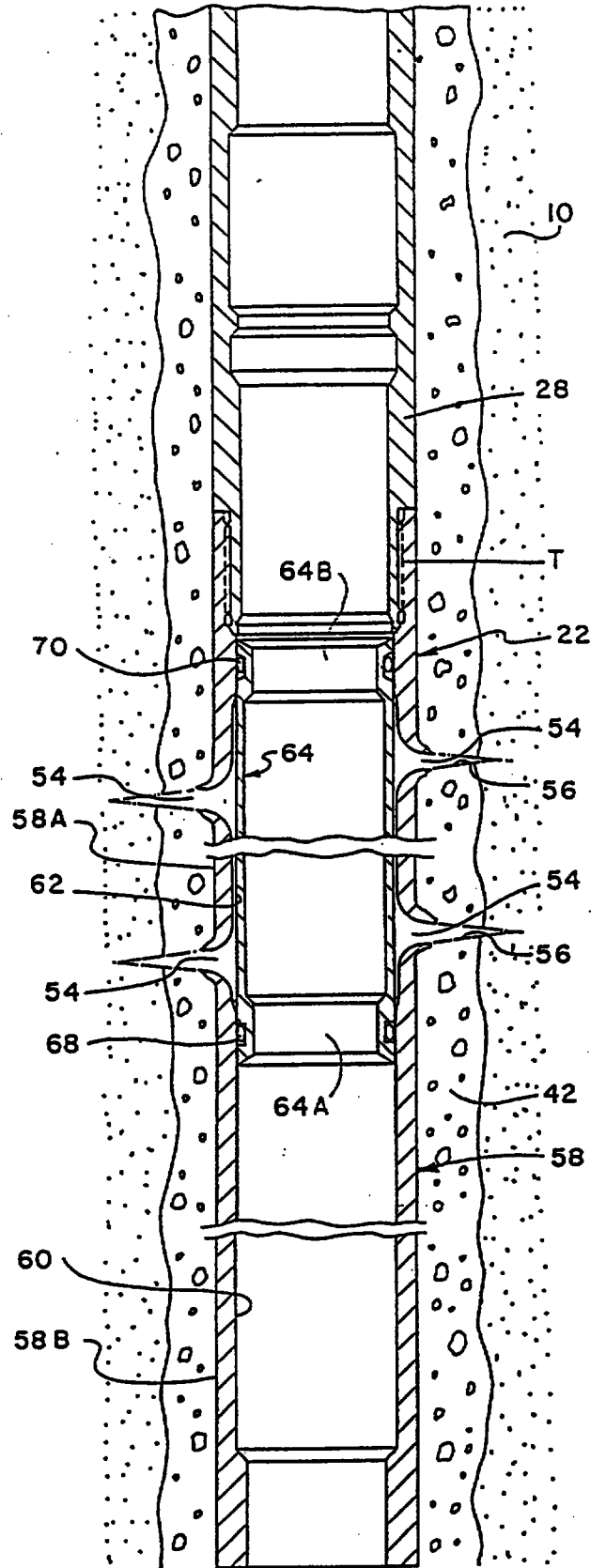


FIG. 6

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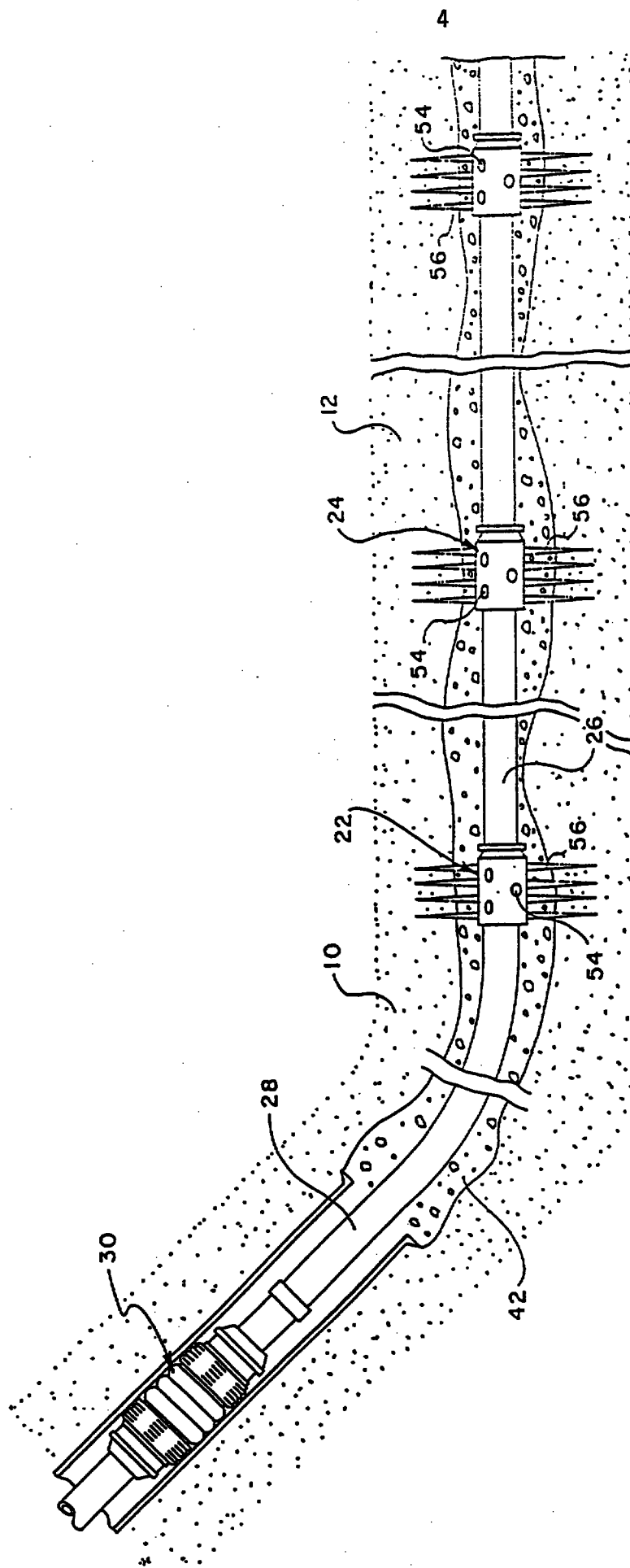


FIG. 7

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