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OMBIA

Señora Jefe de la  
**DIVISION DE NUEVAS CREACIONES**  
Superintendencia de Industria y Comercio  
E. S. D.

Referencia : Expediente No. 00.030.399  
Solicitante : **MARATHON OIL COMPANY**  
Asunto : Solicitud de patente para: **"PROCESO Y  
APARATO PARA PERFORACION GUIADA CON  
PLACA DE REVESTIMIENTO"**  
Fecha de la solicitud : 27 de abril de 2000.

**TRAMITE: 002 - EVENTO: 001 - ACTUACION: 444**

1. Yo, Emilio FERRERO, obrando como apoderado del solicitante en el asunto antes identificado, me refiero al auto número 1286, notificado por estado del 18 de mayo de 2000. Para atender a la providencia anterior solicité un plazo por medio de mi memorial número 00030399 00000001 radicado el 30 de junio de 2000.

2. Mediante el auto número 1286 se puso en conocimiento del solicitante el informe que contiene las observaciones hechas por su Despacho sobre la presente solicitud de patente. Atiendo a las observaciones de la manera siguiente:

2.1. En la descripción. Presento junto con este memorial unas nuevas páginas 4, 20, 27, 28, 34 y 36 a 40, pertenecientes al capítulo descriptivo, en las cuales se ha realizado la respectiva conversión de unidades al Sistema Internacional y donde se han modificado los

RESPUESTA AL AUTO 1286  
DEL DIA 18 de mayo 2000

numerales de referencia que no concordaban con los dibujos, de acuerdo con lo requerido por ese Despacho. Le solicito se sirva aceptar estas nuevas páginas en sustitución de las presentadas originalmente.

2.2. Arte Final. Adjunto a este memorial presento los artes finales de acuerdo con lo requerido.

2.3. Dibujos. Presento junto con este escrito los dibujos de las figuras 10c, 12a, 14a-c, 15a y 16a, que se mencionan en la descripción y ahora contienen los números de referencia correctos y completos. Le solicito se sirva aceptar estos nuevos dibujos en sustitución de los presentados originalmente.

2.4. Copia Certificada. Presento con este escrito copia certificada de la solicitud de patente estadounidense número 09/300,056 del 27 de abril de 1999 junto con su respectiva traducción de sus reivindicaciones y certificaciones, en la cual se basa la reivindicación de la prioridad.

3. Puesto que se han atendido a cabalidad las observaciones hechas por su Despacho sobre la presente solicitud de patente, atentamente solicito que se continúe su tramitación.

Bogotá,  
Señora Jefe,



EMILIO FERRERO

T.P.A. No. 31.929

COLO 00729-801-003-9

MRE-84

pozo y se las hace detonar. Cuando se utiliza un método determinado de detonación y la(s) zona(s) subterráneas y/o formación de interés son relativamente delgadas, por ejemplo 4,6 m o menos, la perforadora se ubica en forma adyacente a la zona de interés y algunas de las cargas con forma de la perforadora son detonadas para perforar en forma selectiva esta zona o formación. Luego se ubica nuevamente la perforadora por medio de un cableado en otra zona y formación y se detonan algunas cargas con forma para perforar en forma selectiva esta zona o formación. Este procedimiento se repite hasta que toda(s) la(s) zona(s) y/o formación(es) sean perforadas y la perforadora sea recuperada a la superficie por medio de un cableado. En la opción de las perforadoras espaciadas conducidas por tuberías, dos o más perforadoras son transportadas hacia el interior del pozo en el mismo tubo en un modo espaciado de modo que cada perforadora esté ubicada en forma adyacente a una de las zonas y/o formaciones subterráneas de interés. Una vez ubicadas en el pozo, las perforadoras pueden ser detonadas en forma simultánea o selectiva para perforar el placa de revestimiento y establecer comunicación con cada zona(s) y/o formación(es).

Si la(s) zona(s) y/o formación(es) que han sido perforadas por medio del modo convencional deben ser fracturadas en forma hidráulica, se bombea el fluido hacia el interior del pozo bajo presión que excede la presión en la cual la(s) zona(s) y/o formación(es) se fracturarán. Sin embargo, el fluido de fractura preferiblemente fluirá hacia el interior de la(s) zona(s) y/o formación(es) que normalmente tienen la mayor porosidad y/o la menor

perforadora, y el espaciado entre las placas de revestimiento y el montaje. Por ejemplo, el ángulo  $\alpha$  para un montaje de la perforadora de 5,4 cm y una placa de revestimiento de 11,4 cm es de 30°, para un montaje de 6,0 cm y una tubería de 8,9 cm es de 22,5° y para un montaje de 7,3 cm y una placa de revestimiento de 7,3 cm es de 17,5°. Los túneles de perforación 40, 42, 44 y 46-48 se forman por medio de la explosión de las cargas explosivas en secuencias que comienzan desde cualquier extremo de la perforadora. Además, aunque se prefiera que las cargas explosivas de cada montaje estén orientadas para disparar en un plano que es perpendicular al eje del montaje, una o más cargas pueden ser dispuestas para dispararse en un ángulo con respecto al del plano horizontal.

En otra realización de la presente invención, el montaje de la presente invención está construido con una placa de revestimiento 112 y múltiples montajes de perforadoras 120 a-e (FIG 9). Montados y ubicados dentro del túnel del pozo 102, los montajes de perforación están ubicados en la parte externa de la placa de revestimiento 112 en forma adyacente al diámetro exterior del mismo. Se prefiere que los montajes de perforadora 120 a-e estén asegurados a la placa de revestimiento 112 por cualquier medio apropiado, por ejemplo por bandas de metal que envuelven tanto la placa de revestimiento 112 como los montajes de perforadora 120 a-e o un conector especial, para asegurar que la posición relativa entre cada montaje de la perforadora 120 y la placa de revestimiento 112 totalmente montado no cambie sustancialmente durante la colocación del montaje de la presente invención en el túnel del pozo

de macho a hembra 314, un montaje secundario de válvula con lengüeta 380, un segundo tramo de la placa de revestimiento 310, un anillo 316, un tercer tramo de la placa de revestimiento 310 y un segundo anillo especial 304 están asegurados juntos, en una secuencia como la que se mencionó anteriormente y que está ilustrada en la FIG. 12, a través de cualquier medio adecuado, tal como tornillos. Como se ilustra en las FIGS. 12 y 13, cada anillo especial 304 tiene un primer túnel 305 que se extiende en forma axial que tiene forma generalmente cilíndrica, que tiene extremos atornillados y un segundo túnel 306 más pequeño en diámetro que se extiende en forma axial, que está desviado del eje del túnel 305 y que tiene un extremo agrandado 307 que está provisto de roscas de tornillo para lograr la unión con un montaje de la perforadora y un segundo extremo que está atornillado para encastrar con una línea hidráulica como se describirá más adelante.

El montaje secundario de válvula con lengüeta 380 comprende generalmente secciones de un cuerpo tubular 381, 383, 385 y 386 que están aseguradas entre sí por cualquier medio adecuado, tal como roscas de tornillo. Los sellos en forma de anillo tipo O 382, 388 y 387 suministran una conexión muy fluida entre estas secciones del cuerpo generalmente tubulares. La sección del cuerpo 383 está provista de un puerto 389 que suministra comunicación fluida a través de la pared de la sección 383 y está atornillada a un extremo para su unión a una línea hidráulica, como se describirá más adelante. Se recibe una manguera 400 dentro de las secciones del cuerpo 381, 383, 385 y 386 de modo tal que, cuando están dispuestas en la posición ilustrada en las

FIGS. 14a y 15a, dos cámaras anulares 394 y 395 se definen entre ellas. La manguera 400 tiene una porción exterior levantada 401 intermedia a la longitud de ella, lo cual define muescas 411 y 406 generalmente opuestas. La manguera puede moverse con respecto a las secciones del cuerpo donde la cantidad de movimiento está limitada por la porción exterior levantada 401 que limita los extremos de la cámara anular 395. Los anillos en forma anular que sirven de sello 392 y 393 suministran un sello fluido entre la manguera 400 y las secciones del cuerpo 381 y 383. Una válvula con lengüeta 396 está asegurada de un modo que le permite la rotación a la porción del cuerpo 386 y está orientada hacia una posición cerrada enganchada con una base generalmente anular 399 formada por un extremo de la porción del cuerpo 386 por medio de un espiral 398 de modo que bloquea el flujo de fluidos a través del túnel interior 390 del montaje secundario. Cuando está montada, la válvula con lengüeta 396 está ubicada en una posición abierta y retraída dentro de la cámara anular 394 y está sostenida a la misma por la manguera 400. La manguera 400 está sostenida en esta posición por medio de la presión del aire del ambiente en la cámara 395 que actúa contra la muesca 411. La válvula con lengüeta 396 está construida con cualquier material apropiado, por ejemplo cerámica o un metal relativamente blando como aluminio o hierro fundido, que puede ser eliminada por taladrado rotativo o un medio de percusión.

Los montajes de perforadora 320 y 320a comprenden cada uno un montaje de detonación 330 y una perforadora 350. Se puede utilizar cualquier montaje de detonación apropiado conocido por aquellos con experiencia en el

propagan dentro de la formación 206a. Donde se emplean fluidos de estimulación, como los fluidos de acidificación, y/o fluidos de tratamiento, no es necesario bombear estos fluidos a presiones suficientes para provocar las fracturas 256a.

Cuando el proceso de estimulación y/o tratamiento está completo, se aumenta la presión hidráulica en la línea 402 hasta que los pernos de seguridad 338 en el montaje de la perforadora 320a se cizallan. En este momento, el pistón 336 en el montaje de la perforadora tiene un movimiento libre que hace que el perno 315 haga contacto, provocando que el manguito 317 que se encuentra en el montaje de la perforadora 320a se mueva (FIG. 19) sellando de este modo la sonda 365 en el grifo 364 contra el flujo del fluido. El movimiento del pistón 336 también hace que el pistón de encendido 340 golpee el cabezal de encendido 342 logrando el encendido del detonador de percusión 343, haciendo detonar el conductor 349 y las cargas 356 (FIG. 13c) en el portador de carga 352, formando la(s) perforación(es) 260b (FIG. 11c), es decir, las perforaciones 313 a través de la placa de revestimiento 310 (FIG. 13c). La presión del fluido en el interior de la placa de revestimiento 310 se comunica al interior 325 del gabinete 324 forzando de este modo al pistón 326 en el montaje 320a, para que haga fluir el fluido hidráulico a través de la línea 407, puerto 389 y que actúe contra la muesca 406 del manguito 400. En respuesta a esto, el manguito 400 se mueve hasta que la muesca 411 haga tope con el extremo de la cámara 395 permitiendo que la válvula con lengüeta 396 haga una rotación hasta encastrarse con la base 399 (FIG. 15c). De este modo,

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El siguiente ejemplo demuestra la práctica y la utilidad de la presente invención, aunque no está realizado con la intención de limitar el alcance de la misma.

### EJEMPLO

Se cava un pozo con una barrena de 20 cm hasta una profundidad de 1219 m con lodo de perforación de 1,32 kg/l y se fija una placa de revestimiento de superficie de 24,4 cm a 152,4 m. Se realizan y se analizan indicadores con forma de huecos abiertos, junto con otro tipo de información como datos de desviación geológica, datos de excavado e indicadores de lodo. Se determinan tres intervalos productores de petróleo potenciales existentes en el pozo. Se ubica una formación de carbonato desde 1127,8 m hasta 1132,3 m y se espera tener una productividad escasa, salvo que se la estimule. Se ubica una formación de arena desde 1097,3 m hasta 1100,3 m y se espera tener una baja productividad a menos que se la estimule. Carbonato altamente fracturado se localiza desde 1066,8 m hasta 1069,8 m, y se cree que no requerirá ninguna estimulación. Todas las profundidades antes mencionadas son en base a los indicadores de los huecos abiertos. Una realización del montaje de la presente invención se construye con una placa de revestimiento que tiene un diámetro externo de 8,9 cm y un equipamiento de paleta para cemento ubicado en el extremo de la placa de revestimiento. El montaje además contiene tres perforadoras con un diámetro externo de 6,0 cm montadas externamente, que se encuentran orientadas para disparar tanto a la placa de revestimiento como a la formación, todas cargadas con 6 cargas que tienen

forma, por 0,305 m. El Montaje de la perforadora A contiene 4,6 m de cargas de perforación con forma, mientras que los Montajes de Perforadora B y C contienen 3,0 m de cargas de perforación con forma. También se utiliza una válvula con lengüeta en la cual la lengüeta está hecha de cerámica, Montaje D. Aproximadamente 30,5 m de la placa de revestimiento, con el equipamiento de paleta para cemento, se extienden por debajo del conector del Montaje de Perforación A. El equipamiento está ubicado utilizando conectores especiales en la placa de revestimiento de 8,9 m y un caño espaciador, y utiliza la carga de perforación superior en el Montaje A como punto de referencia de modo tal que la válvula con lengüeta D está a 24,4 m de distancia del punto de referencia, la parte superior del Montaje de perforación B está a 30,5 m de distancia del punto de referencia, y el montaje de perforación C está a 61 m de distancia del punto de referencia. Se conecta una línea de control hidráulica a todos los montajes apropiados y se hace llegar hasta el hueco de la sonda con los tramos adicionales de la placa de revestimiento de 8,9 m requeridos para formar la cadena completa de placa de revestimiento, por medio de la ubicación de bandas de acero alrededor de la línea de control y la placa de revestimiento, cada 9,1 m hasta la parte posterior del túnel del pozo.

Se hace correr la serie de placas de revestimiento hacia el interior del túnel del pozo hasta que las medidas del caño indiquen que la parte posterior del Montaje de Perforación A está ubicado en una medida del caño de 1127,8 m. Se circunda el pozo con lodo de perforación y se coloca un indicador de rayos gama en forma de anillo de la placa de revestimiento para determinar la

posición relativa del Montaje de Perforación A para abrir las profundidades de indicación de los huecos abiertos. Sobre la base de las correlaciones, se determinan que las necesidades del equipamiento y la placa de revestimiento deben ser disminuidas en el túnel del pozo en un total de 1,52 m para que se encuentren exactamente en la profundidad, y se elimine la herramienta indicadora del pozo. Se baja el caño hacia el interior del túnel del pozo a un total de 1,8 m, dado que los cálculos de ingeniería indican que el movimiento de la placa de revestimiento contraerá la cadena aproximadamente en un pie durante las operaciones de cementado. Se apoya la placa de revestimiento en el equipamiento del borde del pozo y se cementa en el interior del hueco abierto bombeando cemento de 1,9 kg/l en cantidad suficiente para llenar la totalidad del anillo, y se reemplaza el cemento con salmuera de 1,1 kg/l en el equipamiento de flotación del cemento.

Un tiempo después, cuando el cemento está curado, el Montaje de Perforación A es detonado por medio de la conexión sobre la superficie a la línea de control hidráulica que está cementada en la parte posterior de la placa de revestimiento, y la aplicación de 10,35 MPa de presión superficial para hacer funcionar el cabezal de encendido que funciona a presión. Se puede desear intentar permitir que este intervalo fluya hacia el interior de la placa de revestimiento y hacia la parte posterior de la placa de revestimiento hasta la superficie para obtener información preliminar del depósito. Entonces, este intervalo más bajo del pozo es estimulado con ácido por medio del bombeo de 37,85 m<sup>3</sup> de ácido clorhídrico al 15% a 24,17 MPa una velocidad de 0,8

m<sup>3</sup> por minuto. Se desplaza el ácido con la primera etapa de un fluido de fractura que será utilizado para estimular el segundo intervalo, desde 1097,3 m hasta 1100,3 m. El desplazamiento del ácido es interrumpido mientras que la última porción del ácido permanece ubicada desde las perforaciones de la parte más baja (1127,8 hasta 1132,3 m) hasta 1005,8 m. El Montaje de Perforación B es detonado en forma inmediata por medio de la aplicación de 17,26 MPa de presión superficial para hacer funcionar este cabezal de encendido activado por presión. Este acontecimiento de perforación permite que la presión hidrostática interior de la placa de revestimiento ingrese en el interior del Montaje de Perforación B y transfiera hacia abajo la línea secundaria para hacerla funcionar y cerrar la válvula con lengüeta del Montaje D. Este intervalo también es perforado con ácido a lo ancho de las perforaciones, que puede ayudar en la disolución del cemento aglomerado de la perforación. Una estimulación de fractura hidráulica cargada de arena (13607,8 kg de arena en 45,42 m<sup>3</sup> de fluidos de fractura) se bombea en forma subsiguiente en el intervalo medio del pozo, y se desplaza al interior de las perforaciones con salmuera. En forma subsiguiente, la perforación del Montaje C es detonada por la aplicación de 24,17 MPa de presión superficial para hacer funcionar este cabezal de encendido que actúa por presión. La totalidad de los tres intervalos se producen juntos subiendo por la placa de revestimiento hasta la superficie. Unos días después se determina por medio de un trabajo con cable metálico hacia el interior de la placa de revestimiento que no queden restos de arena en la parte superior del Montaje D con válvula con lengüeta. Se interrumpe el

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flujo hacia la superficie y se deja caer una barra de 2,54 cm de diámetro por una longitud de 3,0 m que rompe la válvula con lengüeta en fragmentos. Luego el pozo vuelve a la producción.

El proceso y el montaje de la presente invención también puede incluir el uso de material propulsor en conjunción con el montaje de la perforadora para aumentar en forma substancialmente simultánea la efectividad de las perforaciones resultantes y para estimular la formación subterránea. De acuerdo con esta realización, el propulsor en forma de manga, tira, parche o cualquier otra configuración, se encuentra afuera del montaje de la perforadora y la placa de revestimiento, y en el sentido en el cual está orientada por lo menos una de las cargas explosivas en por lo menos uno de los montajes de perforadora es utilizada en el proceso de la presente invención. El material propulsor puede estar ubicado tanto en uno o en más de los montajes de perforadora 20, 120, 220 o 350 o placa de revestimiento, 12, 112, 212 o 310, respectivamente. Luego de la detonación de una carga explosiva en un montaje de la perforadora, el material propulsor que está ubicado en el sentido que está orientada la carga explosiva se rompe y se enciende a causa de la descarga, el calor y la presión de la carga explosiva detonada. Cuando una o más cargas explosivas penetran en una formación subterránea, el gas presurizado generado de la combustión del material propulsor ingresa en la formación a través de las perforaciones recientemente formadas eliminando de este modo los escombros de dichas perforaciones. Estos gases propulsores también estimulan la formación por medio de la extensión de la conexión de la formación con el

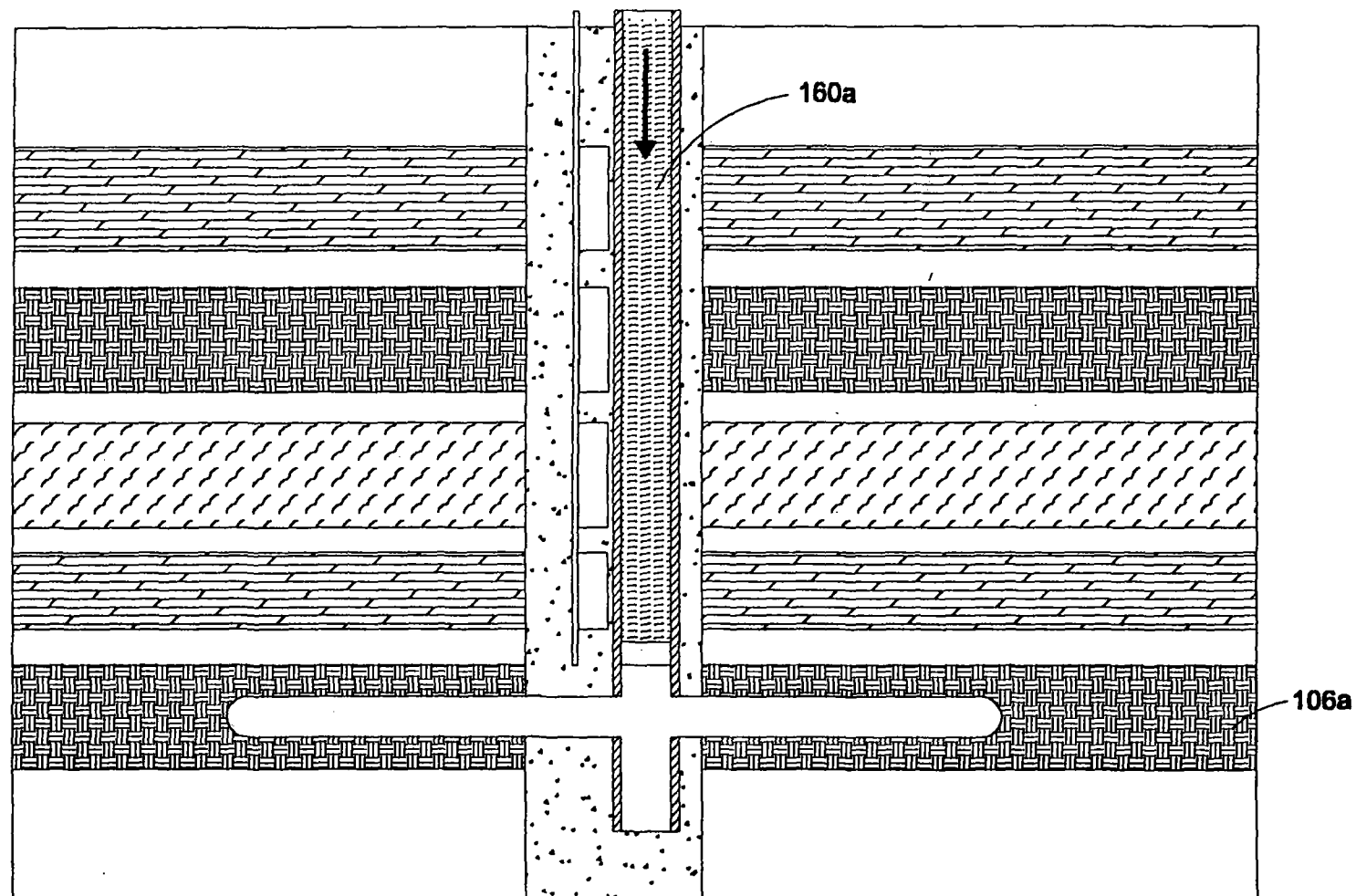


Fig. 10c

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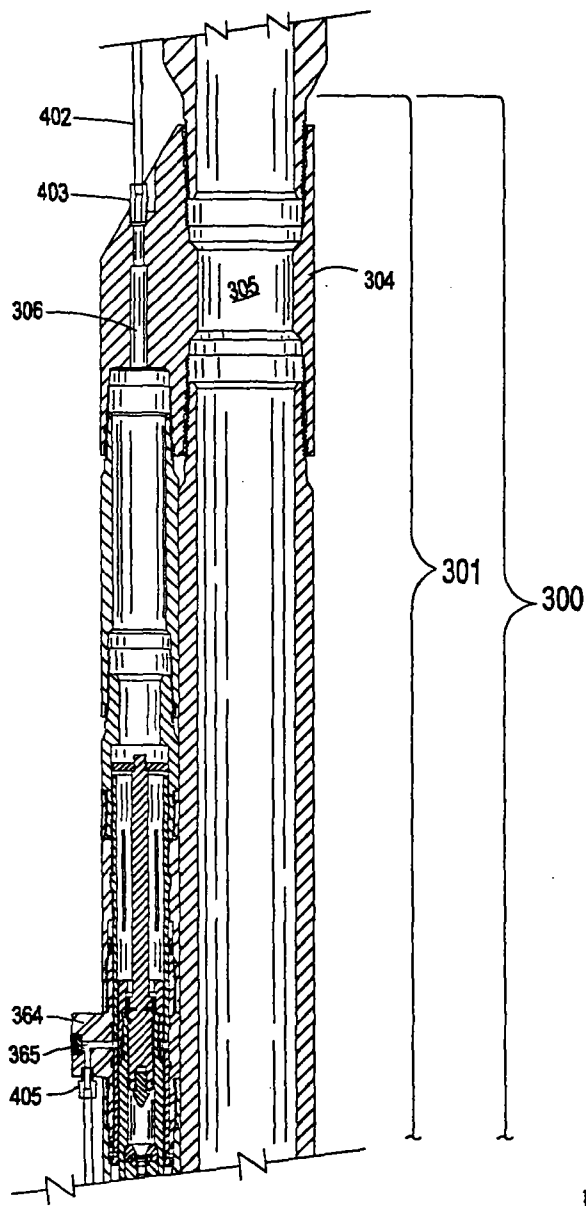


Fig. 12 a

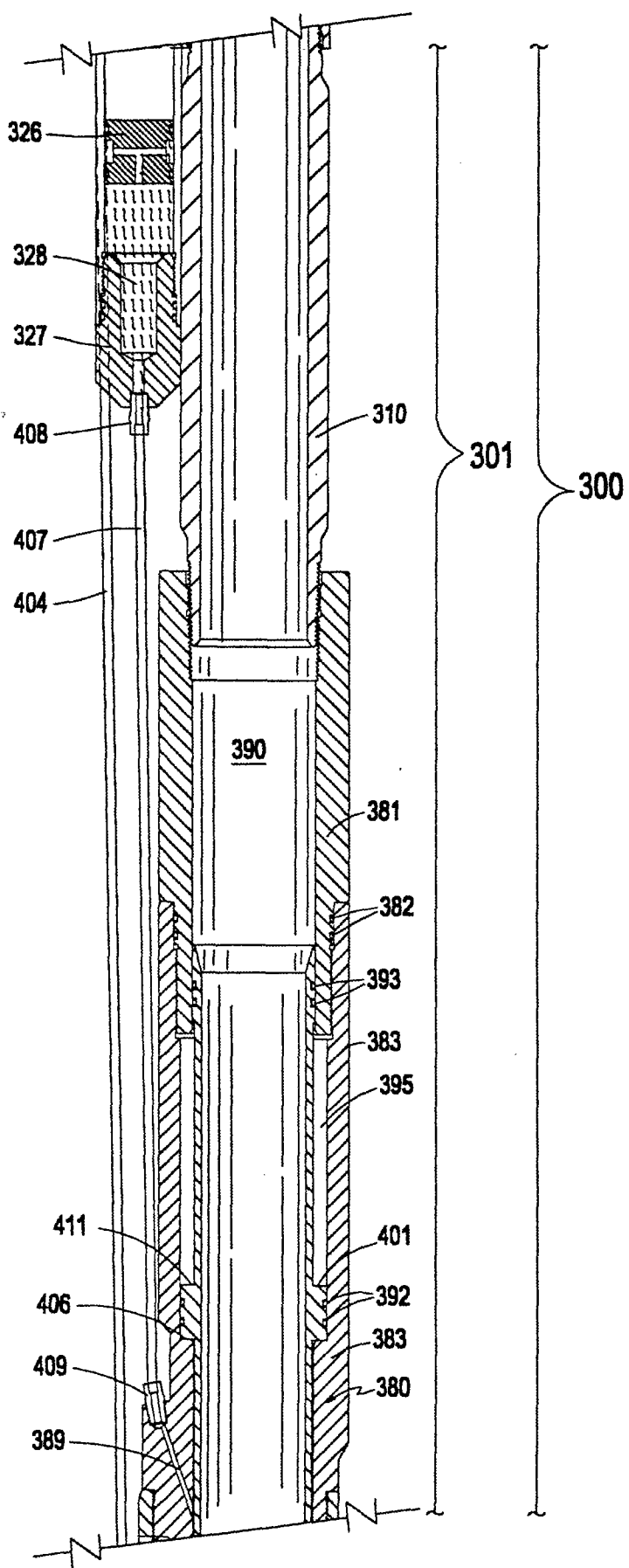


Fig. 14 a

Fig. 14b

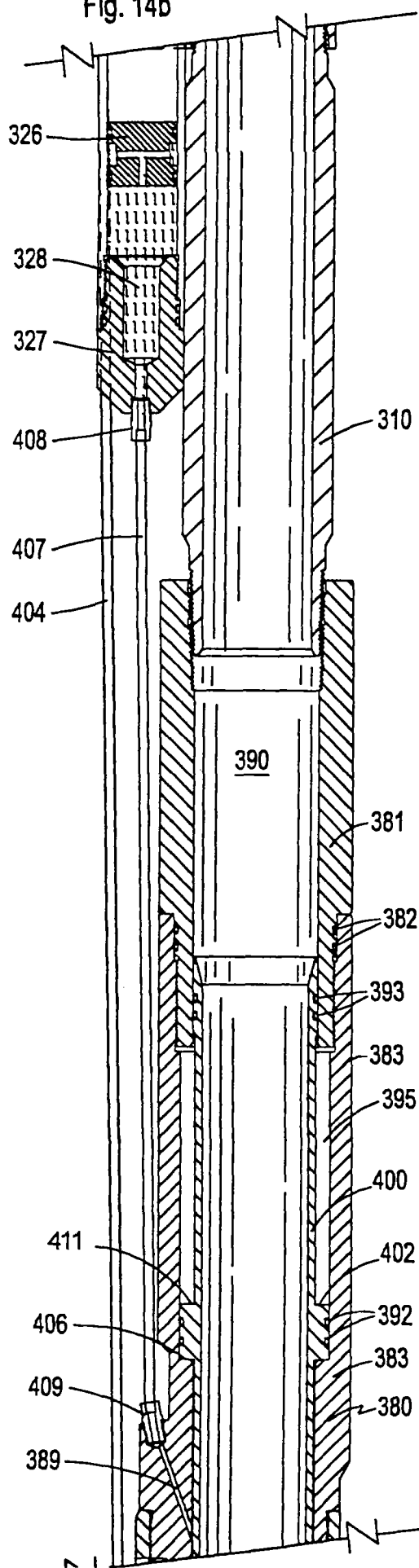
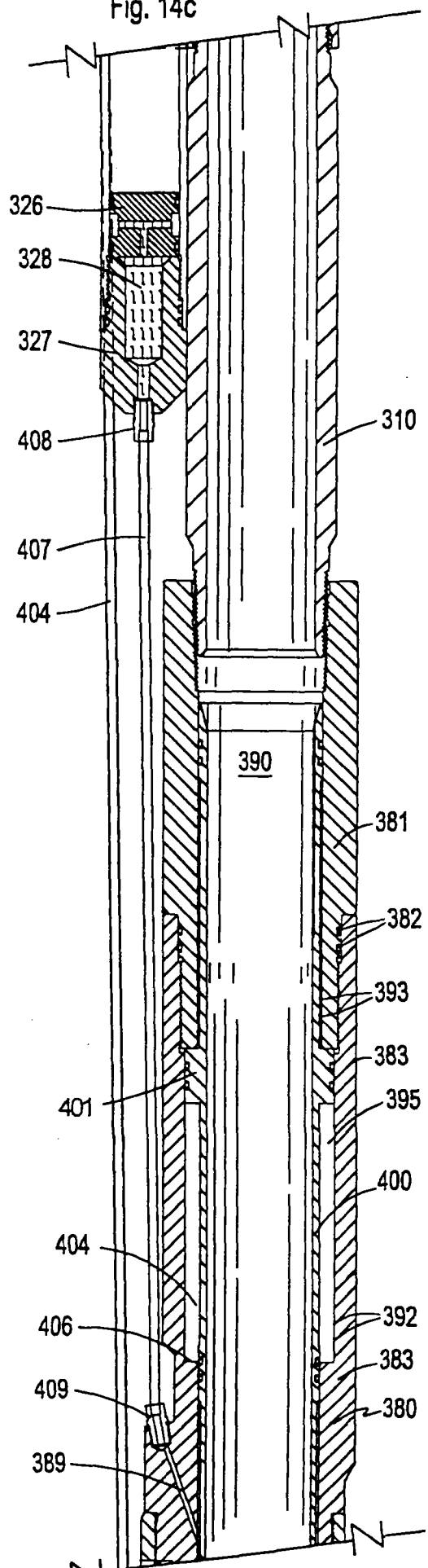


Fig. 14c



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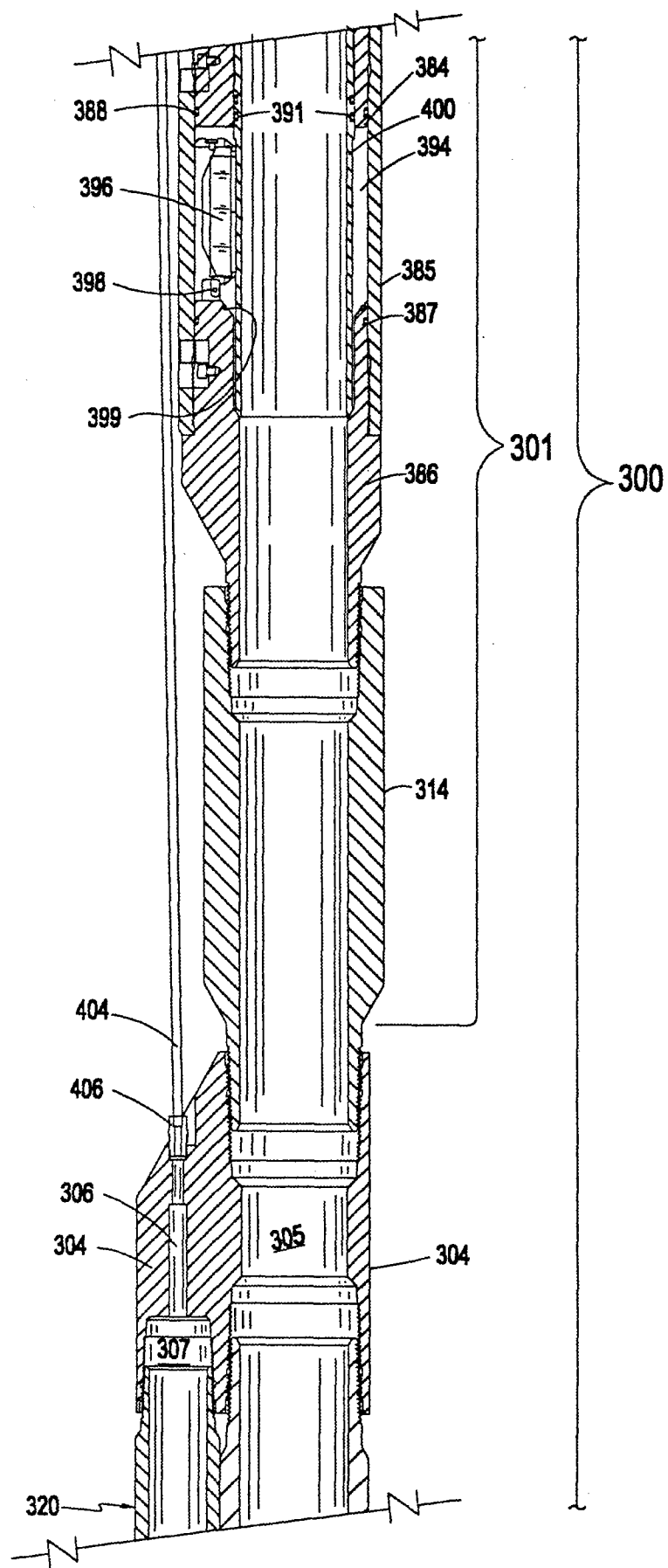


Fig. 15 a

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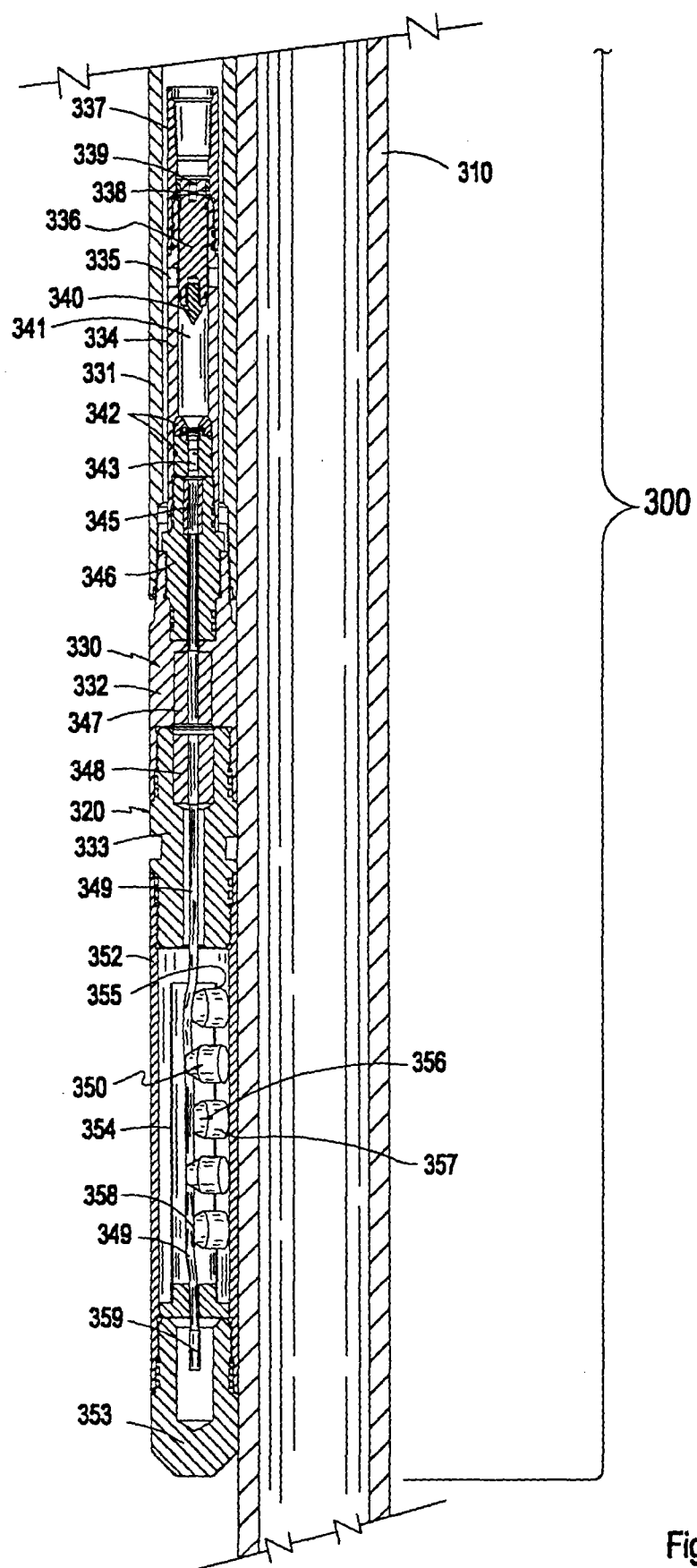
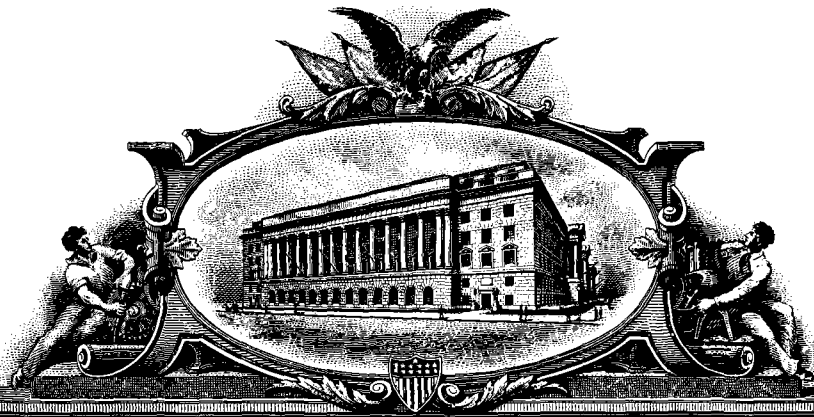


Fig. 16 a



# THE UNITED STATES OF AMERICA

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**February 16, 2000**

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**APPLICATION NUMBER: 09/300,056**

**FILING DATE: April 27, 1999**



**By Authority of the  
COMMISSIONER OF PATENTS AND TRADEMARKS**

*T. Wallace*  
**T. WALLACE**

**Certifying Officer**

10557 U.S. PTO  
04/27/99

In The United States Patent and Trademark Office

Docket No. 980019 USA

DATE: April 27, 1999

Assistant Commissioner for Patents  
Washington, D.C. 20231

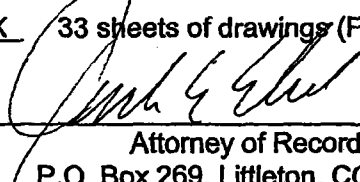
Ladies and Gentlemen:

Transmitted herewith for filing is the patent application of:

Inventor(s): Philip M. Snider and Eldon G. Williams, Jr.  
Entitled: CASING CONVEYED PERFORATING PROCESS AND APPARATUS

Enclosed are:

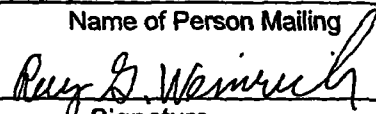
- ☒ Cover Letter with Certificate of Mailing by Express Mail dated 4/27/99.
- ☒ Utility Patent Application Transmittal, Form PTO/SB/05.
- ☒ Fee Transmittal Form PTO/SB 17 (in duplicate).
- ☒ 32 pages of specification, including claims and abstract.
- ☒ 33 sheets of drawings (FIGS. 1-19) (in triplicate).

  
\_\_\_\_\_  
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P.O. Box 269, Littleton, CO 80160  
(303) 347-5622

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Signature

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Docket Number  
April 27, 1999  
Date

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09/300056  
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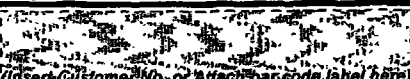
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| <b>UTILITY<br/>PATENT APPLICATION<br/>TRANSMITTAL</b><br><small>(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))</small> |                                                   |
| Attorney Docket No.                                                                                                                          | 980019 USA                                        |
| First Inventor or Application Identifier                                                                                                     | Philip M. Snider                                  |
| Title                                                                                                                                        | Casing Conveyed Perforating Process and Apparatus |
| Express Mail Label No.                                                                                                                       | IB243126004                                       |

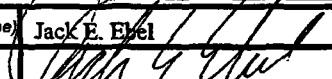
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| <b>APPLICATION ELEMENTS</b><br>See MPEP chapter 600 concerning utility patent application contents.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                   | <b>ADDRESS TO:</b><br>Assistant Commissioner for Patents<br>Box Patent Application<br>Washington, DC 20231 |
| 1. <input checked="" type="checkbox"/> <b>*Fee Transmittal Form</b> (e.g., PTO/SB/17)<br><small>(Submit an original and a duplicate for fee processing)</small><br>2. <input checked="" type="checkbox"/> <b>Specification</b> <small>(Total Pages 32)</small><br><small>(preferred arrangement set forth below)</small><br>- Descriptive title of the invention<br>- Cross References to Related Applications<br>- Statement Regarding Fed sponsored R & D<br>- Reference to Microfiche Appendix<br>- Background of the invention<br>- Brief Summary of the invention<br>- Brief Description of the Drawings (if filed)<br>- Detailed Description<br>- Claim(s)<br>- Abstract of the Disclosure<br>3. <input checked="" type="checkbox"/> <b>Drawing(s)</b> (35 U.S.C. 113) <small>(Total Sheets 33)</small><br>4. <b>Oath or Declaration</b> <small>(Total Pages)</small><br>a. <input type="checkbox"/> Newly executed (original or copy)<br>b. <input type="checkbox"/> Copy from a prior application (37 C.F.R. § 1.63(d))<br><small>(for continuation/divisional with Box 17 completed)</small><br><small>[Note Box 6 below]</small><br>i. <input type="checkbox"/> <b>DELETION OF INVENTOR(S)</b><br>Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).<br>5. <input type="checkbox"/> <b>Incorporation By Reference</b> (useable if Box 4b is checked)<br>The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered to be part of the disclosure of the accompanying application and is hereby incorporated by reference therein. | 6. <input type="checkbox"/> <b>Microfiche Computer Program</b> (Appendix)<br>7. <b>Nucleotide and/or Amino Acid Sequence Submission</b><br><small>(if applicable, all necessary)</small><br>a. <input type="checkbox"/> Computer Readable Copy<br>b. <input type="checkbox"/> Paper Copy (identical to computer copy)<br>c. <input type="checkbox"/> Statement verifying identity of above copies |                                                                                                            |
| <b>ACCOMPANYING APPLICATION PARTS</b><br>8. <input type="checkbox"/> Assignment Papers (cover sheet & document(s))<br>9. <input type="checkbox"/> 37 C.F.R. §3.73(b) Statement <input type="checkbox"/> Power of Attorney<br><small>(when there is an assignee)</small><br>10. <input type="checkbox"/> English Translation Document (if applicable)<br>11. <input type="checkbox"/> Information Disclosure <input type="checkbox"/> Copies of IDS<br>Statement (IDS)PTO-1449 Citations<br>12. <input type="checkbox"/> Preliminary Amendment<br>13. <input checked="" type="checkbox"/> Return Receipt Postcard (MPEP 503)<br><small>(Should be specifically itemized)</small><br>14. <input type="checkbox"/> <b>*Small Entity</b> <input type="checkbox"/> Statement filed in prior application,<br>Statement(s) <input type="checkbox"/> Status still proper and desired<br><small>(PTO/SB/09-12)</small><br>15. <input type="checkbox"/> Certified Copy of Priority Document(s)<br><small>(if foreign priority is claimed)</small><br>16. <input checked="" type="checkbox"/> Other: Cover letter with Certification of Express Mail.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                            |

17. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:  
☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: \_\_\_\_\_  
 Prior application information: Examiner \_\_\_\_\_ Group / Art Unit: \_\_\_\_\_

**18. CORRESPONDENCE ADDRESS**

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|-------------------|-------------------------------------------------------------------------------------|-----------------------------------|---------|
| Name (Print/Type) | Jack E. Ebel                                                                        | Registration No. (Attorney/Agent) | 28,148  |
| Signature         |  | Date                              | 4/27/99 |

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**SECRET**

**5 FIELD OF THE INVENTION:**

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formation. The perforating gun is then removed from the well bore or dropped to the bottom thereof. The formation is often stimulated to enhance production of hydrocarbons therefrom by pumping fluid under pressure into the well and into the formation to induce hydraulic fracturing of the formation or by pumping fluid into the well and formation to treat or stimulate the formation. Thereafter, fluid may be produced from the formation through the casing string to the surface of the earth or injected from the surface through the casing string into the subterranean formation.

In some formations, it is desirable to conduct the perforating operations with the pressure in the well overbalanced with respect to the formation pressure. Under overbalanced conditions, the well pressure exceeds the pressure at which the formation will fracture, and hydraulic fracturing occurs in the vicinity of the perforations. The perforations may penetrate several inches into the formation, and the fracture network may extend several feet into the formation. Thus, an enlarged conduit can be created for fluid flow between the formation and the well, and well productivity may be significantly increased by deliberately inducing fractures at the perforations.

Frequently, a subterranean well penetrates multiple zones of the same subterranean formation and/or a plurality of formations of interest, which are hydrocarbon bearing. It is usually desirable to establish communication with each zone and/or formation of interest for injection and/or production of fluids. Conventionally, this is accomplished in any one of several ways. First, a single perforating gun may be conveyed on wireline or tubing into the subterranean well bore and fired to perforate a zone and/or formation of interest. This procedure is repeated for each zone to be treated. Alternately, a single perforating gun is conveyed on wireline or tubing into the subterranean well and the gun is positioned adjacent to each zone and/or formation of interest and selectively fired to perforate each zone and/or formation. In accordance with another approach, two or more perforating guns are positioned in a spaced apart manner on the same tubing, are conveyed into the well and fired. When the select firing method is used and the subterranean zone(s) and/or formation(s) of interest are

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980019 USA

relatively thin, e.g. 15 feet or less, the perforating gun is positioned adjacent the zone of interest and some of the shaped charges of the perforating gun are fired to selectively perforate only this zone or formation. The gun is then repositioned by means of the wireline to another zone or formation and certain shaped

5 charges are fired to selectively perforate this zone or formation. This procedure is repeated until all zone(s) and/or formation(s) are perforated and the perforating gun is retrieved to the surface by means of the wireline. In the tubing conveyed, spaced gun approach, two or more perforating guns are conveyed into the well bore on the same tubing in a spaced apart manner such that each

10 gun is positioned adjacent one of the subterranean zone(s) and/or formation(s) of interest. Once positioned in the well, the guns may be simultaneously or selectively fired to perforate the casing and establish communication with each such zone(s) and/or formation(s).

If the zone(s) and/or formation(s) which have been perforated by either

15 conventional approach are to be hydraulically fractured, fluid is pumped into the well under pressure which exceeds the pressure at which the zone(s) and/or formation(s) will fracture. However, the fracturing fluid will preferential flow into those zone(s) and/or formation(s) which typically have the greatest porosity and/or the lowest pressure thereby often resulting in little or no fracturing of

20 some of the zone(s) and/or formation(s). Further, considerable expense can be incurred in pumping fluid under sufficient pressure to fracture multiple zone(s) and/or formation(s) penetrated by a subterranean well bore. In an effort to rectify this problem, a procedure has been utilized wherein a perforating gun is lowered into a well on tubing or wireline adjacent the lowermost zone of interest

25 and fired to perforate the casing and zone. Thereafter, the it is necessary to trip out of the well and remove the perforating gun to the surface. Fluid is then pumped into the well at sufficient pressure to fracture or stimulate the lowermost zone. The stimulation fluid may be recovered from the zone just perforated and fractured to inhibit any damage to the zone which may occur as a result of

30 prolonged contact with the fracturing fluid. Prior to perforating and stimulating the next deepest zone of interest, a mechanical device or plug or sand fill is set in the well between the zone just fractured and the zone to be fractured to isolate

the stimulated zone from further contact with fracturing fluid. This procedure is repeated until all zone(s) and/or formation(s) are perforated and fractured. Once this completion operation is finished, each plug must be drilled out of or otherwise remove the well to permit fluid to be produced to the surface through the well. However, the necessity of tripping in and out of the well bore to perforate and stimulate each of multiple zone(s) and/or formation(s) and the use of such plugs to isolate previously treated zone(s) and/or formation(s) from further treatment fluid contact is time consuming and expensive. In view of this, multiple zone(s) and/or formation(s) are often stimulated at the same time even though this results in unacceptable of treatment of certain zone(s) and/or formation(s). Thus, a need exists for apparatus and processes to perforate casing which is positioned within a subterranean well bore which eliminates the need to run perforating equipment in and out of the well when completing multiple zone(s) and/or formation(s).

Accordingly, it is an object of the present invention to provide a method and apparatus for economically and effectively perforating and stimulating multiple subterranean zone(s) and/or formation(s) which are penetrated by a subterranean well.

It is another object of the present invention to provide a process and apparatus for completing a subterranean well wherein casing is perforated to provide for fluid communication across the wall of the casing by means of a perforating gun assembly located in a subterranean well bore outside the casing.

It is a further object of the present invention to provide a process and apparatus wherein for completing and stimulating a cased, subterranean well bore wherein entry into the well bore to effectuate completion and/or stimulation is obviated.

It is still another object of the present invention to provide a process and apparatus for expeditiously treating and/or stimulating each subterranean formation penetrated by a subterranean well bore individually and therefore economically.

It is a still further object of the present invention to provide a process and apparatus for completing a subterranean well wherein multiple perforating gun

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980019 USA

assemblies are positioned in the well bore external to casing and adjacent to multiple subterranean formations of interest and selectively detonated to establish fluid communication between a subterranean formation and the interior of the casing.

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### SUMMARY OF THE INVENTION

To achieve the foregoing and other objects, and in accordance with the purposes of the present invention, as embodied and broadly described herein, one characterization of the present invention may comprise a process for  
10 establishing fluid communication. The process comprises positioning at least one explosive charge in a subterranean well bore such that the at least one explosive charge is placed external to casing which is also positioned within the well bore and is aimed toward the casing and detonating the at least one explosive charge so as to perforate the wall of the casing at least once.

15 In another characterization of the present invention, a process is provided for completing a subterranean well bore which comprises penetrating the wall of a casing which is positioned and cemented within a subterranean well bore from the exterior of the casing to the interior.

In yet another characterization of the present invention, a process is  
20 provided for completing a subterranean well which comprises positioning at least one explosive charge in a subterranean well bore outside of casing and detonating the at least one explosive charge so as to perforate the casing.

In yet another characterization of the present invention, a process is set  
25 forth for providing fluid communication across the wall of a casing. The process comprises detonating a first perforating gun assembly which is positioned outside of a casing in a subterranean well bore thereby perforating the casing.

In a further characterization of the present invention, a process is  
30 provided for completing one or more subterranean formations. The process comprises detonating a first perforating gun assembly which is positioned outside of a casing in a subterranean well bore thereby perforating the casing and a first subterranean formation.

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980019 USA

In a still further characterization of the present invention, a process is provided for completing a subterranean well which comprises penetrating casing which is positioned in a subterranean well bore while the interior of the casing remains unoccupied by perforating guns or other equipment, tools, tubulars or  
5 lines.

In a still further characterization of the present invention, a subterranean completion system is provided which comprises a casing which is at least partially positioned within a subterranean well bore and at least one perforating gun assembly which is positioned external to the casing and within the well bore.  
10 The perforating gun assembly has at least one explosive charge aimed in the direction of the casing.

In a still further characterization of the present invention, a completion system is provided which comprises a casing and at least one perforating gun which is connected to the exterior of the casing and has at least one explosive  
15 charge aimed toward the casing.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate the embodiments of the present invention and,  
20 together with the description, serve to explain the principles of the invention.

In the drawings:

FIG. 1 is a sectional view of the assembly of the present invention as positioned within a subterranean well bore;

FIG. 2 is a cross sectional view of the assembly of the present invention  
25 as positioned within a subterranean well bore taken along the line 2-2 of FIG. 1;

FIG. 3 is a cross sectional view of the assembly of the present invention as positioned within a subterranean well bore taken along the line 2-2 of FIG. 1 after at least one explosive charge of a perforating gun has been detonated;

FIG. 4 is a cross sectional view of the assembly of the present invention  
30 as positioned and cemented within a subterranean well bore;

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FIG. 6 is a cross sectional view of the assembly of the present invention as positioned and cemented within a subterranean well bore taken along the line 5-5 of FIG. 4 after at least one explosive charge of a perforating gun has been detonated;

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FIG. 9 is a partially cut away, partially sectional view of the assembly of the present invention, including a perforating gun assembly having multiple explosive charges, as positioned and cemented in a subterranean well bore;

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FIGS. 11a-f are partially cut away, schematic views of another embodiment of the present invention which is utilized to stimulate and/or treat multiple subterranean formations wherein a zone isolation device is positioned between perforating gun assemblies;

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perforating gun assemblies and wherein one of the perforating gun assemblies has been detonated;

FIGS. 12c, 13c, 14c, 15c and 16c are partial cross sectional views which, as combined in the sequence noted, illustrate another embodiment of the present invention which is utilized to stimulate and/or treat multiple subterranean formations wherein flapper valve sub-assemblies are positioned between perforating gun assemblies and wherein both of the perforating gun assemblies have been detonated;

FIG. 17 is a sectional view of a specialty collar utilized in the embodiment of the present invention which is illustrated FIGS. 12a - 16a as assembled;

FIG. 18 is a sectional view of a portion of one of the perforating gun assemblies which is illustrated in FIGS. 12a and 12b; and

FIG. 19 is a sectional view of a portion of one of the perforating gun assemblies which is illustrated in FIG. 12c.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the present invention, an assembly is provided for positioning within a subterranean well bore during completion thereof. The assembly comprises one or more perforating guns which are positioned adjacent the exterior of casing such that at least one explosive charge of the perforating gun is oriented to strike the casing. As utilized throughout this disclosure, the term "casing" refers to the tubulars, usually a string made up of individual joints of steel pipe, used in a well bore to seal off fluids from the well bore, to keep the walls of the well bore from sloughing off or caving in and through which fluids are produced from and/or injected into a subterranean formation or zone. The term "perforating gun" refers to an assembly for positioning in a subterranean well bore which contains one or more explosive charges which are ballistically connected to the surface and which are designed to penetrate the wall of casing.

Referring to FIG. 1, a subterranean well bore 2 is illustrated as extending from the surface of the earth or sea floor 4 and penetrating at least one subterranean formation 6. "Subterranean formation" as utilized throughout this disclosure refers to a subterranean formation, a layer of a subterranean formation and/or a zone of a layer of a subterranean formation which represents

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980019 USA

a given stratigraphic unit, such as a unit of porosity, permeability and/or hydrocarbon saturation. The assembly of the present invention is illustrated generally as 10 in FIG. 1 and comprises a perforating gun assembly 20 and casing 12. As assembled and positioned within well bore 2, the perforating gun assembly is positioned on the exterior of casing 12 adjacent the outer diameter thereof. Preferably, the perforating gun assembly 20 is secured to casing 12 by any suitable means, for example by metal bands, such as stainless steel bands, wrapped around both casing 12 and perforating gun assembly 20 or with specialty connections, to ensure that the relative position between perforating gun assembly 20 and casing 12, as fully assembled does not substantially change, either axially or rotationally, during positioning of the assembly of the present invention in well bore 2. The assembly of the present invention is preferably constructed either before and/or at the well site, i.e. either onshore location or offshore platform, at the surface 4 prior to running the assembly into well bore 2. As illustrated in FIG. 1, a control system 18, for example an electric line, extends from a suitable power source (not illustrated) at the surface 4 as will be evident to a skilled artisan to the perforating gun assembly 20 to provide an appropriate signal to ignite the perforating gun assembly. Where electric line is utilized, it is preferred that the line is armored for protection against damage during placement of the assembly in the well bore and that the line be secured to the casing by any suitable means, such as those described above with respect to securing the perforating gun assemblies. Other suitable control systems for igniting the explosive charge(s) contained in perforating gun assembly 20, such as hydraulic lines connected to a suitable source of pressurized hydraulic fluid (liquid or gas) or electromagnetic or acoustic signaling and corresponding receivers (not illustrated) connected to the perforating gun assemblies for wave transmissions through the casing, soil and/or well bore fluids, may also be employed in the present invention. Any line or any other instrument mentioned below in conjunction with the assembly of the present invention should be secured to the casing at appropriate intervals to inhibit damage during positioning of the assembly in the well bore.

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980019 USA

Perforating gun assembly 20 has at least one explosive charge 22 contained therein which is aimed toward casing 12. As illustrated in FIG. 2, assembly 20 has two explosive charges 22, 26 which are axially spaced apart within assembly 20 and which, although oriented at slightly different angles, are both aimed toward casing 12. Upon transmission of a suitable signal, for example, electrical current via line 18, explosive charge 22 detonates and fires a shaped charge along path 24 creating perforations 13 and 14 in the wall of casing 12 while explosive charge 26 detonates and fires a shaped charge along path 28 creating perforations 15 and 16 in the wall of casing 12. It should be noted that although each charge is illustrated as being capable of creating two perforations in the wall of casing 12, these charges may be constructed so as just to punch a single perforation, for example 13 and 15, through the wall of casing 12 where desirable. For example, the assembly of the present invention may be employed wherever it is desirable to create fluid communication across the wall of casing, such as to monitor conditions within the interior of the well bore or to actuate a tool which is positioned on the outside of casing 12.

In one embodiment as illustrated in FIG. 4, the assembly of the present invention is positioned within a subterranean well bore after the well bore is drilled but prior to completing the well. Preferably, the assembly is positioned adjacent a subterranean formation of interest by any suitable means. The position of subterranean formation 6 will be known from open hole logs, such as gamma ray logs, which are run during or after a well bore is drilled and to a lesser extent by certain indications obtained during drilling, such as mud logs and/or changes in drilling penetration rates. As the assembly is being positioned within the well bore, a log may be obtained by extending a logging tool, such as a gamma ray tool, through casing 12 so as to align perforating assembly 20 with formation 6, or alternatively, by securing a logging tool 50 on the outside of casing 12 and adjacent the perforating gun assembly to obtain real time logs. By correlating these logs with open hole logs, the perforating gun assembly may be accurately positioned adjacent the subterranean formation 6 of interest. Often it is desirable to circulate fluid through the casing and the annulus defined between the casing and the well bore prior to cementing. As will be evident to

980019 USA

a skilled artisan, the temperature of such fluid and of the cement during setting may cause the casing to contract or expand and such change should be taken into consideration during the initial placement of the assembly of the present invention in the well bore, especially where the formation of interest is relatively  
 5 thin or short in length. Once the perforating gun assembly is properly positioned within the well bore, cement 17 is circulated either down through the interior 13 of casing 12 and back towards the surface via the annulus 19 formed between the casing and the well bore or, less preferably, down annulus 19 towards the bottom of the well bore. Prior to cement 17 being fully cured, casing 12 may be  
 10 axially reciprocated to ensure that the cement is uniformly positioned about casing 12.

In the manner just described, the assembly of the present invention is cemented in the well bore (FIG. 4) between the casing and the face of the well bore and is capable of being remotely actuated by any suitable means 18, such  
 15 as electric line, hydraulic line, radio signals, etc. at a later time. Perforating gun assembly 20 has at least one explosive charge 22 contained therein which is aimed toward casing 12. As illustrated in FIG. 5, assembly 20 has two explosive charges 22, 26 which are axially spaced apart and which, although oriented at slightly different angles, are both aimed toward casing 12. Upon transmission  
 20 of a suitable signal via means 18, for example electric current via an electric line, explosive charges 22 and 26 detonate. Upon detonation, explosive charge 22 fires a shaped charge along a path 24 thereby creating perforations 13 and 14 in the wall of casing 12 and a perforating tunnel 32 which extends through cement 17 and into subterranean formation 6, while explosive charge 26 fires a  
 25 shaped charge along path 28 thereby creating perforations 15 and 16 in the wall of casing 12 and a perforating tunnel 34 which extends through cement 17 and into the subterranean formation 6. In this manner, fluid communication is established between formation 6 and the interior of casing 10. It should be noted that although each charge is illustrated as being capable of creating two  
 30 perforations in the wall of casing 12, these charges may be constructed so as just to punch a single perforation, for example 13 and 15, through the wall of casing 12 where desirable. For example, it may be desirable to establish fluid

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980019 USA

communication between a separate tool (not illustrated), such as pressure gauge, which is located on the exterior of the casing adjacent and in fluid communication with the perforating assembly.

Thus, the process or method of the present invention broadly entails

5 positioning a perforating gun assembly in a subterranean well bore outside of and juxtaposed to casing and detonating at least one explosive charge in the perforating gun assembly to penetrate the casing wall at least once. Preferably, the assembly of the present invention is cemented in the subterranean well bore and detonation of the explosive charge creates a perforation tunnel through the

10 cement and into the subterranean formation. Even though each perforating gun assembly 20 may contain a multitude of explosive charges 30 as will be evident to a skilled artisan, it is only necessary to aim one such charge at casing 12 to practice the present invention. However, as a perforating gun assembly conventionally contains several explosive charges per foot, e.g. 6 (FIG. 7), it is

15 usually desirable to have several charges in a given assembly aimed at the casing as run in a well bore. A preferred phasing pattern for six explosive charges in an assembly having at least six explosive charges is illustrated in FIG. 8. In this embodiment, the six charges 30 are axially and radially spaced in perforating gun assembly 20 in a spiral pattern. Three of the six charges are

20 oriented to perforate casing 12 and create perforating tunnels 40, 42 and 44 upon detonation which extend through cement 17 into formation 6 while the remaining three charges are oriented so as to create perforating tunnels 46, 47 and 48 upon detonation penetrate the cement 17 and formation 6 but not casing 12. As illustrated in FIG. 8, the angle  $\alpha$  between tunnels 40 and 42 and between

25 tunnels 42 and 44 is substantially equal and will depend upon the diameter of the casing and perforating gun assembly and the spacing between the casing and assembly. For example, the angle  $\alpha$  for a 2 1/8" perforating gun assembly and 4 1/2" casing is 30°, for a 2 3/8" assembly and 3 1/2" tubing is 22.5° and for a 2 7/8 " assembly and 2 7/8" casing is 17.5°. Perforating tunnels 40, 42, 44 and

30 46-48 are formed by firing the explosive charges in sequence beginning from either end of the gun. Further, although it is preferred that the explosive charges of each assembly are oriented to shoot in a plane which is perpendicular to the

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980019 USA

axis of the assembly, one or more charges may be arranged to be shot at an angle with respect to the horizontal plane.

In a further embodiment of the present invention, the assembly of the present invention is constructed of casing 112 and multiple perforating gun assemblies 120a-e (FIG. 9). As assembled and positioned within well bore 102, the perforating gun assemblies are positioned on the exterior of casing 112 adjacent the outer diameter thereof. It is preferred that the perforating gun assemblies 120a-e be secured to casing 112 by any suitable means, for example by metal bands wrapped around both casing 112 and perforating gun assemblies 120a-e or a specialty connector, to ensure that the relative position between each perforating gun assembly 120 and casing 112 as fully assembled does not substantially change during positioning of the assembly of the present invention in well bore 102. Each perforating gun assembly has at least one explosive charge which is aimed so as to perforate the casing upon detonation thereof. The assembly of the present invention is preferably fully constructed at the well site, i.e. either onshore well head or offshore platform, at the surface 104 prior to running the assembly into well bore 102. As illustrated in FIG. 9, a signal means 118, for example an electric line, extends from a suitable power source (not illustrated) at the surface 104 to the perforating gun assemblies 120a-e to provide a power source for ignition.

Multiple perforating gun assemblies 120a-e are positioned within a subterranean well bore 102 adjacent multiple subterranean formations of interest 106a-e after the well bore is drilled but prior to completing the well. The assembly is positioned adjacent a subterranean formation of interest by any suitable means. The position of subterranean formations 106a-e will be known from open hole logs and drilling data as previously discussed. As the assembly is being positioned within the well bore, a cased hole log may be obtained and correlated with open hole logs to accurately position perforating gun assemblies 120a-e adjacent the subterranean formations 106a-e of interest. Often it is desirable to circulate fluid through the casing and the annulus defined between the casing and the well bore prior to cementing. As will be evident to a skilled artisan, the temperature of such fluid and of the cement during setting may

980019 USA

cause the casing to contract or expand and such change should be taken into consideration during the initial placement of the assembly of the present invention in the well bore, especially where the formation of interest is relatively thin. Once the perforating gun assemblies are properly positioned within the well

5 bore, cement 117 is circulated either down through the interior 113 of casing 112 and back to the surface via the annulus 119 formed between the casing and the well bore or, alternatively, down annulus 119 and through casing 112 up to the surface. Prior to cement 117 being fully cured, casing 112 may be axially reciprocated to ensure that the cement is uniformly positioned about casing 112.

10 As thus constructed, the multiple perforating gun assemblies 120a-e which are positioned adjacent subterranean zones of interest 106a-e may be subsequently detonated simultaneously, sequentially or in any desired order by transmission of a suitable signal to each perforating gun assembly via electrical, hydraulic, audio wave or any other suitable means.

15 In accordance with one aspect of the embodiment of the present invention which is illustrated in FIG. 9, perforating gun 120a is fired or detonated upon receiving a signal via signal means 118 thereby forming perforation(s) 150a (FIG. 10a) through casing 112 and cement 117 into formation 106a in a manner as previously described with respect to the embodiments illustrated in FIGS. 6-8

20 above. Thereafter, stimulation fluids 160a, such as fracturing fluid containing proppants and/or acids containing balls which act as diverting agents in the formation, and/or treatment fluids, for example scale inhibitors and/or gelation solutions, are pumped from surface 104 through the interior 113 of casing 112 and into perforations 150a (FIG. 10b). Radioactive tracers may be incorporated

25 into the stimulation and/or treatment fluids to ensure proper placement of fluids and/or solids contained therein. In the case of fracturing fluids, fractures 156a are formed and propagated within formation 106a. Where stimulation fluids, such as acidizing fluids, and/or treatment fluids are employed, these fluids need not be pumped at pressures sufficient to create fractures 156a. As the

30 stimulation and/or treatment process continues, screen out occurs during the pumping operation when the proppant and/or balls create a significant flow restriction in the well bore 102. At this point (FIG. 10c), the process may be

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980019 USA

suspended, for example where it is desirable to produce fluids from formation 106a for testing and/or evaluation purposes, or the next formation 106b may be immediately treated in a similar fashion to that just described with respect to formation 106a (FIGS. 10d-f). This process is repeated for each zone to be  
5 treated until conclusion (FIG. 10g).

In accordance with another embodiment of the assembly of the present invention which is illustrated in FIG. 11, zone isolation devices 230a and 230b are secured to casing 212 between perforating gun assemblies 220 a-c. As illustrated, the zone isolation devices are connected to signal means 218 and  
10 preferably are secured to casing 212 by any suitable means, for example by screw threads or welds. Suitable zone isolation devices, for example flapper valves or ball valves, are employed in the process of the present invention as hereinafter described to selectively shut off flow through the interior 213 of casing 212. In operation, perforating gun 220a is fired or detonated upon  
15 receiving a signal via signal means 218 thereby forming perforation(s) 250a (FIG. 11a) through casing 212 and cement 217 into formation 206a in a manner as previously described with respect to the embodiments illustrated in FIGS. 6-10 above. Thereafter, stimulation fluids 260a, such as fracturing fluid containing proppants and/or acids, and/or treatment fluids, for example scale inhibitors  
20 and/or gelation solutions, are pumped from surface 204 through the interior 213 of casing 212 and into perforations 250a (FIG. 11b). Radioactive tracers may be incorporated into the stimulation and/or treatment fluids to ensure proper placement of fluids and/or solids contained therein. In the case of fracturing fluids, fractures 256a are formed and propagated within formation 206a. Where  
25 stimulation fluids, such as acidizing fluids, and/or treatment fluids are employed, these fluids need not be pumped at pressures sufficient to create fractures 256a. When the stimulation and/or treatment process is completed, a signal is sent to isolation device 230a and perforating gun 220b via signal means 218. In response, perforating gun 220b is fired or detonated thereby forming  
30 perforation(s) 260b (FIG. 11c) while isolation device 230a is activated to seal interior 213 of casing 212 against fluid flow. Detonation of perforating gun 220b and activation of isolation device 230a may occur substantially simultaneously

138  
136

980019 USA

or sequentially although it is preferred that perforating gun 220b be fired immediately before isolation device 230a is activated. At this point (FIG. 11d), the next formation 206b is immediately treated in a similar fashion to that just described with respect to formation 206a (FIG. 11d). The surface equipment  
5 necessary to pump the stimulation and/or treatment fluids through casing 212 need not be moved off the surface well site during operation in accordance with the present invention nor rigged up or down thereby saving costs associated with such operations. This process is repeated for each zone to be treated (FIG. 11e) until conclusion (FIG. 11f). Upon completion, zone isolation devices 230a  
10 and 230b may be actuated into an open position or destructed by any suitable means, such as drilling, to permit flow through the interior 213 of casing 212 for fluids produced from and/or injected into formations 206a, 206b and/or 206c. Although illustrated in FIGS. 11a-11f as being applied to three formations, the process illustrated for this embodiment of the present invention may be applied  
15 to any number of subterranean formations which are penetrated by a subterranean well bore.

An embodiment of the assembly and process of the present invention which utilizes zone isolation devices between perforating gun assemblies is illustrated generally as 300 in FIGS. 12a - 16a and comprises at least two  
20 perforating gun assemblies 320 and 320a which are secured to the outside of casing 310 which is made up of individual lengths of pipe in a manner as described below and a flapper valve assembly 380 which is positioned between perforating gun assemblies 320, 320a as described below. A first length of casing 310, a first specialty collar 304, a first male to female connector 314, a  
25 flapper valve sub-assembly 380, a second length of casing 310, a collar 316, a third length of casing 310 and a second specialty collar 312 are secured together in the sequence as just described and illustrated in FIG. 12 by any suitable means, such as screws threads. As illustrated in FIGS. 12 and 13, each specialty collar 304 has a first generally cylindrical shaped, axially extending bore  
30 305 therethrough having screw threaded ends and a second smaller diameter axially extending bore 306 which is axially offset from bore 305 and having an enlarged end 307 which is provided with screw threads for engagement with a

134  
137

980019 USA

perforating gun assembly and a second end which is threaded for engagement with a hydraulic line as hereinafter described.

Flapper valve subassembly 280 comprises generally tubular body sections 381, 383, 385 and 386 which are secured together by any suitable means, such as by screw threads. O-ring seals 382, 388 and 387 provide a fluid tight connection between these generally tubular body sections. Body section 383 is provided with a port 389 which provides for fluid communication through the wall of section 383 and is threaded on one end for attachment to a hydraulic line as hereinafter described. A sleeve 400 is received within body sections 381, 383, 385 and 386 such that, when assembled in the positioned illustrated in FIGS. 14a and 15a, two annular chambers 394 and 395 are defined therebetween. Sleeve 400 has a raised outer portion 402 intermediate the length thereof thereby defining opposing generally annular shoulders 404 and 406. Sleeve 400 may move with respect to the body sections with the amount of movement being limited by raised outer portion 402 abutting the ends of annular chamber 395. Annular seal rings 392 and 393 provide a fluid tight seal between sleeve 400 and body sections 381 and 383. A flapper valve 396 is rotatably secured to body portion 386 and is biased toward a closed position in engagement with generally annular seat 399 formed by one end of body portion 386 by means of spring 398 so as to block fluid flow through the interior bore 390 of the sub-assembly. As assembled, flapper valve 396 is positioned in an open, retracted position within annular chamber 394 and held therein by sleeve 400. Sleeve 400 is held in this position by means of ambient air pressure in chamber 395 acting against shoulder 404. Flapper valve 396 is constructed of any suitable material, for example ceramic or relatively soft metal such as aluminum or cast iron, which may be removed by rotary drilling or percussive means.

Perforating gun assemblies 320 and 320a each comprise a detonating assembly 330 and a perforating gun 350. Any suitable detonating assembly known to those skilled in the art may be used. An example of a detonating assembly suitable for use with the casing conveyed perforating assembly of the present invention is shown in FIGS. 13a and 16a. One end of an outer generally cylindrical housing 331 is secured to enlarged end 307 of specialty collar 304

140  
138

980019 USA

while the other end is secured to a second sub 332 which in turn is secured to a third sub 333 by any suitable means, such as by screw threads. In addition, the outer housing 331 of perforating gun assembly 320a has a outwardly extending spigot 364 which contains a bore 365 in fluid communication with in  
5 interior of outer housing 331 as hereinafter described in greater detail. Vent housing 334 which has a vent 335 formed intermediate the length thereof has one end thereof secured to internal sub 346 which in turn is secured to second sub 332. A piston 336 is received within vent housing 334 and tubular end cap 337 and is initially held in place by means of shear pins 338 mounted in shear  
10 set 339. Piston 336 is elongated and is connected to pin 315 in assembly 320a. A firing pin 340 extends from one end of the bottom of piston 336. An annular chamber 341 defined between piston 336 and firing head 342 is filled with air at atmospheric pressure. Firing head 342 abuts a shoulder in the interior wall of vent housing 334 in the detonator assembly as fully constructed and functions  
15 to retain percussion detonator 343 against an ignition transfer 345 in one end of internal sub 346. Internal sub 346 is secured to second sub 334 by any means, such as screw threads. Each of ignition transfer 345, internal sub 346, second sub 332 and third sub 334 are provided with an internal bore through which detonating cord 349 passes. Booster transfers 347, 348 are located in second  
20 and third subs 332, 334, respectively, linking segments of the detonating cord 349 above and below the junction between second and third subs 332, 334. One end of third sub is secured to one end of a perforating charge carrier 352 of perforating gun assembly 350 while the other end of charge carrier 352 is secured to bull plug 353 by any suitable means, such as screw threads. Charge  
25 carrier 352 may be a commercially available carrier for perforating charges and contains at least one conventional perforating charge 356 capable of creating an aperture in casing and a portion of the adjacent subterranean formation. A perforating charge tube 354 is positioned within carrier 352 and has at least one relatively large aperture or opening 355 therein which may be spaced both  
30 vertically along and angularly about the axis of the tube. Charge carrier 352 and perforating charge tube 354 have generally elongated tubular configurations. A

141  
139

980019 USA

lined perforating charge 356 is secured in an aperture or opening 355 in perforating charge tube 354 in a manner as will be evident to a skilled artisan, such that the large end 357 thereof is aligned with and protrudes through opening or aperture 355 in tube 354. If multiple charges are present, they may  
5 be spaced vertically along and angularly about the axis of the carrier. The charge density is an appropriate density determined by methods known to those skilled in the art. Common charge densities range between two and twenty four per foot. Detonating cord 349 is connected to the small end 358 of each perforating charge 356 and to end cap 359 in bull plug 353.

10 As illustrated in FIGS. 13a and 14a, perforating gun assembly 320a is provided with a sub 322 in lieu of a bull plug. Sub 322 has a bore 323 therethrough and is secured at the other end to piston housing 324 which slidably receives a piston 326 in the interior 325 thereof. The other end of piston housing is connected to a plug 327 having a bore 328 therethrough which has  
15 one end thereof threaded for connection to a hydraulic line.

As assembled and illustrated in FIGS. 12a-16a, a first hydraulic line 402 extends to a suitable source (not illustrated) of hydraulic fluid under pressure at the surface as will be evident to a skilled artisan and is secured within one end of bore 306 through specialty connector 304 by any suitable means, such as by  
20 a threaded ferule 403. Another hydraulic line 404 has one end thereof connected to connected to bore 365 in spigot 364 of perforating gun assembly 320a while the other end thereof is connected to one end of bore 306 through specialty connector 304 by any suitable means, such as by a threaded ferules 405 and 406, respectively. Still another hydraulic line 407 has one end thereof connected  
25 to connected to one end of bore 328 in plug 327 of perforating gun assembly 320a while the other end thereof is connected to the threaded end of port 389 in body section 383 of flapper valve subassembly 380 by any suitable means, such as by a threaded ferules 408 and 409, respectively.

In operation, the embodiment of the assembly of the present illustrated  
30 in FIGS. 12a - 16a is positioned in a subterranean well bore such that perforating gun assemblies are adjacent subterranean formations of interest 206a and 206b

147  
140

980019 USA

(FIG. 11a). Hydraulic fluid is then transported under pressure from a suitable source via hydraulic line 402 to the internal bore through perforating gun assembly 320a where, as illustrated in greater detail in FIG. 18, the hydraulic fluid is diverted through bore 365 in spigot 364 and into hydraulic line 404 and

5 perforating gun assembly 320 where the pressure exerted by the hydraulic fluid causes shear pins 338 to shear and firing pin 340 to strike firing head 342 and igniting percussion detonator 343. The ignition of percussion detonator 343 causes a secondary detonation in ignition transfer 345, which in turn ignites detonating cord 349. Detonating cord 349 comprises an explosive and runs

10 between the ends of each charge carrier, passing between the backs of the charges and the charge clips holding the charges in the carrier. Cord 349 ignites the charges 356 in charge carrier 352 and booster transfers, which contains a higher grade explosive than detonating cord 349. Detonation of charges 356 in perforating gun assembly 320 forms perforation(s) 250a through casing 212

15 (FIG. 16b), i.e. perforations 311 through casing 310 (FIGS. 16b and 16c), and cement 217 into formation 206a in a manner as previously described with respect to the embodiments illustrated in FIG. 11a above. Thereafter, stimulation fluids 260a, such as fracturing fluid containing proppants and/or acids, and/or treatment fluids, for example scale inhibitors and/or gelation

20 solutions, are pumped from surface 204 through the interior 213 of casing 212 and into perforations 250a (FIG. 11b). Radioactive tracers may be incorporated into the stimulation and/or treatment fluids to ensure proper placement of fluids and/or solids contained therein. In the case of fracturing fluids, fractures 256a are formed and propagated within formation 206a. Where stimulation fluids,

25 such as acidizing fluids, and/or treatment fluids are employed, these fluids need not be pumped at pressures sufficient to create fractures 256a.

When the stimulation and/or treatment process is completed, hydraulic pressure is increased in line 402 until shear pins 338 in perforating gun assembly 320a shear. At this point, piston 336 in perforating gun assembly is

30 free to move which caused pin 315 to contact causing sleeve 317 in perforating gun assembly 320a to shift (FIG. 19) thereby sealing bore 365 in spigot 364

143  
141

980019 USA

against fluid flow. Movement of piston 336 also causes firing pin 340 to strike firing head 342 thereby igniting percussion detonator 343, detonating cord 349 and charges 356 (FIG. 13c) in charge carrier 352 forming perforation(s) 260b (FIG. 11c), i.e. perforations 313 through casing 310 (FIG. 13c). The pressure  
5 from fluid in the interior of casing 310 is communicated to the interior 325 of housing 324 thereby forcing piston 326 in assembly 320a to flow hydraulic fluid to flow through line 407, port 389 and act against shoulder 406 of sleeve 400. In response, sleeve 400 moves until shoulder 404 abuts the end of chamber 395 thereby permitting flapper valve 396 to rotate into engagement with seat 399  
10 (FIG. 15c). In this manner, flapper valve 380 seals the interior of casing 310 (212 in FIG. 11b) against fluid flow. Thereafter, stimulation fluids 260b, such as fracturing fluid containing proppants and/or acids, and/or treatment fluids, for example scale inhibitors and/or gelation solutions, are pumped from surface 204 through the interior 213 of casing 212 (310) and into perforations 250b (FIG.  
15 11d), i.e. perforations 313 (FIG. 13c). Upon completion, zone isolation devices 230a and 230b may be actuated into an open position or destructed by any suitable means, such as drilling, to permit flow through the interior 213 of casing 212 for fluids produced from and/or injected into formations 206a, 206b and/or 206c.

20 While the embodiment of the assembly of the present invention which is illustrated in FIG. 12a-16a as having two perforating assemblies 320 and 320a for completion of two subterranean formations, it will be evident to a skilled artisan that the assembly of this embodiment may be applied to three or more subterranean formations by repeating the portion of assembly 300 denoted as  
25 301 in FIGS. 12A-16A. Proper spacing between perforating gun assemblies 320 and 320a or repetitive assemblies 320a for treatment of multiple subterranean formations is achieved by varying the lengths of first and/or second lengths of casing 310 as will be evident to a skilled artisan.

30 The following example demonstrates the practice and utility of the present invention, but is not to be construed as limiting the scope thereof.

## EXAMPLE

A well is drilled with a 7.875" bit to 4,000 feet with 11 lb./gal drilling mud and 9.625" surface casing is set at 500 feet. Open hole logs are run and analyzed, along with other information such as geologic offset data, drilling data, and mud logs. It is determined three potential oil productive intervals exist in the well. A carbonate formation is located from 3,700 feet to 3,715 feet and is believed to have low productivity unless stimulated. A sandstone formation is located from 3,600 feet to 3,610 feet and is believed to have low productivity unless stimulated. A highly fractured carbonate is located from 3,500 feet to 3,510 and is believed to not require any stimulation. All of the above depths are based upon open hole logs. An embodiment of the assembly of the present invention is run with 3.5" outside diameter casing and cement float equipment located on the end of the casing. The assembly also contains three externally mounted 2.375" outside diameter perforating guns oriented to shoot into both the casing and the formation, all loaded with 6 shaped charges per foot. Perforating Assembly A contains 15 feet of perforating shaped charges, while Perforating Assemblies B and C contain 10 feet of perforating shaped charges. A flapper valve with the flapper made of ceramic, Assembly D, is also utilized. Approximately 100 feet of casing, with the cement float equipment extends below the connector to Perforating Assembly A. The equipment is positioned utilizing specialty connectors on the 3.5" casing and spacer pipe, and utilizing the top perforating charge in Assembly A as a reference point such that flapper valve Assembly D is 80 feet in distance from the reference point, the top of Perforating Assembly B is 100 feet in distance from the reference point, and Perforating Assembly C is 200 feet in distance from the reference point. Hydraulic control line is connected to all of appropriate assemblies and run into the borehole with the additional lengths of 3.5" casing required to comprise the complete casing string by placing steel bands around the control line and the casing every 30 feet up the wellbore.

The casing string is run into the wellbore until pipe measurements suggest the top of Perforating Assembly A is located at 3,700 feet pipe measurement. The well is circulated with drilling muds and a gamma ray casing

980019 USA

collar log is run to determine the relative position of the Perforating Assembly A to open hole logging depths. Based upon correlations, it is determined the equipment and casing needs to be lowered into the wellbore an additional 5 feet to be exactly on depth and the logging tool is removed from the well. The pipe  
5 is lowered into the wellbore a total of 6 feet, as engineering calculations suggest casing movement will contract the string approximately one foot during cementing operations. The casing is landed on the wellhead equipment and cemented into the open hole by pumping 15.8 lb./gal. cement in sufficient quantity to fill the entire annulus, and the cement is displaced with a 9.0 lb/gal  
10 brine to the cement float equipment.

At some later date in time, when the cement has cured, Perforating Assembly A is detonated by connecting on surface to the hydraulic control line that is cemented outside of the casing and applying 1500 psi surface pressure to actuate the pressure actuated firing head. It may be desired to attempt to  
15 allow this interval to flow into the interior of the casing and up the casing to surface to obtain preliminary reservoir information. This lowermost interval of the well is then acid stimulated by pumping 10,000 gallons of 15% hydrochloric acid at 3,500 psi at 5 barrels per minute injection rate. The acid is displaced with the first stage of a fracturing fluid which will be utilized to stimulate the  
20 second interval, from 3,600 feet to 3,610 feet. Displacement of the acid is ceased while the last portion of the acid remains located from the lowermost perforations (3,700 feet to 3,715 feet) to 3,300 feet. Perforating Assembly B is immediately detonated by applying 2,500 psi surface pressure to actuate this pressure actuated firing head. This perforating event allows interior casing  
25 hydrostatic pressure to enter the interior of Perforating Assembly B and transfer down the secondary line to actuate and close flapper valve Assembly D. This interval is also perforated with acid across from the perforations, which can aid in dissolving crushed cement from the perforating event. A sand laden hydraulic fracture stimulation (30,000 pounds of sand in 12,000 gallons of  
30 fracturing fluids) is subsequently pumped into this middle interval of the well and displaced to the perforations with brine. Perforating Assembly C is subsequently detonated by applying 3,500 psi surface pressure to actuate this

980019 USA

pressure actuated firing head. All three intervals are produced together up the casing to surface. At a later date it is determined by wireline work down the interior of the casing that no sand is lodged on top of the flapper valve Assembly D. Flow to surface is ceased and a 1" diameter bar by 10 feet in  
5 length is dropped and breaks the flapper valve into fragments. The well is then returned to production.

The process and assembly of the present invention may also involve the use of *propellant material in conjunction* with the perforating gun assembly to substantially simultaneously enhance the effectiveness of the resulting  
10 perforations and to stimulate the subterranean formation(s). In accordance with this embodiment, propellant in the form of a sleeve, strip, patch or any other configuration is outside of the perforating assembly and casing and in the path in which at least one of the explosive charges in at least one perforating assembly which is utilized in the process of the present invention is aimed. The  
15 propellant material may be positioned on either one or more perforating assembly 20, 120, 220 or 350 or casing 12, 112, 212 or 310, respectively. Upon detonation of an explosive charge in a perforating assembly, propellant material which is positioned in the path in which the explosive charge is aimed breaks apart and ignites due to the shock, heat, and pressure of the detonated  
20 explosive charge. When one or more explosive charges penetrate a subterranean formation, pressurized gas generated from the burning of the propellant material enters the formation through the recently formed perforations thereby cleaning such perforations of debris. These propellant gases also stimulate the formation by extending the connectivity of formation  
25 with the well bore by means of the pressure of the propellant gases fracturing the formation. Additionally or alternatively, the carrier of perforating assembly, e.g. charge carrier 352, may be constructed of propellant material which ignites upon detonation of the explosive charge. Disintegration of the carrier upon ignition may assist the connectivity between perforations formed via perforating  
30 gun assemblies having multiple explosive charges. Preferably, the propellant material is a cured epoxy, carbon fiber composite having an oxidizer

147  
145

980019 USA

incorporated therein such as that commercially available from HTH Technical Services, Inc. of Coeur d'Alene, Idaho.

5 In addition to the equipment, such as a gamma ray logging tool mentioned above, the assembly of the present invention may also include other equipment, for example temperature and pressure gauges, which are positioned on the exterior of the casing of the assembly and connected to the signal device 18, if necessary to power the equipment. The use of a gamma ray logging tool, pressure gauge and temperature gauge can provide invaluable real time information to enable a skilled artisan to monitor fracture growth where  
10 the subterranean formation(s) are fracture using the processes and assembly of the present invention.

15 While the foregoing preferred embodiments of the invention have been described and shown, it is understood that the alternatives and modifications, such as those suggested and others, may be made thereto and fall within the scope of the invention.

**CLAIMS**

I claim:

- 1 1. A process for establishing fluid communication comprising:
  - 2 positioning at least one explosive charge in a subterranean well bore
  - 3 such that said at least one explosive charge is placed external to casing which
  - 4 is also positioned within said well bore and is aimed toward said casing; and
  - 5 detonating said at least one explosive charge so as to perforate the wall
  - 6 of said casing at least once.
- 1 2. The process of claim 1 wherein said explosive charge perforates the wall of
- 2 said casing twice.
- 1 3. The process of claim 1 further comprising:
  - 2 cementing said at least one explosive charge and said casing in said well
  - 3 bore prior to the step of detonating.
- 1 4. The process of claim 1 wherein said at least one explosive charge is
- 2 positioned in said subterranean well bore substantially simultaneously with said
- 3 casing.
- 1 5. A process for completing a subterranean well bore comprising:
  - 2 penetrating the wall of a casing which is positioned and cemented within
  - 3 a subterranean well bore from the exterior of the casing to the interior.
- 1 6. A process for completing a subterranean well comprising:
  - 2 positioning at least one explosive charge in a subterranean well bore
  - 3 outside of casing; and
  - 4 detonating said at least one explosive charge so as to perforate said
  - 5 casing.
- 1 7. The process of claim 6 further comprising:
  - 2 positioning said at least one explosive charge adjacent a subterranean
  - 3 formation, the step of detonating said at least one explosive charge also
  - 4 perforates said subterranean formation.
- 1 8. The process of claim 7 further comprising:
  - 2 injecting fluid through the casing and into said subterranean formation.
- 1 9. The process of claim 7 further comprising:

149  
147

980019 USA

- 2           producing fluid from said subterranean formation into the casing.
- 1   10. The process of claim 6 further comprising:
- 2           cementing said at least one explosive charge and said casing in said
- 3   subterranean well bore prior to the step of detonating.
- 1   11. The process of claim 10 further comprising:
- 2           positioning said at least one explosive charge adjacent a subterranean
- 3   formation, the step of detonating said at least one explosive charge also
- 4   perforates said cement and said subterranean formation.
- 1   12. The process of claim 11 further comprising:
- 2           injecting fluid through the casing and into said subterranean formation.
- 1   13. The process of claim 11 further comprising:
- 2           producing fluid from said subterranean formation into the casing.
- 1   14. The process of claim 6 further comprising:
- 2           positioning at least one tool in said subterranean well bore outside said
- 3   casing for monitoring conditions of said well bore or a subterranean formation,
- 4   wherein said tool is a logging tool, a temperature gauge or a pressure gauge.
- 1   15. The process of claim 14 further comprising:
- 2           cementing said at least one tool, said at least one explosive charge and
- 3   said casing in said subterranean well bore prior to the step of detonating.
- 1   16. The process of claim 6 further comprising:
- 2           positioning at least two explosive charges in a subterranean well bore
- 3   outside of casing, one of said at least two explosive charges being positioned
- 4   adjacent a first subterranean formation while another of said at least two
- 5   explosive charges being positioned adjacent a second subterranean formation;
- 6           detonating said one of said at least two explosive charges so as to
- 7   perforate said casing and said first subterranean formation; and
- 8           detonating said another of said at least two explosive charges so as to
- 9   perforate said casing and said second subterranean formation.
- 1   17. The process of claim 16 further comprising:
- 2           cementing said at least two explosive charges and said casing in said
- 3   subterranean well bore prior to the steps of detonating.

980019 USA

- 1 18. The process of claim 16 wherein said steps of detonating occur  
2 substantially simultaneously.
- 1 19. The process of claim 16 wherein said step of detonating said one of said  
2 at least two explosive charges occurs prior to said step of step of detonating  
3 said another of said at least two explosive charges.
- 1 20. The process of claim 16 further comprising:  
2 producing fluid from said first subterranean formation into said casing  
3 after detonating said one of said at least two explosive charges.
- 1 21. The process of claim 16 further comprising:  
2 producing fluid from said second subterranean into said casing after  
3 detonating said another of said at least two explosive charges.
- 1 22. The process of claim 19 further comprising:  
2 injecting fluid through the casing and into said first subterranean  
3 formation after detonating said one of said at least two explosive charges and  
4 prior to said step of step of detonating said another of said at least two  
5 explosive charges so as to treat and/or fracture said first subterranean  
6 formation.
- 1 23. The process of claim 19 further comprising:  
2 sealing the interior of said casing to fluid flow between said first and said  
3 second formations; and  
4 injecting fluid through the casing and into said second subterranean  
5 formation after detonating said another of said at least two explosive charges  
6 so as to treat and/or fracture said second subterranean formation.
- 1 24. The process of claim 6 further comprising:  
2 placing fluid within said subterranean well bore prior to detonating said  
3 at least one explosive charge.
- 1 25. The process of claim 24 wherein said fluid comprises an acid.
- 1 26. The process of claim 6 further comprising:  
2 igniting propellant material by detonating said at least one explosive  
3 charge.
- 1 27. The process of claim 6 further comprising:

980019 USA

2 positioning control line in said subterranean well bore outside of said  
3 casing which is connected to said at least one explosive charge.

1 28. A process for providing fluid communication across the wall of a casing  
2 comprising:

3 detonating a first perforating gun assembly which is positioned outside  
4 of a casing in a subterranean well bore thereby perforating said casing.

1 29. The process of claim 28 further comprising:

2 cementing said casing within said well bore.

1 30. A process for completing one or more subterranean formations comprising:

2 detonating a first perforating gun assembly which is positioned outside  
3 of a casing in a subterranean well bore thereby perforating said casing and a  
4 first subterranean formation.

1 31. The process of claim 30 further comprising:

2 injecting one or more stimulation and/or treatment fluids via said casing  
3 into said first subterranean formation.

1 32. The process of claim 31 wherein said at least one of said one or more  
2 stimulation and/or treatment fluids is injected under sufficient pressure to  
3 fracture said first subterranean formation.

1 33. The process of claim 30 further comprising:

2 detonating a second perforating gun assembly which is positioned  
3 outside of said casing in a subterranean well bore thereby perforating said  
4 casing and a second subterranean formation.

1 34. The process of claim 33 further comprising:

2 injecting one or more stimulation and/or treatment fluids via said casing  
3 into said second subterranean formation.

1 35. The process of claim 34 further comprising:

2 isolating said first subterranean formation from injection of fluids prior to  
3 injecting said one or more stimulation and/or treatment fluids via said casing  
4 into said second subterranean formation.

152  
150

980019 USA

- 1 36. The process of claim 35 wherein said at least one of said one or more  
2 stimulation and/or treatment fluids is injected under sufficient pressure to  
3 fracture said second subterranean formation.
- 1 37. The process of claim 35 further comprising:  
2 reversing the step of isolating said first subterranean formation from  
3 injection of fluids after injecting one or more stimulation and/or treatment fluids  
4 via said casing into said second subterranean formation.
- 1 38. A process for completing a subterranean well comprising:  
2 penetrating casing which is positioned in a subterranean well bore while  
3 the interior of said casing remains unoccupied by perforating guns or other  
4 equipment, tools, tubulars or lines.
- 1 39. A subterranean completion system comprising:  
2 a casing which is at least partially positioned within a subterranean well  
3 bore; and  
4 at least one perforating gun assembly which is positioned external to said  
5 casing and within said well bore, said perforating gun assembly having at least  
6 one explosive charge aimed in the direction of said casing.
- 1 40. The subterranean completion system of claim 39 wherein said at least one  
2 perforating gun assembly and said casing are connected.
- 1 41. The subterranean completion system of claim 39 further comprising:  
2 a logging tool, temperature gauge and/or pressure gauge which is  
3 positioned external to said casing and within said well bore.
- 1 42. The subterranean completion system of claim 39 further comprising:  
2 a signaling device for transmitting signals from the surface of the earth  
3 to said perforating gun, said signaling device being positioned external to said  
4 casing.
- 1 43. A completion system comprising:  
2 a casing; and  
3 at least one perforating gun connected to the exterior of said casing and  
4 having at least one explosive charge aimed toward said casing.
- 1 44. The completion system of claim 43 further comprising:

2 at least two perforating guns connected to the exterior of said casing,  
3 each of said at least two perforating guns having at least one explosive charge  
4 aimed toward said casing.

1 45. The completion system of claim 44 further comprising:

2 a zone isolation device positioned between said at least two perforating  
3 guns for selectively shutting off flow through said casing.

1 46. The completion system of claim 45 wherein said zone isolation device is  
2 a flapper valve.

1 47. The completion system of claim 46 wherein said flapper valve is  
2 constructed of a destructible material.

1 48. The completion system of claim 43 further comprising:

2 an assembly for providing signals to said at least one perforating gun  
3 which is connected to said perforating gun and is positioned exterior of said  
4 casing.

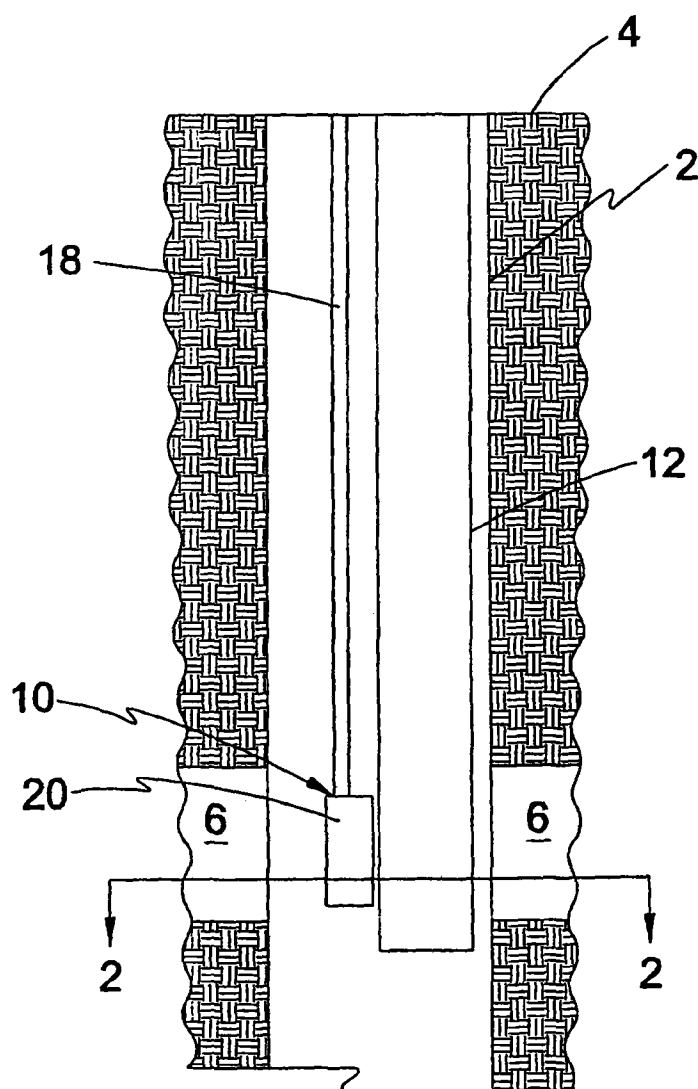
1 49. The completion system of claim 48 wherein said assembly is hydraulically  
2 connected to said perforating gun.

1 50. The completion system of claim 48 wherein said assembly is electrically  
2 connected to said perforating gun.

1 51. The completion system of claim 48 wherein said assembly is connected to  
2 said perforating gun by wave transmission.

### ABSTRACT

A process and apparatus for completing a subterranean well bore in at least one subterranean formation. At least one perforating gun assembly is positioned on the outside of casing in a subterranean well bore. A suitable signal, such as a hydraulic, electric or wave signal, is transported to the perforating gun assembly so as to detonate one or more explosive charges in the perforating gun assembly which are aimed toward the casing. At least one wall in the casing is perforated thereby establishing fluid communication through the wall of the casing. Usually, cement surrounding the casing and a subterranean formation surrounding the casing are also perforated to establish fluid communication between the formation and the interior of the casing. A logging tool may also be positioned exterior to the casing to aid in positioning the perforating gun assembly adjacent a subterranean formation of interest and pressure and/or temperature gauges may also be provided on the exterior of casing to monitor well bore and/or formation conditions. In one embodiment, multiple perforating gun assemblies are located outside casing and juxtaposed to multiple subterranean formations of interest. Thereafter, each perforating gun assembly may be selectively fired to perforate the casing and select formation. Zone isolation devices may be provided on the outside of the casing to permit each formation to be completed and stimulated and/or treated independent of the others. In this manner, multiple subterranean formations may be completed and stimulated and/or treated more efficiently and cost effectively.

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**Fig. 1**

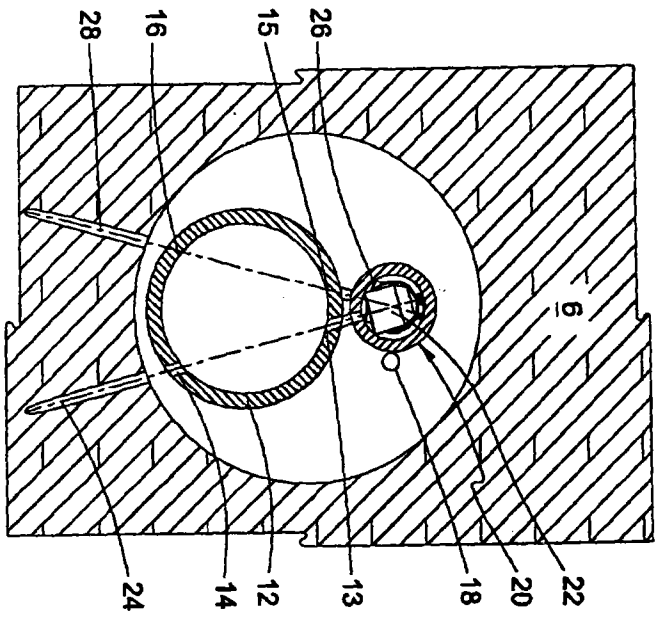


Fig. 3

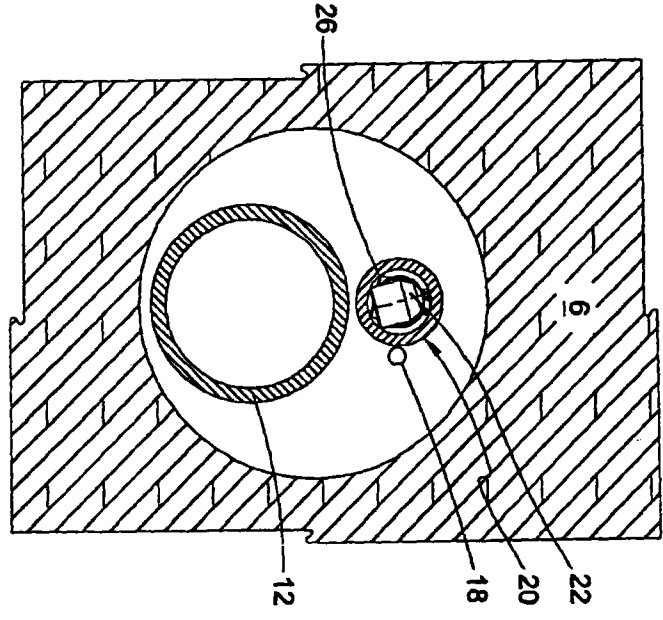


Fig. 2

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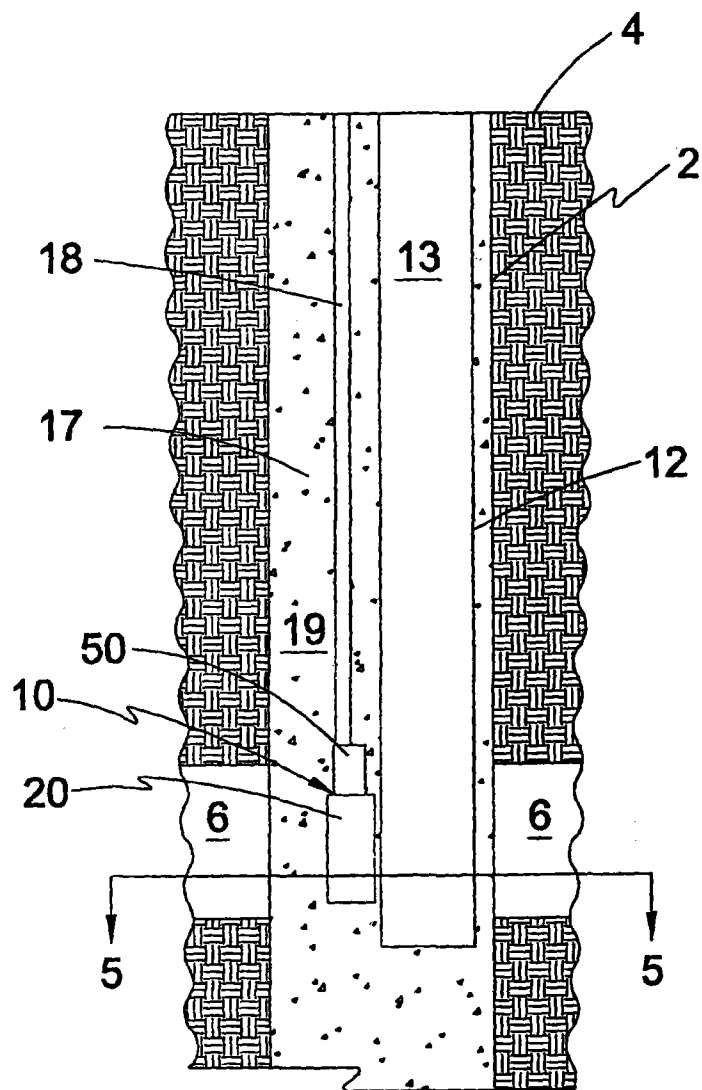


Fig. 4

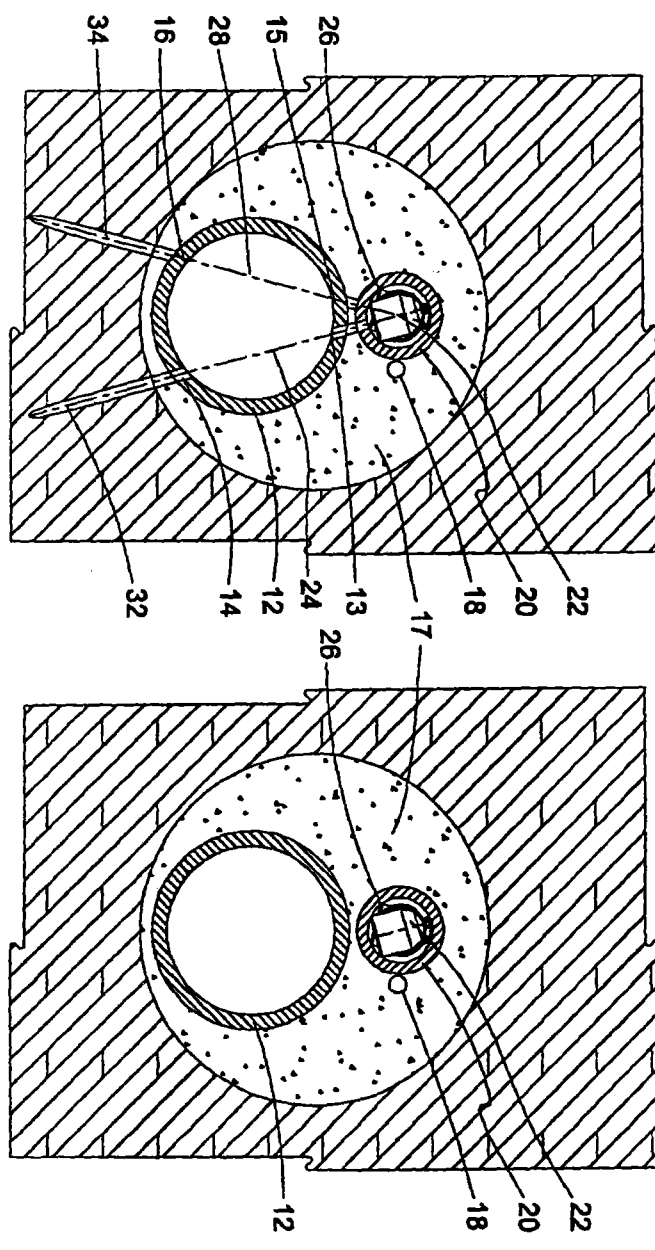


Fig. 6

Fig. 5

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259  
157

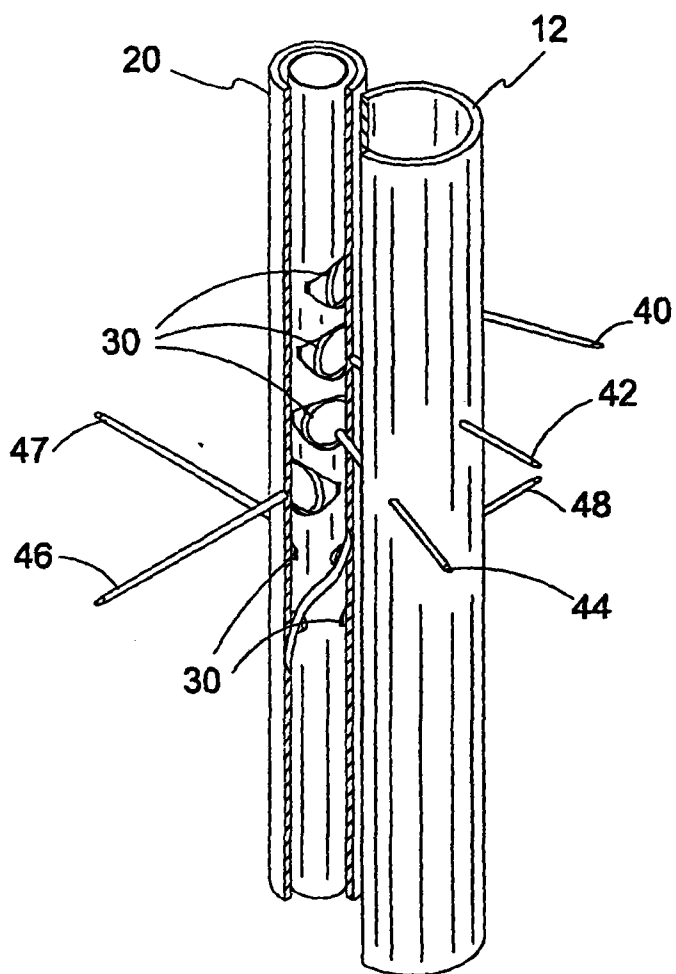


Fig. 7

664340 9903020

460  
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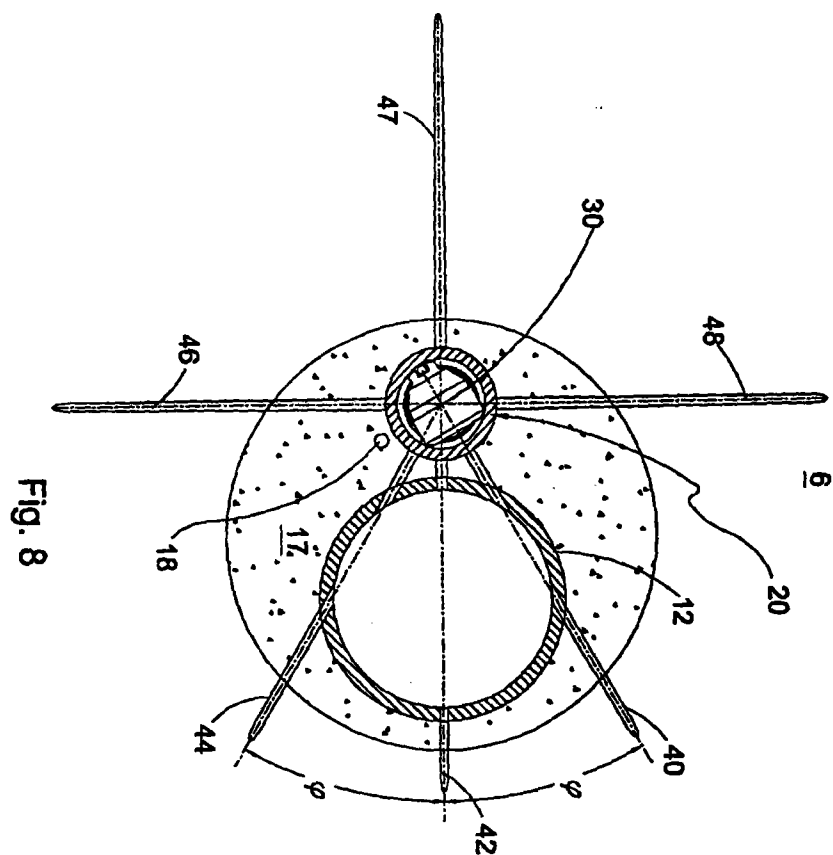


Fig. 8

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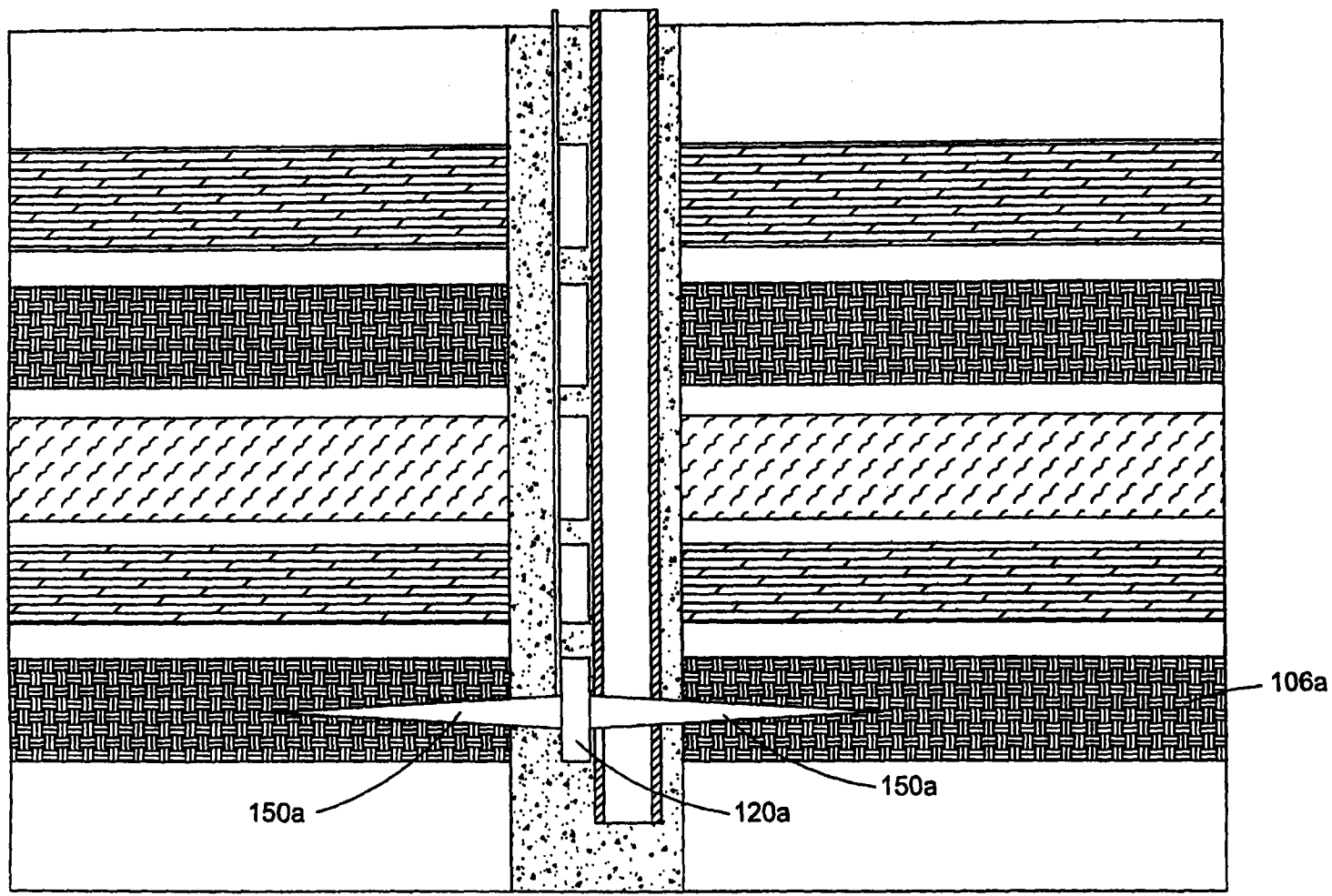


Fig. 10a

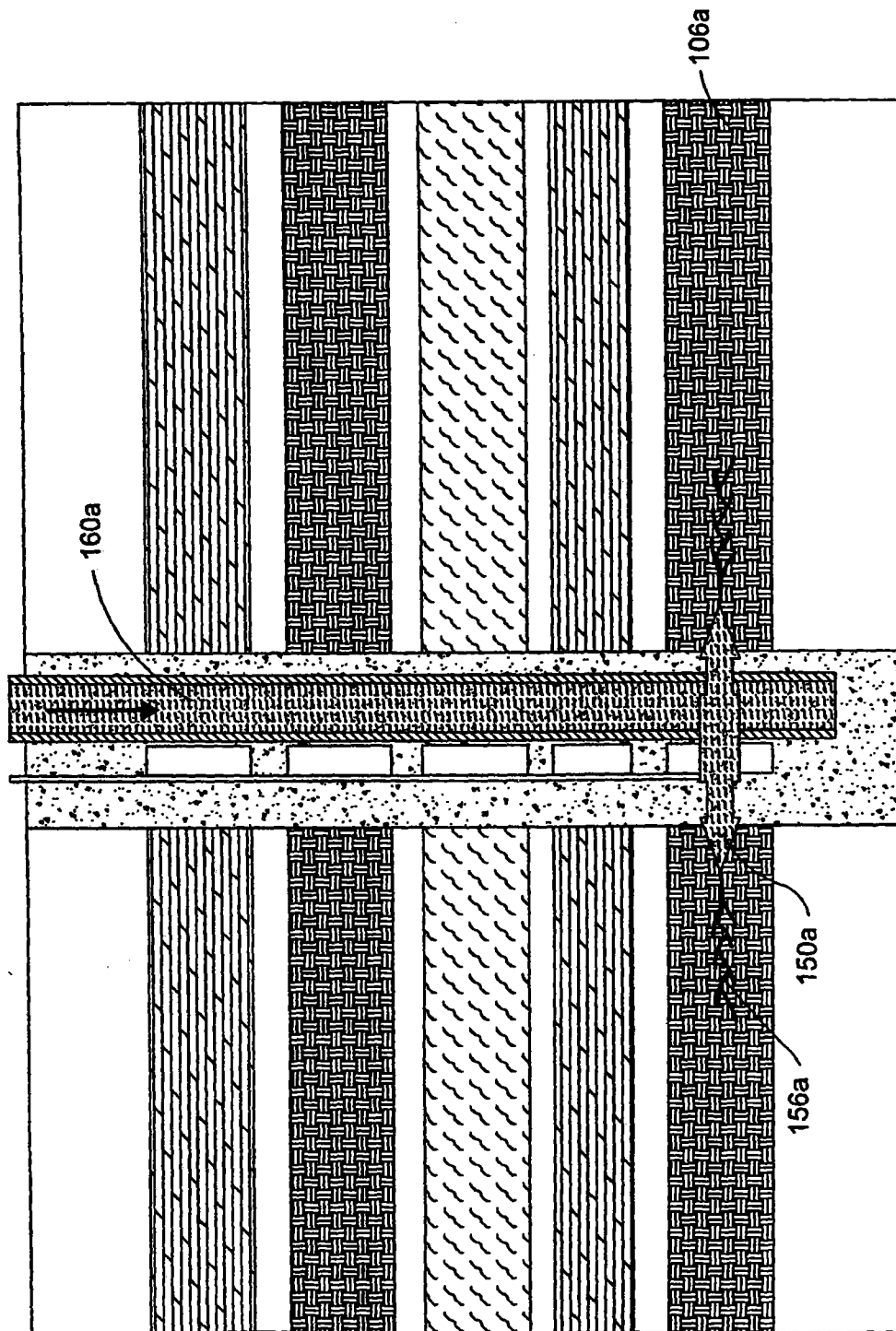


Fig. 10b

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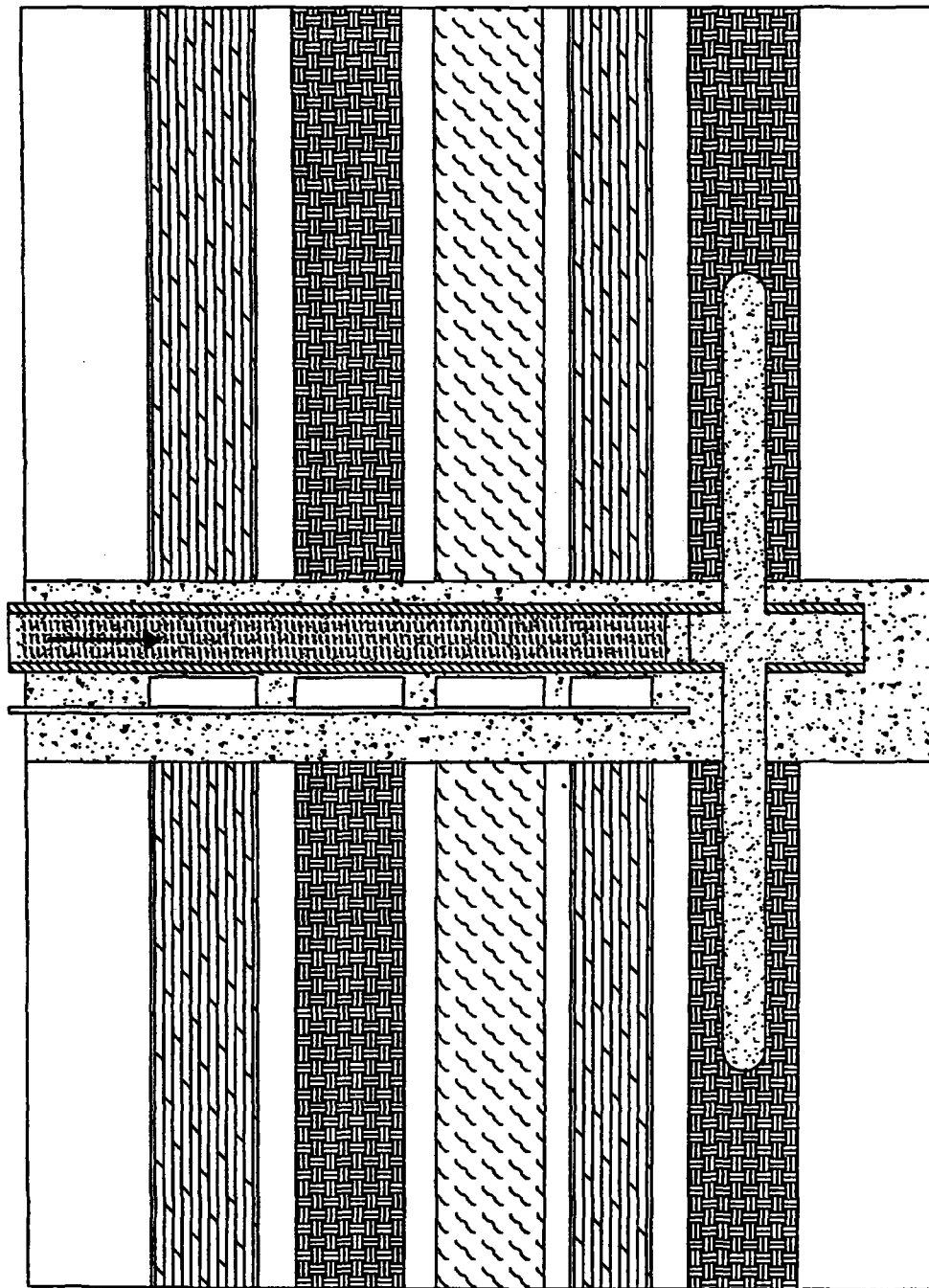


Fig. 10c

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h41

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163

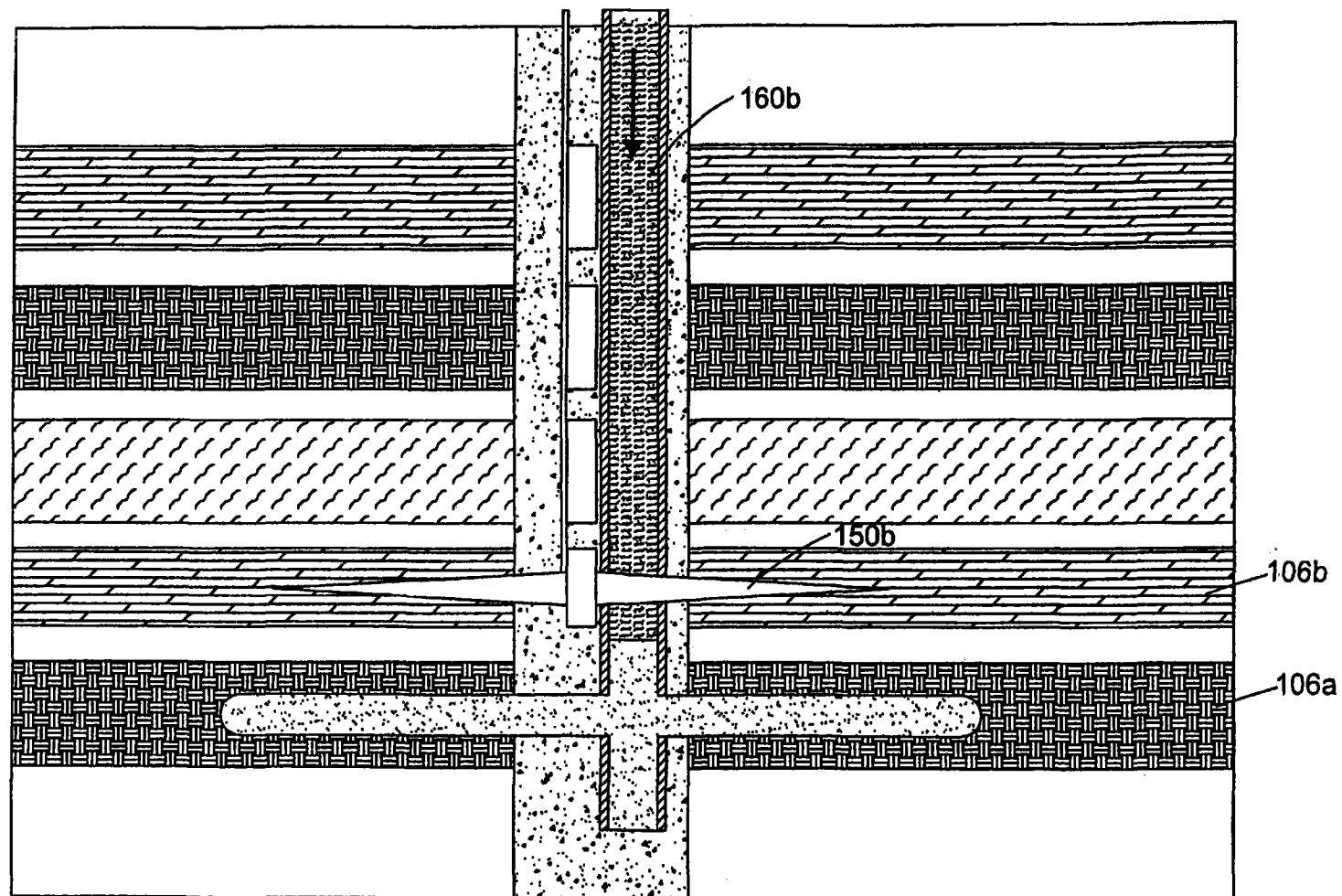


Fig. 10d

0000000000 00000000

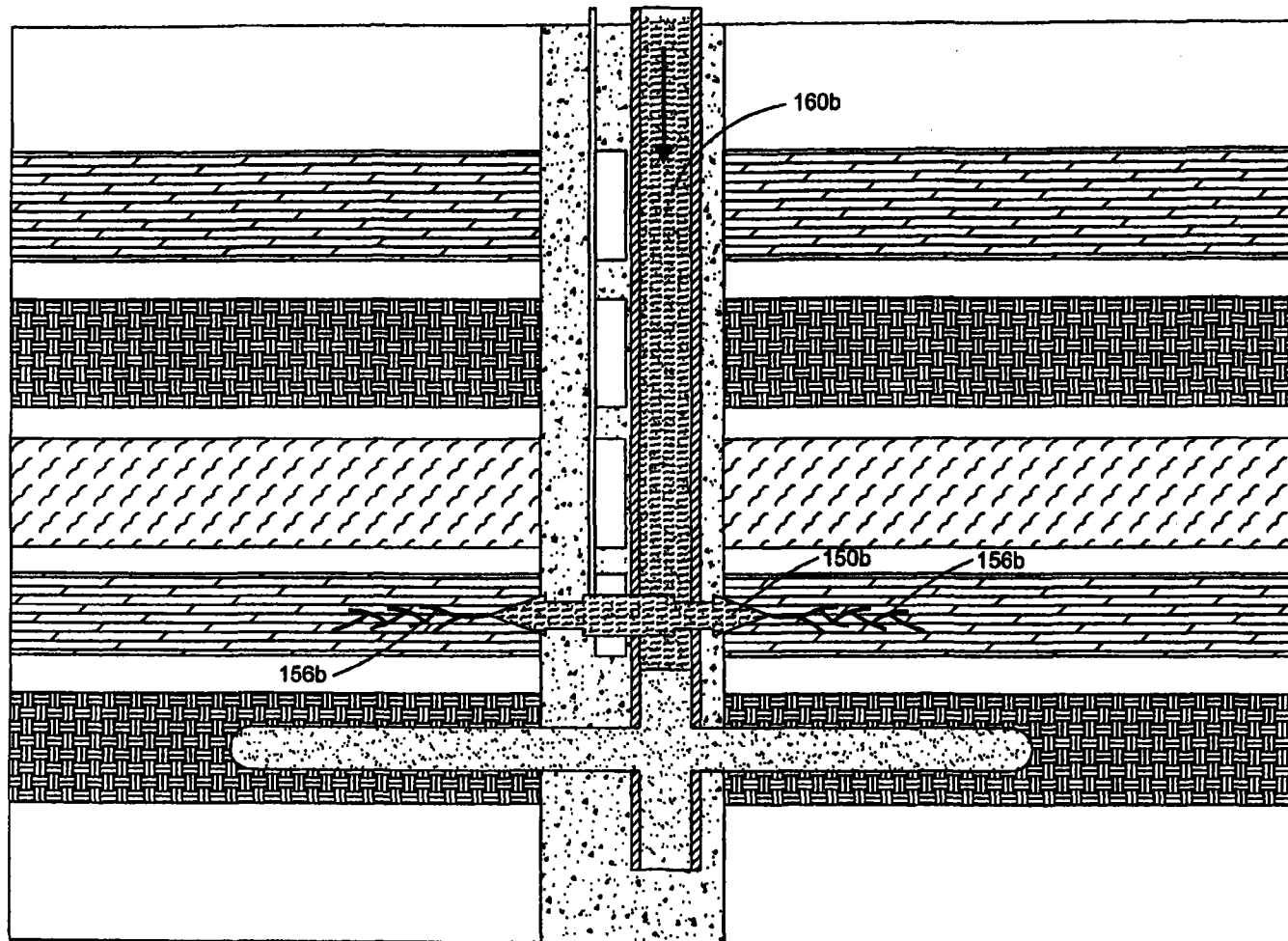


Fig. 10e

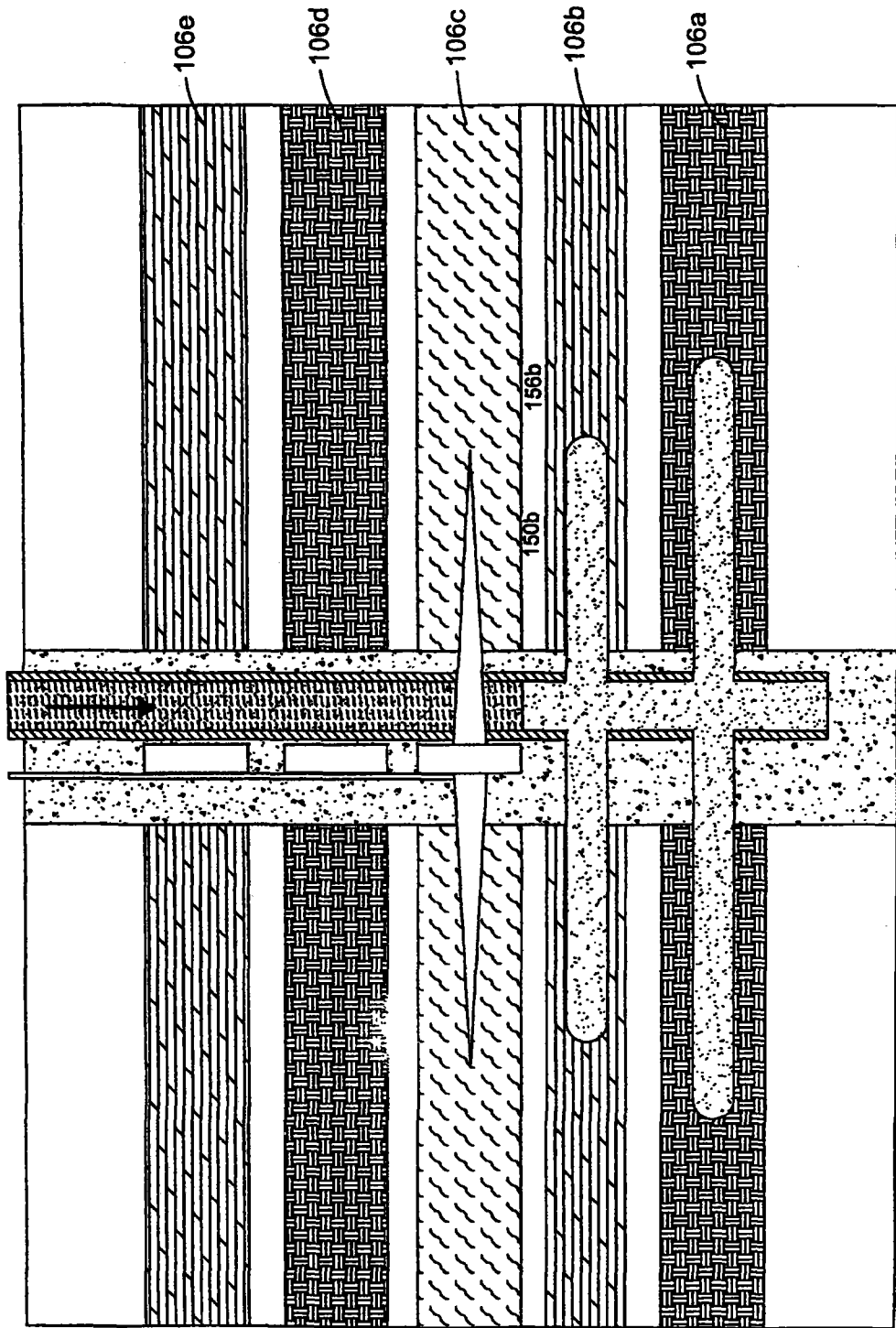


Fig. 10f

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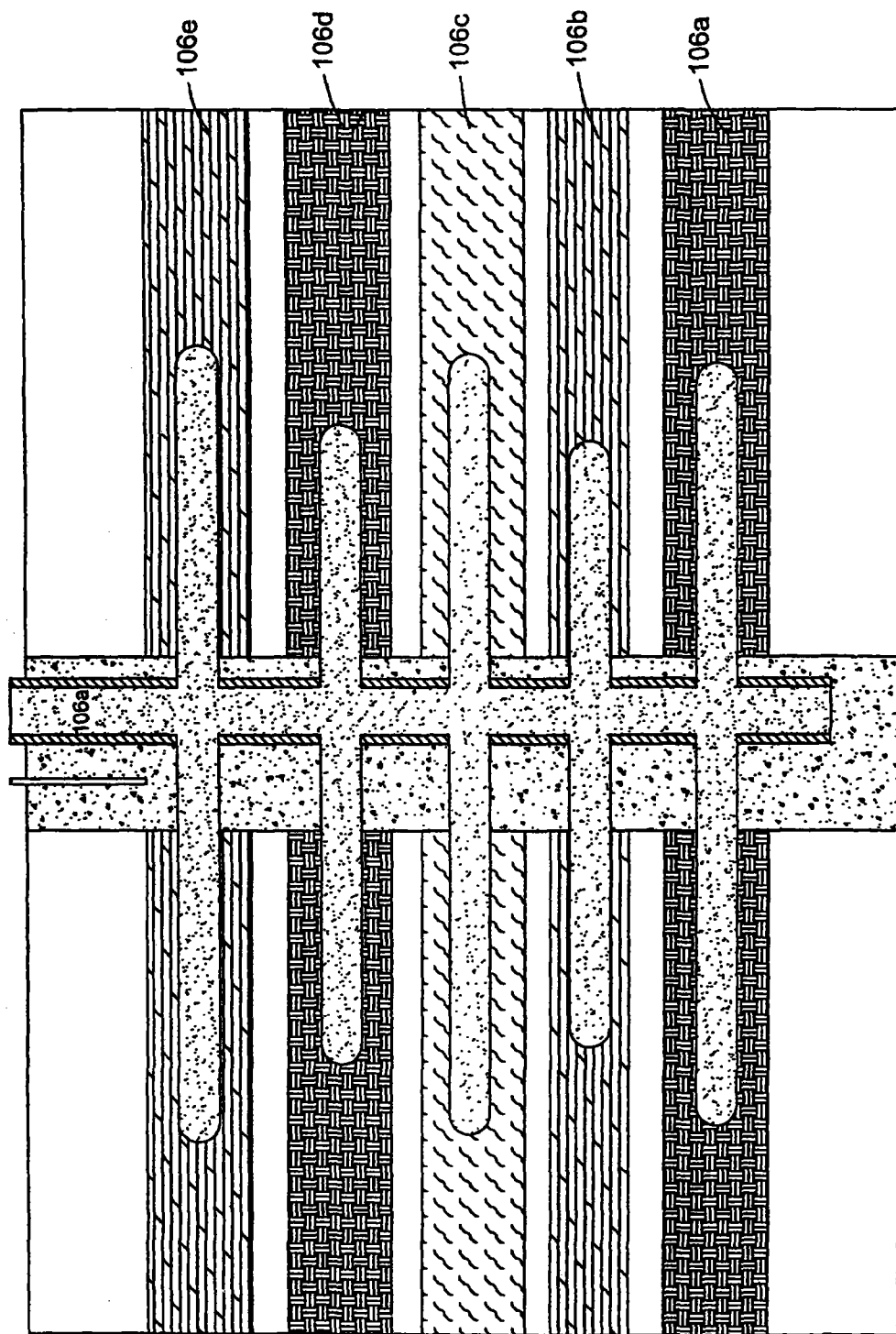


Fig. 10g

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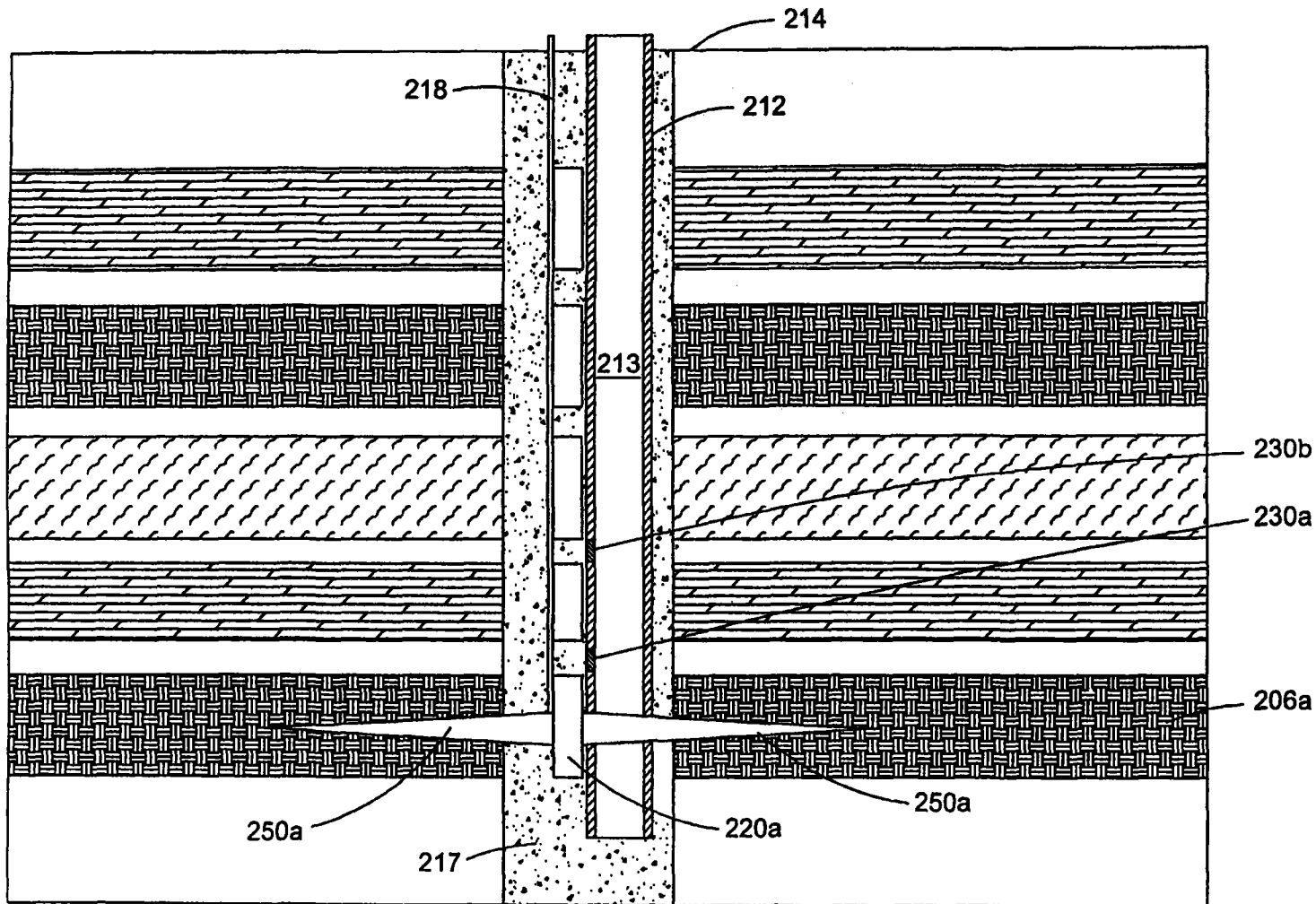


Fig. 11a

168

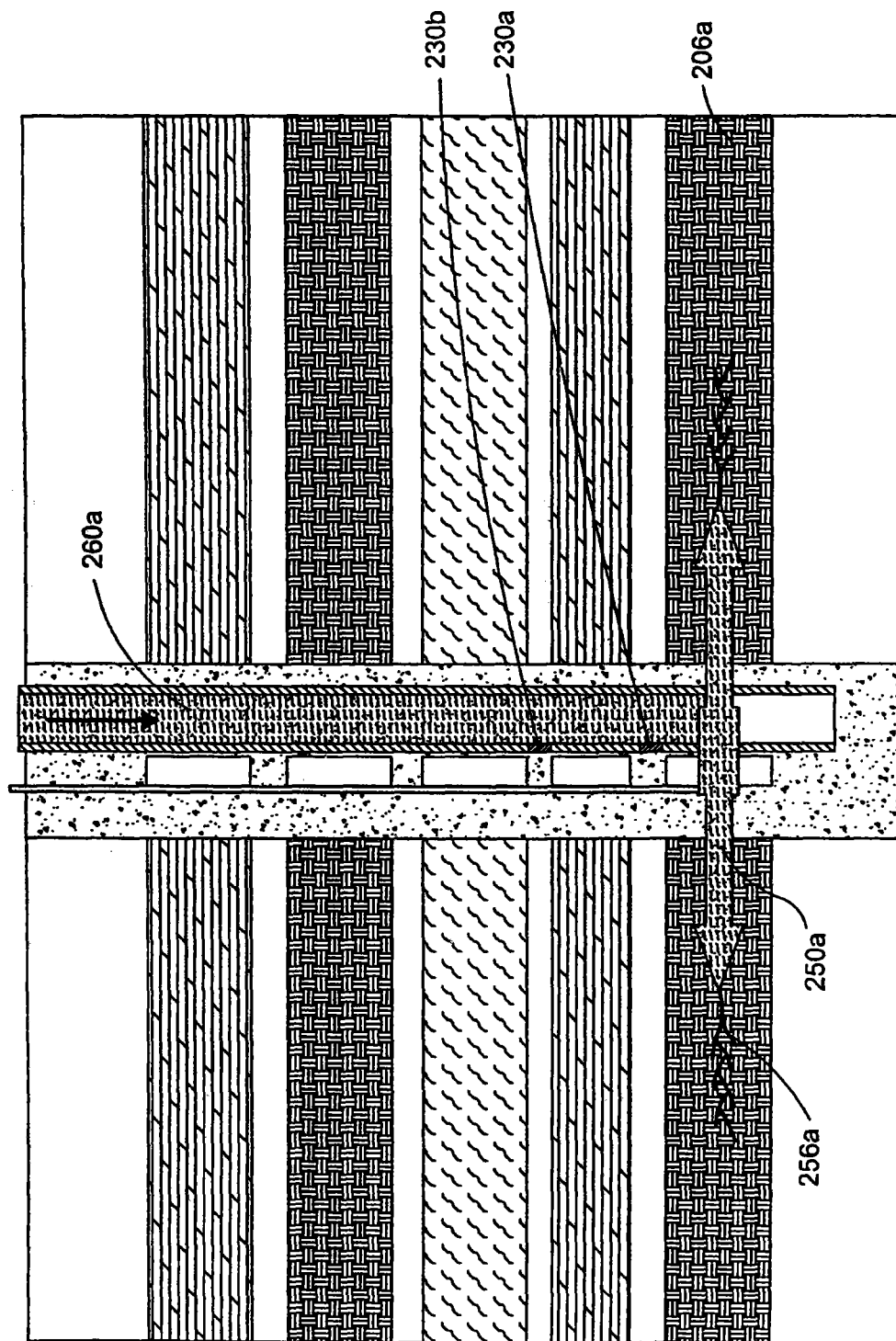


Fig. 11b

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169

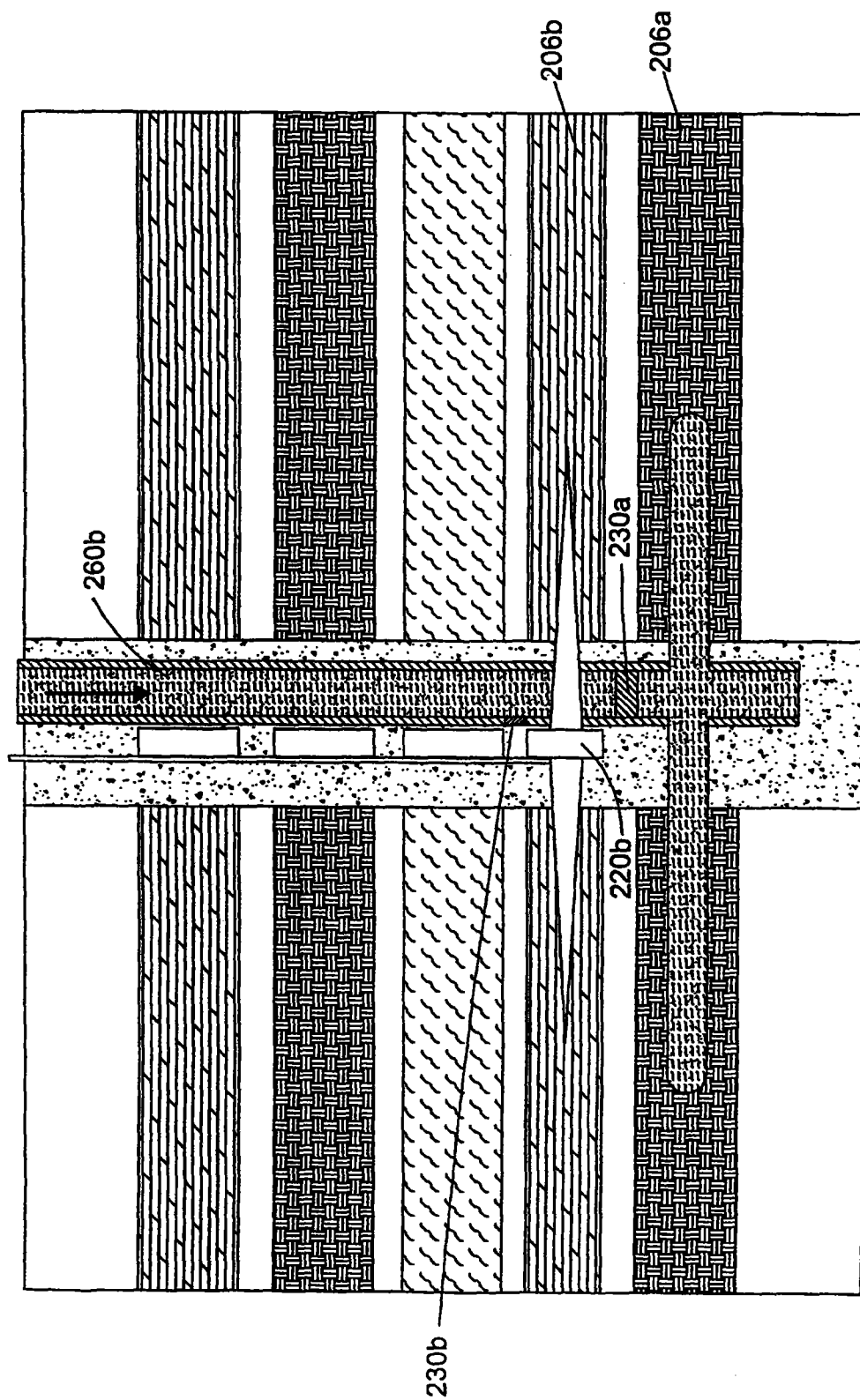


Fig. 11c

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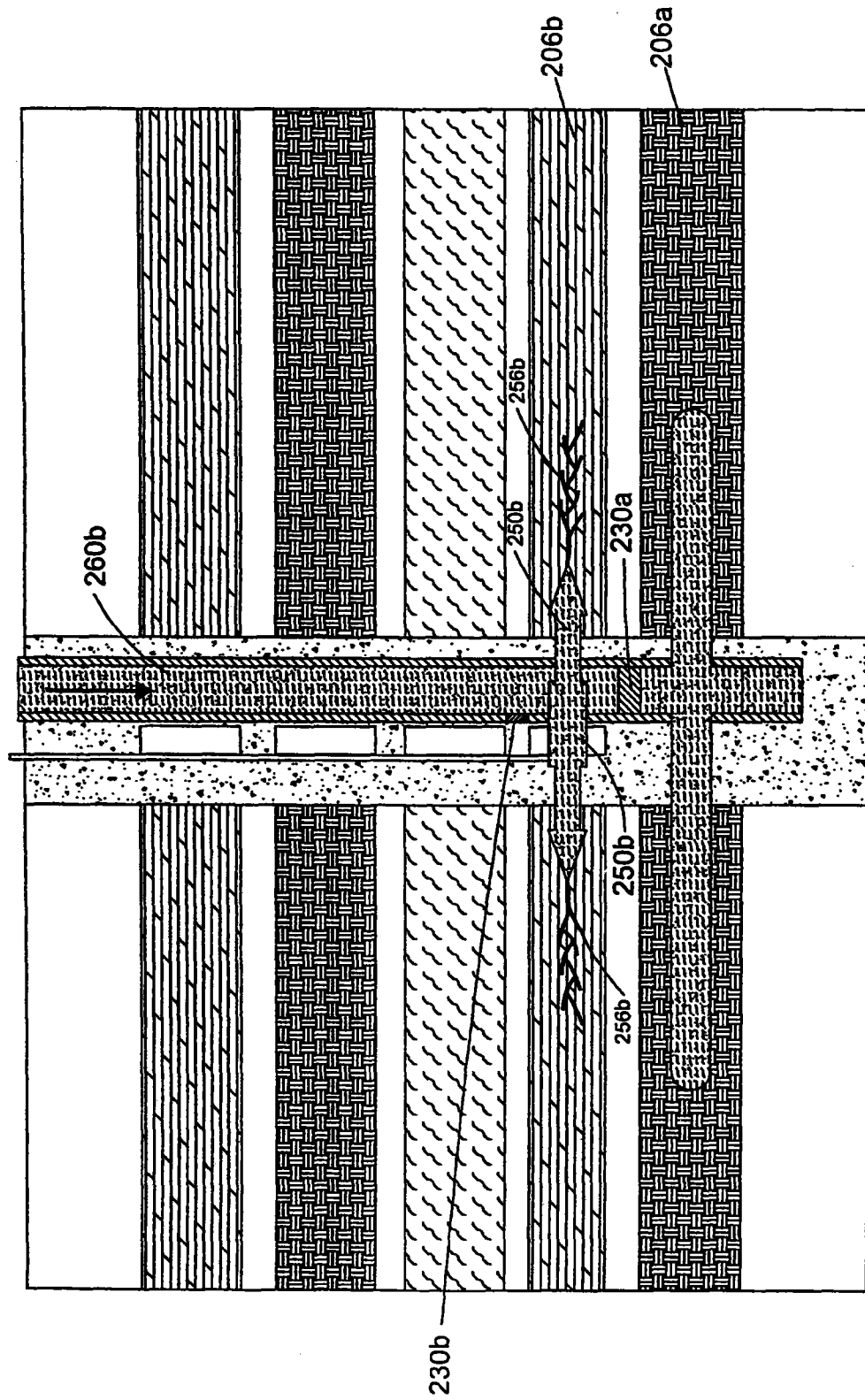


Fig. 11d

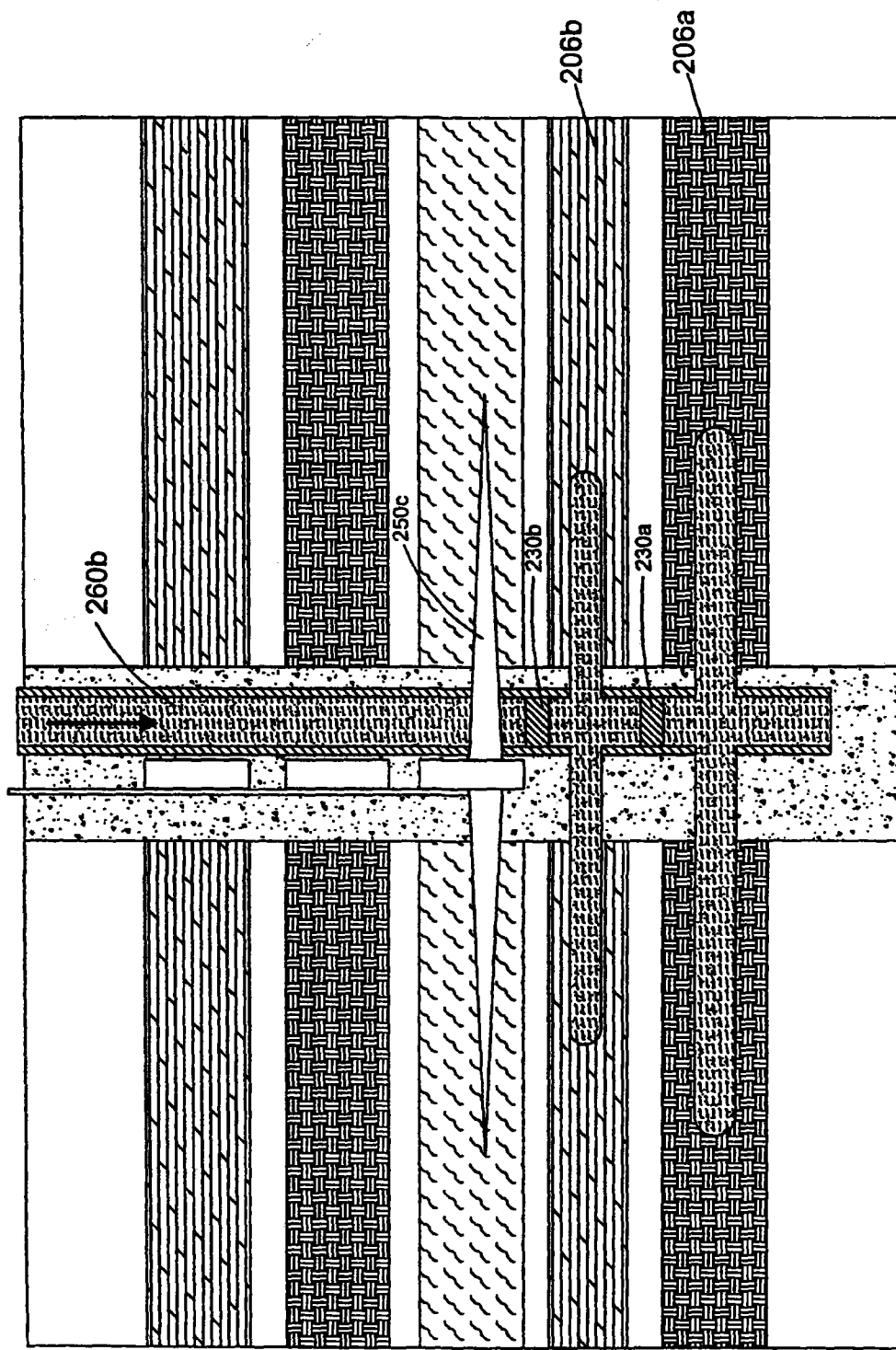


Fig. 11e

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173

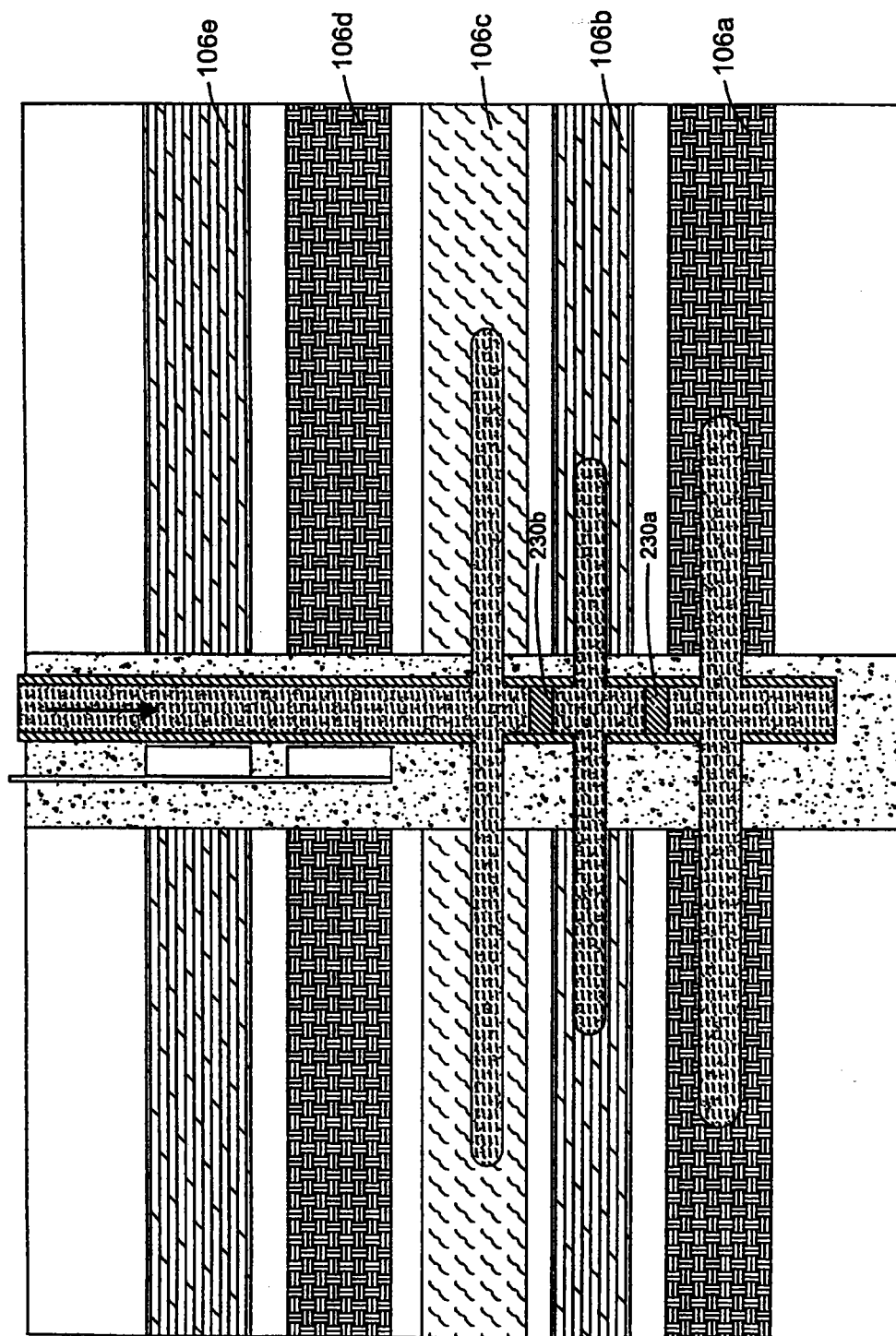


Fig. 11f

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175  
173

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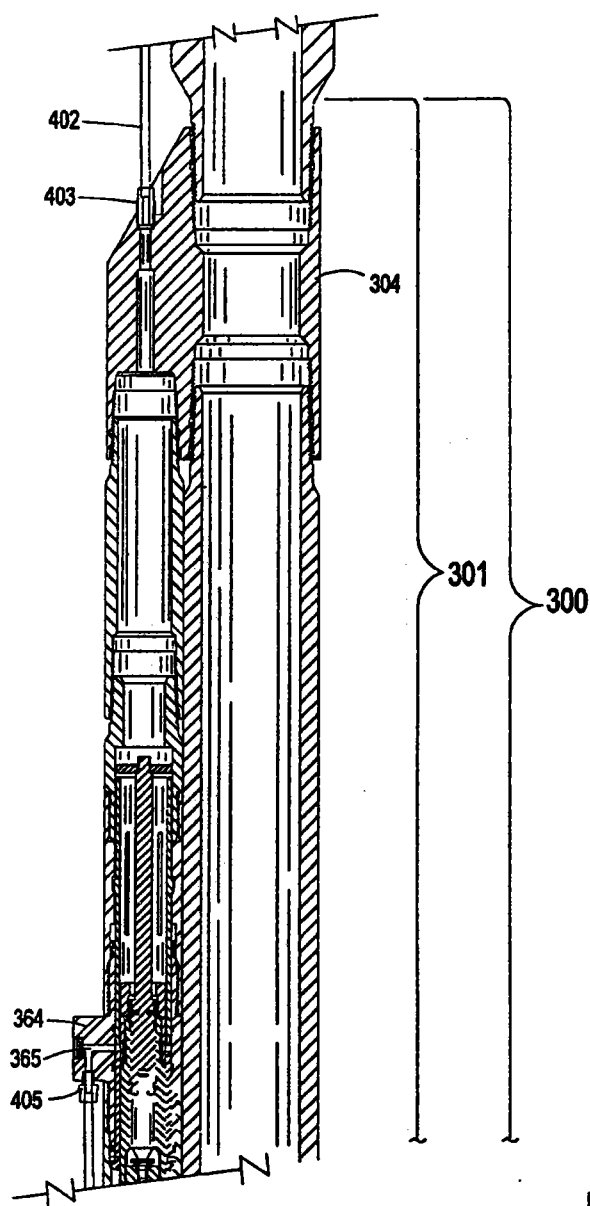


Fig. 12 a

Fig. 12b

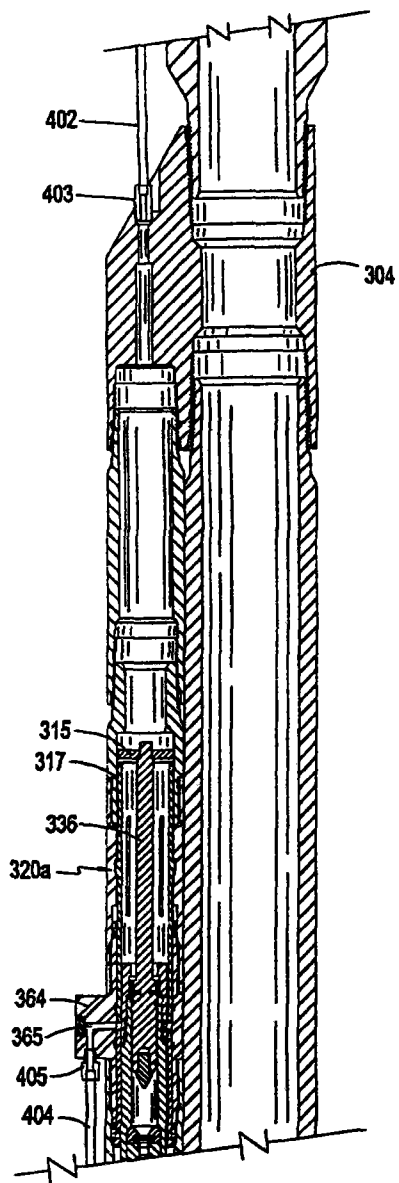
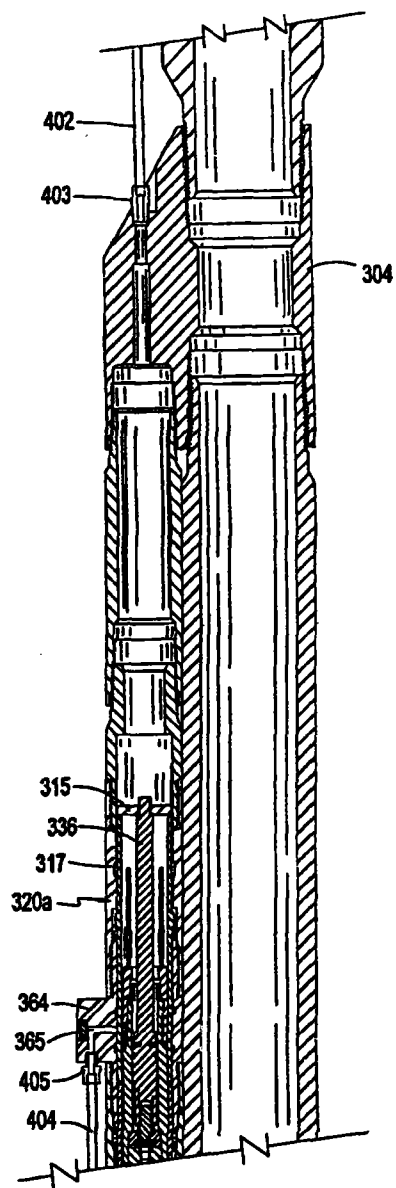
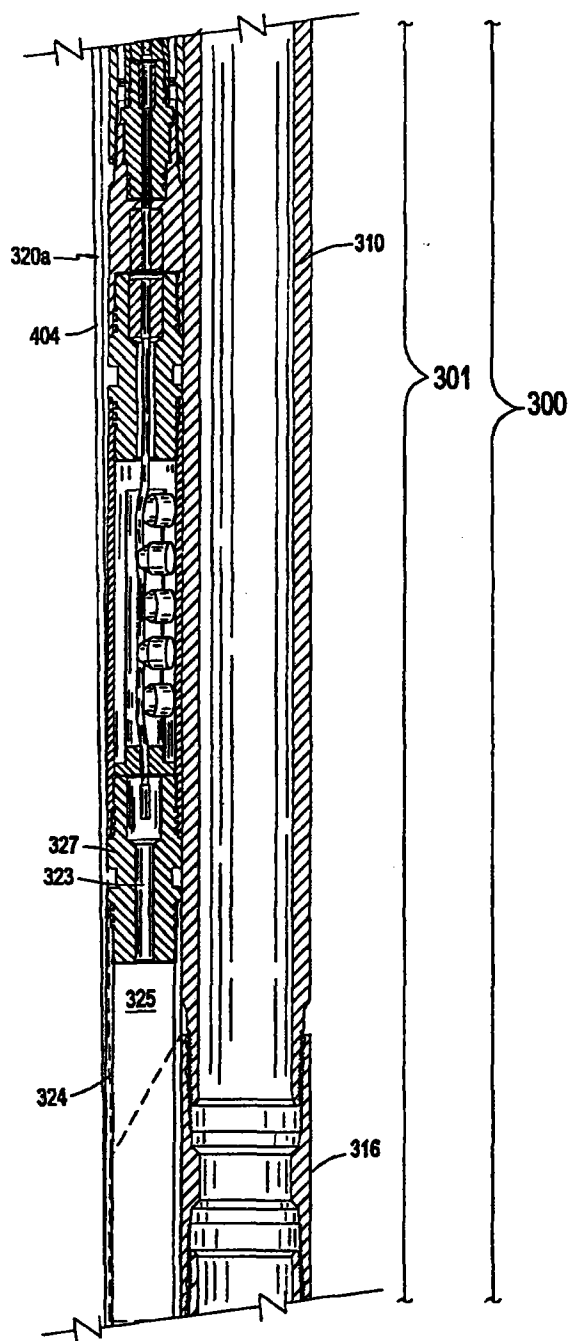


Fig. 12c

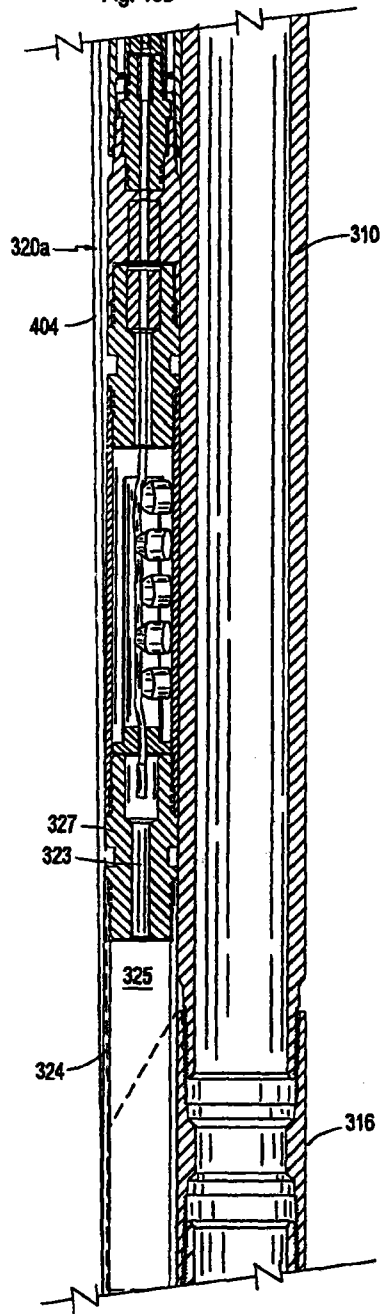


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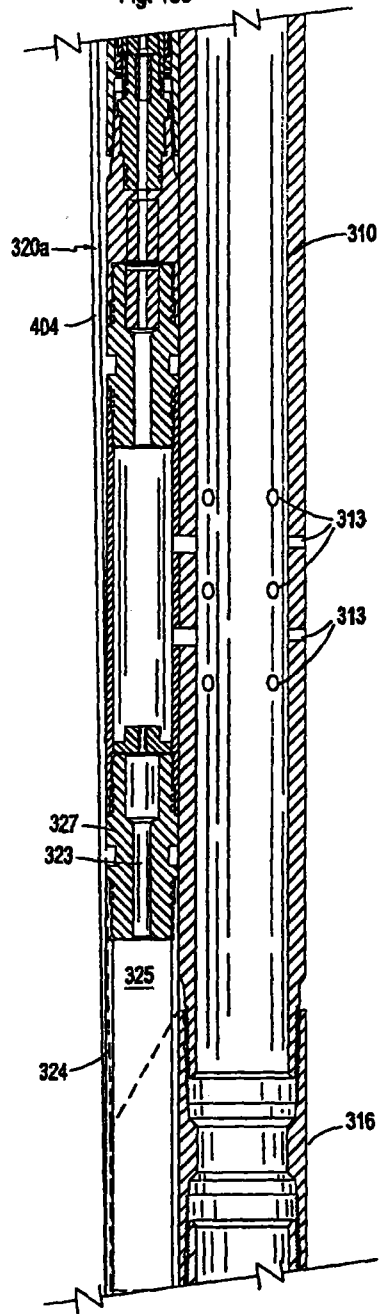


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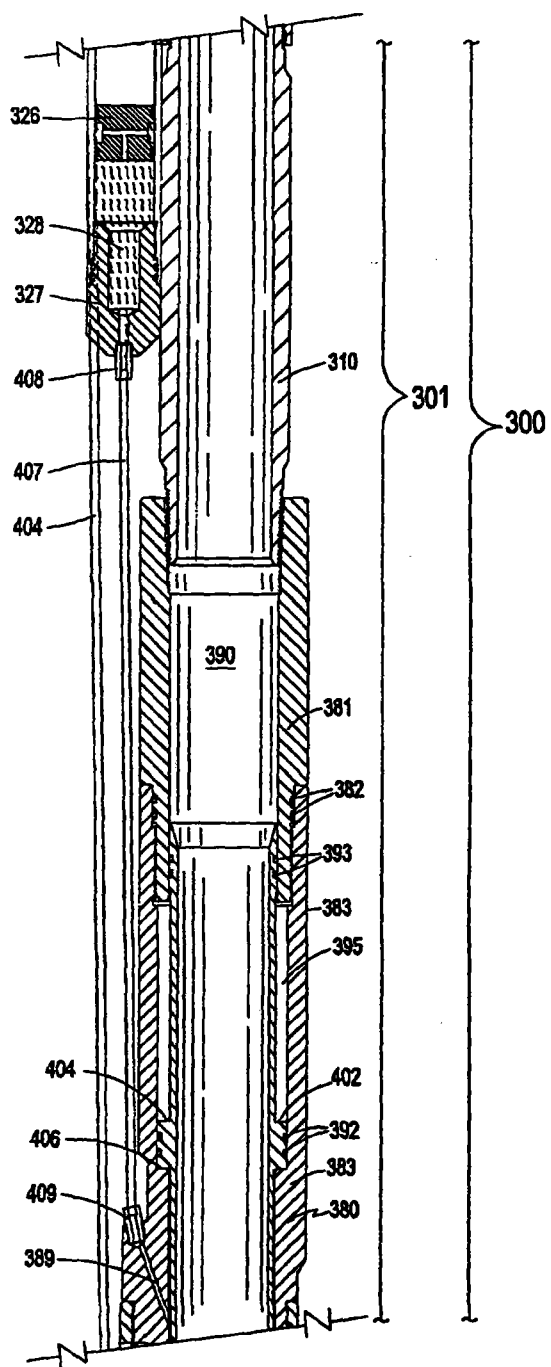
**Fig. 13b**



**Fig. 13c**



179  
122



180  
178

662210" 95000260

Fig. 14b

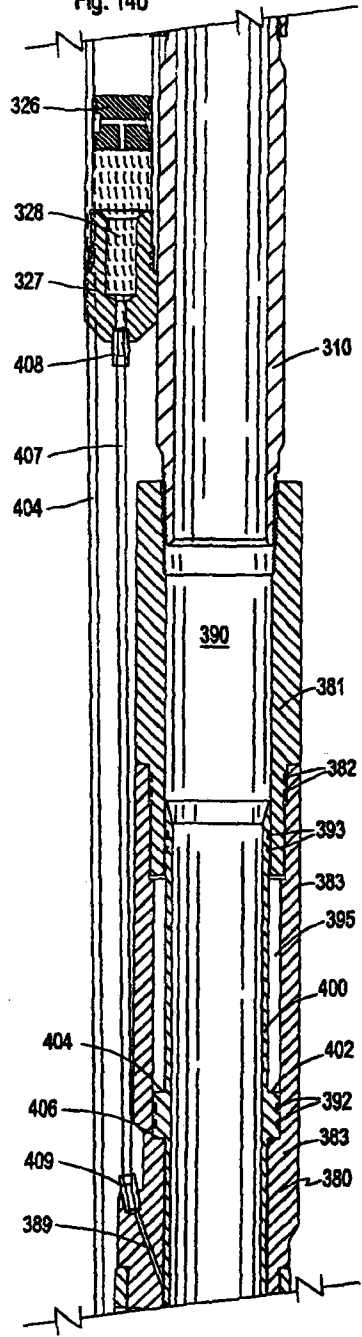
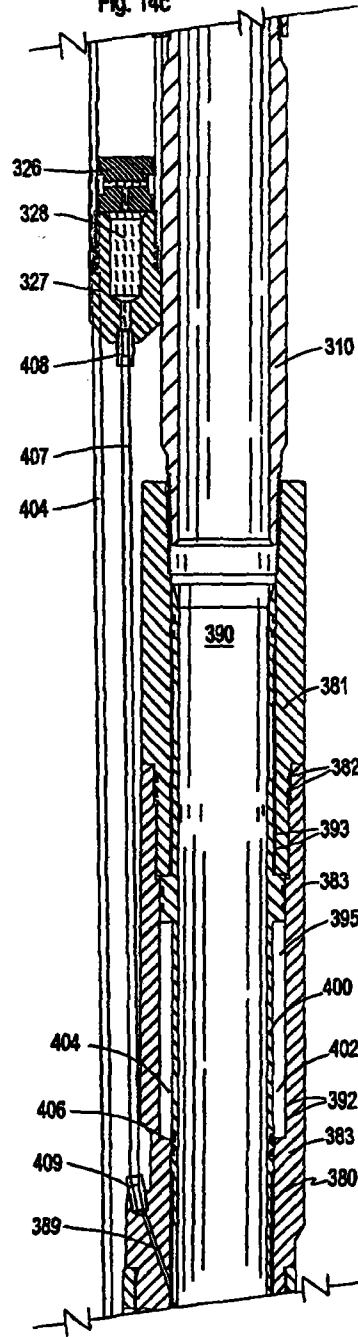


Fig. 14c



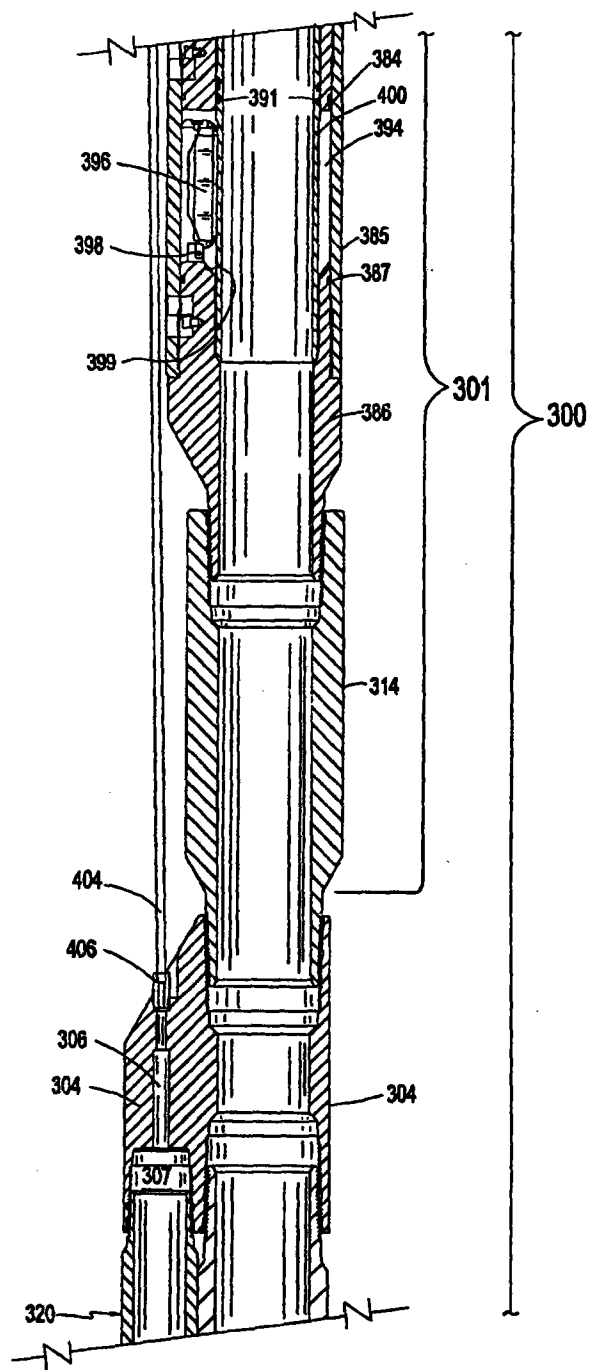
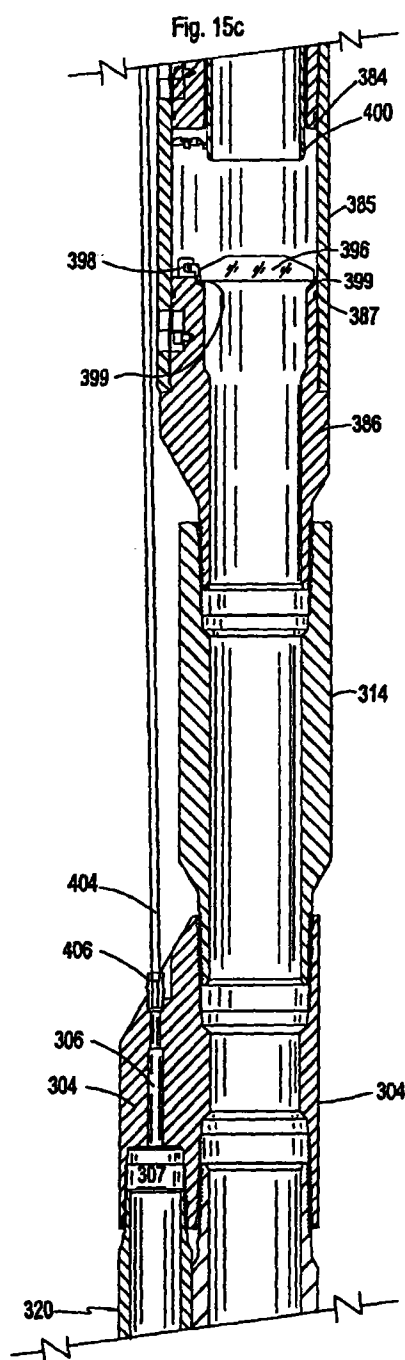
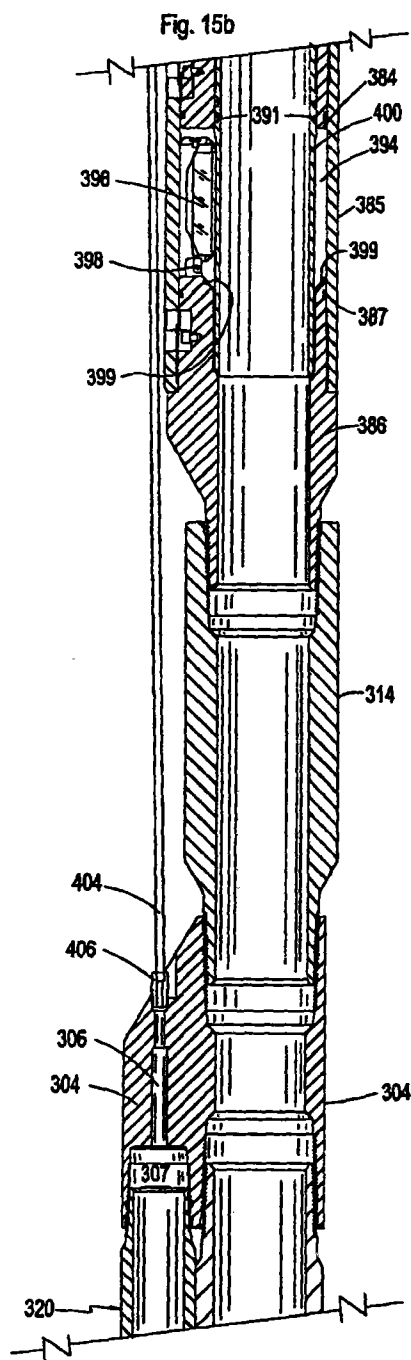


Fig. 15 a

87  
180



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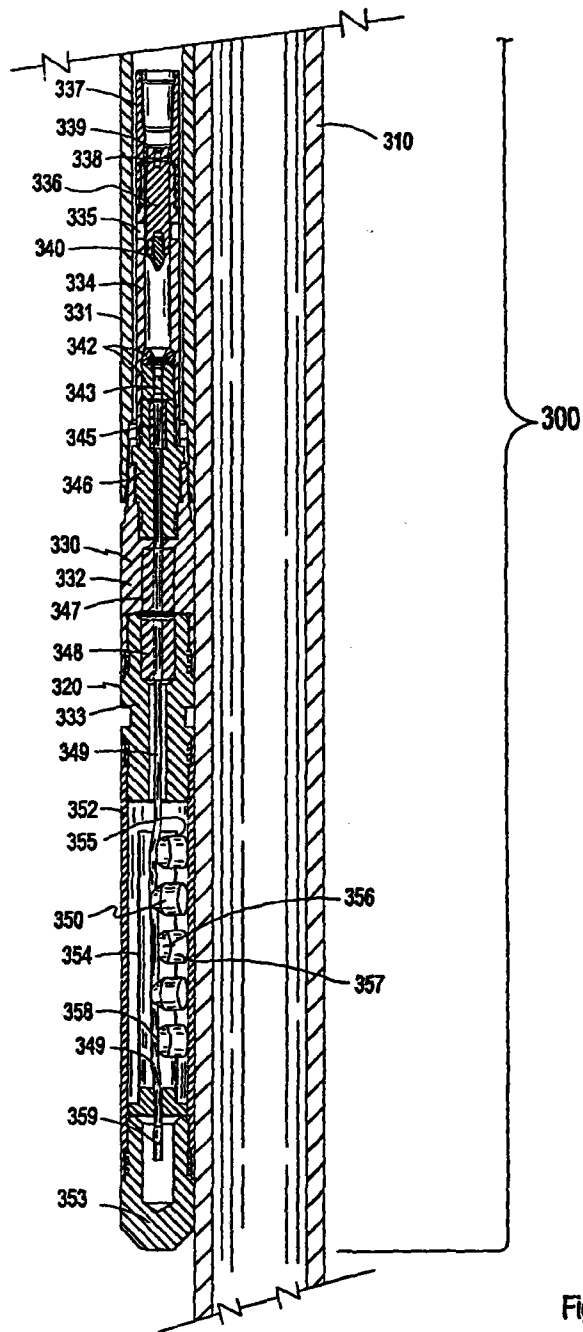
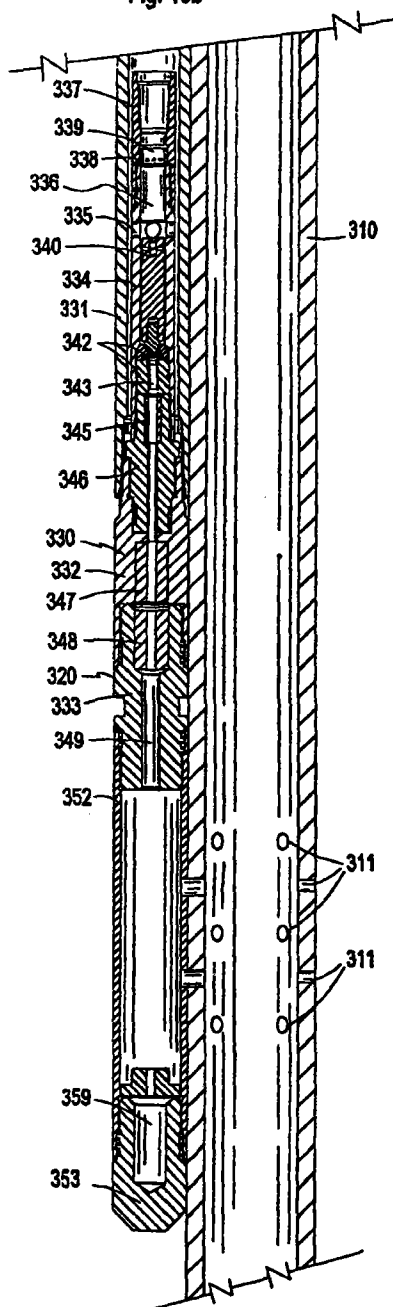


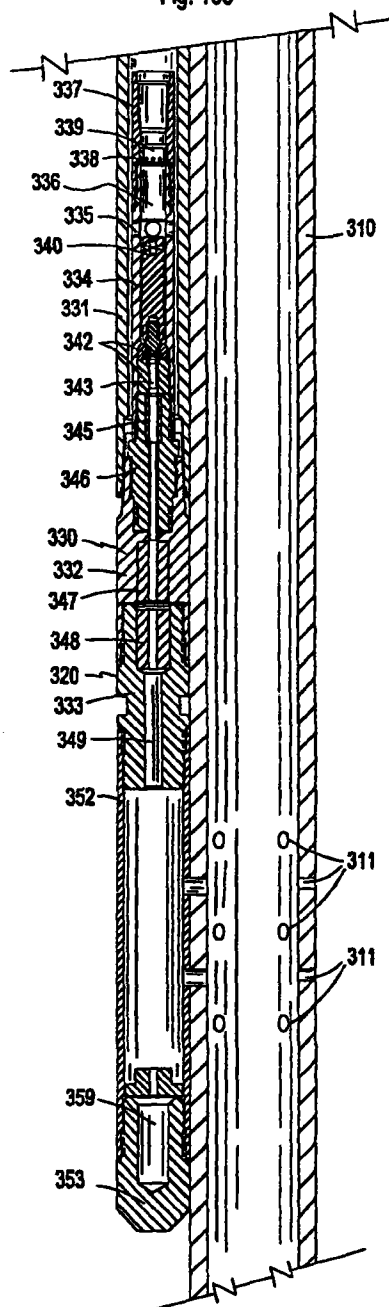
Fig. 16 a

184  
102

**Fig. 16b**



**Fig. 16c**



183

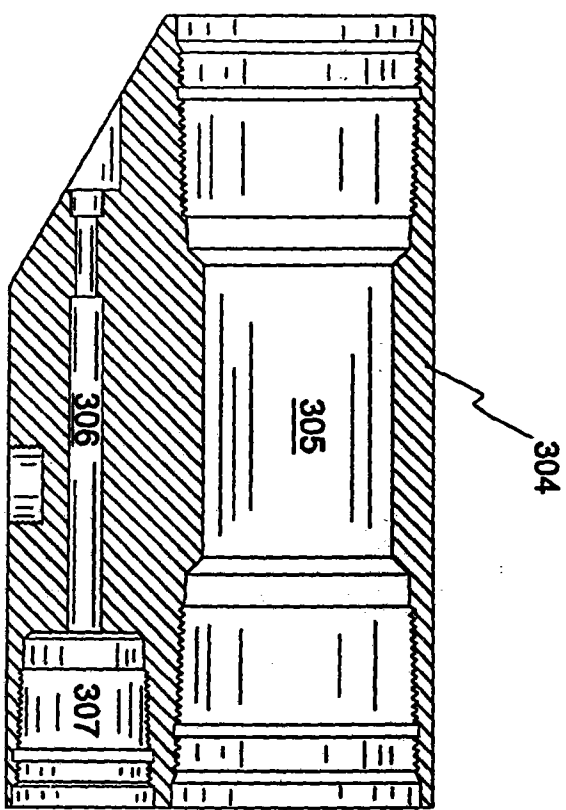


Fig. 17

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186  
184

662210 95000660

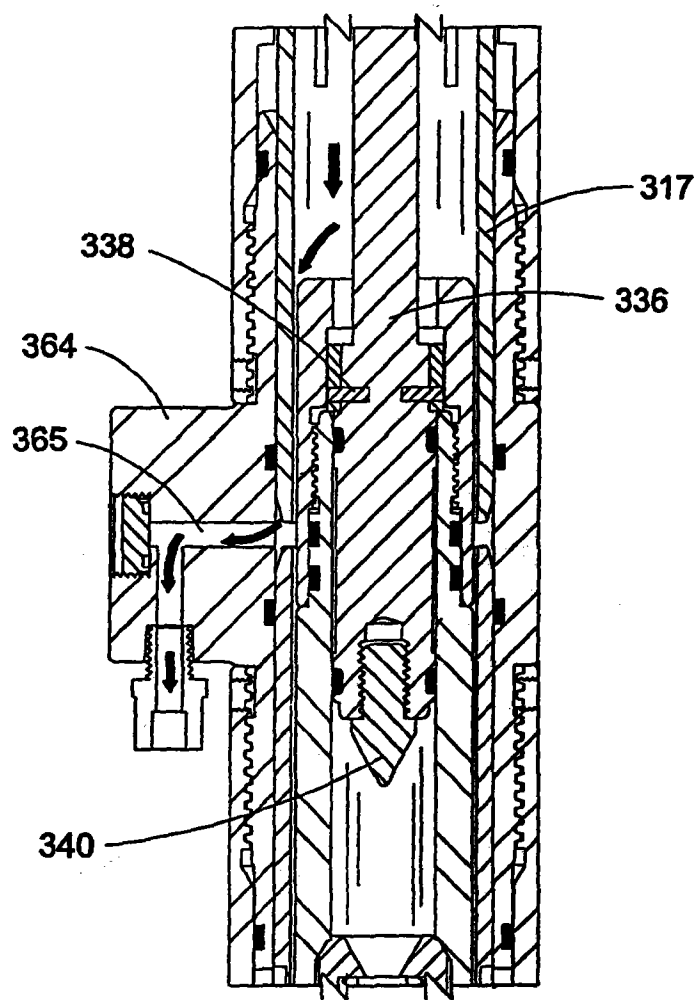
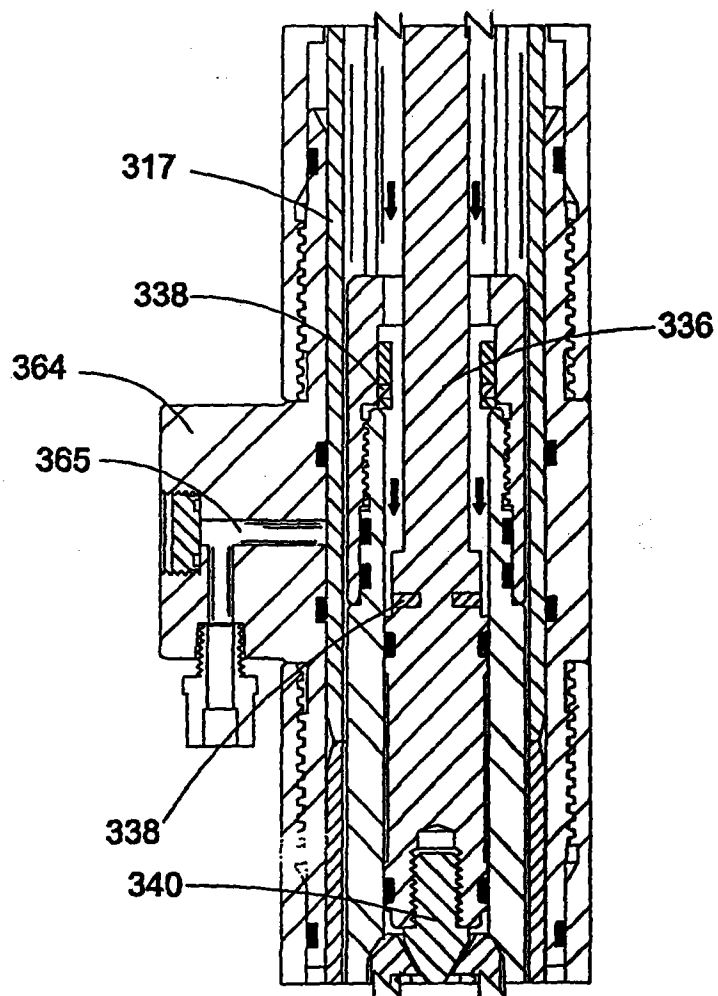


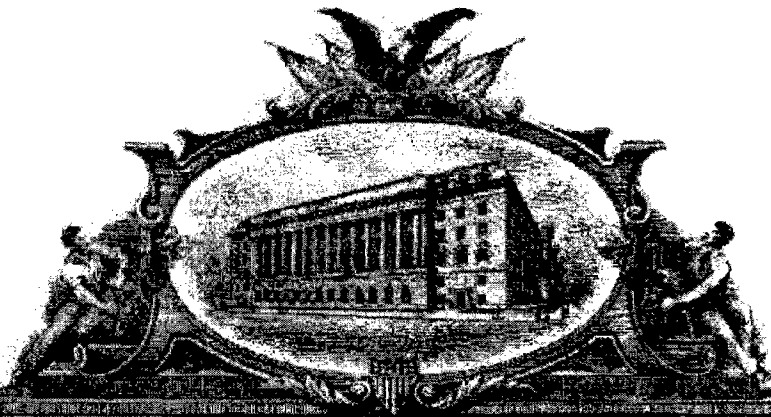
Fig. 18

187  
185



**Fig. 19**

189  
186



# LOS ESTADOS UNIDOS DE AMERICA

**A TODOS AQUELLOS A QUIENES LA PRESENTE CONCIERNE:  
DEPARTAMENTO DE COMERCIO DE LOS ESTADOS UNIDOS**

**Oficina de Patentes y Marcas de los Estados Unidos**

**16 de febrero de 2000**

**LA PRESENTE ES PARA CERTIFICAR QUE LA ANEXA A ESTA ES UNA COPIA FIEL  
DE LOS REGISTROS DE LA OFICINA DE PATENTES Y MARCAS DE LOS ESTADOS  
UNIDOS DE LOS DOCUMENTOS DE LA SOLICITUD DE PATENTE IDENTIFICADA MAS  
ADELANTE QUE SATISFACEN LOS REQUISITOS PARA QUE SE OTORGUE UNA FECHA  
DE PRIORIDAD BAJO 35 USC 111..**

**SOLICITUD NUMERO:**        *09/300,056*

**FECHA DE PRESENTACION:**    *27 de abril de 1999*



**Por la Autoridad del  
COMISIONADO DE PATENTES Y MARCAS**

**Firmado por  
T. WALLACE**

**Funcionario Certificador**

## REIVINDICACIONES

1. Un proceso para establecer comunicación fluida que comprende:

posicionar al menos una carga explosiva en un túnel de pozo subterráneo de manera tal que dicha al menos una carga explosiva se coloca externamente a la carcaza que también se encuentra dentro de dicho túnel de pozo y apunta hacia dicha carcaza; y

detonar dicha al menos una carga explosiva de manera que perfora la pared de dicha carcaza al menos una vez.

2. El proceso de la reivindicación 1 en donde dicha carga explosiva perfora la pared de dicha carcaza dos veces.

3. El proceso de la reivindicación 1 que comprende adicionalmente:

cementar dicha al menos una carga explosiva y dicha carcaza en dicho túnel de pozo antes del paso de detonación.

4. El proceso de la reivindicación 1 en donde dicha al menos una carga explosiva es colocada en dicho túnel de pozo subterráneo sustancialmente de forma simultánea con dicha carcaza.

5. Un proceso para completar un túnel de pozo subterráneo que comprende:

penetrar la pared de una carcaza la cual está posicionada y cementada dentro de un túnel de pozo subterráneo, desde el exterior de la carcaza hacia el interior.

6. Un proceso para completar un túnel de pozo subterráneo que comprende:

posicionar al menos una carga explosiva en un túnel de pozo subterráneo externamente a la carcaza; y

detonar dicha al menos una carga explosiva de manera que perfora dicha carcaza.

7. El proceso de la reivindicación 6 que además comprende:

posicionar dicha al menos una carga explosiva adyacente a una formación subterránea, el paso de detonar dicha al menos una carga explosiva también perfora dicha formación subterránea.

8. El proceso de la reivindicación 7 que además comprende:

inyectar fluido a través de la carcaza y dentro de dicha formación subterránea.

9. El proceso de la reivindicación 7 que además comprende:

producir fluido a partir de dicha formación subterránea dentro de la carcaza.

10. El proceso de la reivindicación 6 que además comprende:

cementar dicha al menos una carga explosiva y dicha carcaza en dicho túnel de pozo subterráneo antes de la etapa de detonación.

11. El proceso de la reivindicación 10 que además comprende:

posicionar dicha al menos una carga explosiva adyacente a una formación subterránea, el paso de detonar dicha al menos una carga explosiva también perfora dicho cemento y dicha formación subterránea.

12. El proceso de la reivindicación 11 que además comprende:

inyectar fluido a través de la carcaza y dentro de dicha formación subterránea.

13. El proceso de la reivindicación 11 que además comprende:

producir fluido a partir de dicha formación subterránea dentro de la carcaza.

14. El proceso de la reivindicación 6 que además comprende:

posicionar al menos una herramienta en dicho túnel de pozo subterráneo por fuera de dicha carcaza para monitorear las condiciones de dicho túnel de pozo o de una formación subterránea, en donde dicha herramienta es una herramienta de registro, un medidor de temperatura o un medidor de presión.

15. El proceso de la reivindicación 14 que además comprende:

cementar dicha al menos una herramienta, dicha al menos una carga explosiva y dicha carcaza en dicho túnel de pozo subterráneo antes de la etapa de detonación.

16. El proceso de la reivindicación 6 que además comprende:

posicionar al menos dos cargas explosivas en un túnel de pozo subterráneo por fuera de la carcaza, en donde una de dichas dos cargas explosivas está colocada adyacente a una primera formación subterránea mientras que la otra de dichas al menos dos cargas explosivas está colocada adyacente a una segunda formación subterránea;

detonar la primera de dichas dos cargas explosivas de manera que se perfore dicha carcaza y dicha primera formación subterránea; y

detonar la otra de dichas dos cargas explosivas de manera que se perfore dicha carcaza y dicha segunda formación subterránea.

17. El proceso de la reivindicación 16 que además comprende:

cementar dichas al menos dos cargas explosivas y dicha carcaza en dicho túnel de pozo

subterráneo antes de las etapas de detonación.

18. El proceso de la reivindicación 16 en donde dichas etapas de detonación ocurren sustancialmente de manera simultánea.

19. El proceso de la reivindicación 16 en donde dicha etapa de detonar dicha primera de dichas al menos dos cargas explosivas ocurre antes que dicha etapa de detonar dicha otra de dichas al menos dos cargas explosivas.

20. El proceso de la reivindicación 16 que además comprende:

producir fluido a partir de dicha primera formación subterránea dentro de dicha carcaza después de detonar dicha primera de dichas al menos dos cargas explosivas.

21. El proceso de la reivindicación 16 que además comprende:

producir fluido a partir de dicha segunda formación subterránea dentro de dicha carcaza después de detonar dicha otra de dichas al menos dos cargas explosivas.

22. El proceso de la reivindicación 19 que además comprende:

inyectar fluido a través de la carcaza y dentro de dicha primera formación subterránea después de detonar dicha primera de dichas al menos dos cargas explosivas y antes de la etapa de detonar dicha otra de dichas al menos dos cargas explosivas de manera que se trate y/o fracture dicha primera formación subterránea.

23. El proceso de la reivindicación 19 que además comprende:

sellar el interior de dicha carcaza al flujo de fluido entre dichas primera y segunda formaciones subterráneas; e

inyectar fluido a través de la carcaza y dentro de dicha segunda formación subterránea después de detonar dicha otra de dichas al menos dos cargas explosivas de manera que se trate y/o fracture dicha segunda formación subterránea.

24. El proceso de la reivindicación 6 que además comprende:

colocar fluido dentro de dicho túnel de pozo subterráneo antes de detonar dicha al menos una carga explosiva.

25. El proceso de la reivindicación 24 en donde dicho fluido comprende un ácido.

26. El proceso de la reivindicación 6 que además comprende:

encender material propulsante al detonar dicha al menos una carga explosiva.

27. El proceso de la reivindicación 6 que además comprende:

posicionar una línea de control en dicho túnel de pozo subterráneo por fuera de dicha carcaza la cual está conectada a dicha al menos una carga explosiva.

28. Un proceso para proporcionar comunicación fluida a través de una pared de una carcaza que comprende:

detonar un primer ensamble de pistola perforadora el cual está posicionado por fuera de una carcaza en un túnel de pozo subterráneo perforando así dicha carcaza.

29. El proceso de la reivindicación 28 que además comprende:

cementar dicha carcaza dentro de dicho túnel de pozo subterráneo.

30. Un proceso para completar una o más formaciones subterráneas que comprende:

detonar un primer ensamble de pistola perforadora el cual está posicionado por fuera de una carcaza en un túnel de pozo subterráneo perforando así dicha carcaza y una primera formación subterránea.

31. El proceso de la reivindicación 30 que además comprende:

inyectar uno o más fluidos de estimulación y/o de tratamiento a través de dicha carcaza dentro de dicha primera formación subterránea.

32. El proceso de la reivindicación 31 en donde dicho al menos uno de dichos al menos uno o más fluidos de estimulación y/o de tratamiento se inyecta bajo presión suficiente para fracturar dicha primera formación subterránea.

33. El proceso de la reivindicación 30 que además comprende:

detonar un segundo ensamble de pistola perforadora el cual está posicionado por fuera de una carcaza en un túnel de pozo subterráneo perforando así dicha carcaza y una segunda formación subterránea.

34. El proceso de la reivindicación 33 que además comprende:

inyectar uno o más fluidos de estimulación y/o de tratamiento a través de dicha carcaza dentro de dicha segunda formación subterránea.

35. El proceso de la reivindicación 34 que además comprende:

aislar dicha primera formación subterránea de la inyección de fluidos antes de inyectar dichos uno o más fluidos de estimulación y/o de tratamiento a través de dicha carcaza dentro de

dicha segunda formación.

36. El proceso de la reivindicación 35 en donde dicho al menos uno de dichos al menos uno o más fluidos de estimulación y/o de tratamiento se inyecta bajo presión suficiente para fracturar dicha segunda formación subterránea.

37. El proceso de la reivindicación 35 que además comprende:

reversar la etapa de aislar dicha primera formación subterránea de la inyección de fluidos después de inyectar dichos uno o más fluidos de estimulación y/o de tratamiento a través de dicha carcaza dentro de dicha segunda formación.

38. Un proceso para completar un pozo subterráneo que comprende:

penetrar una carcaza la cual está posicionada en un túnel de pozo subterráneo mientras que el interior de dicha carcaza permanece desocupada de pistolas perforadoras u otros equipos, herramientas, tubos o líneas.

39. Un sistema de completamiento subterráneo que comprende:

una carcaza la cual está al menos parcialmente posicionada dentro de un túnel de pozo subterráneo; y

al menos un ensamble de pistola perforadora el cual está posicionado por fuera de dicha carcaza y dentro de dicho túnel de pozo, en donde dicho ensamble de pistola perforadora tiene al menos una carga explosiva mirando en la dirección de dicha carcaza.

40. El sistema de completamiento subterráneo de la reivindicación 39 en donde dicho al menos un ensamble de pistola perforadora y dicha carcaza están conectados.

41. El sistema de completamiento subterráneo de la reivindicación 39 que además comprende:

una herramienta de registro, un medidor de temperatura y/o un medidor de presión el cual se encuentra por fuera de dicha carcaza y dentro de dicho túnel de pozo subterráneo.

42. El sistema de completamiento subterráneo de la reivindicación 39 que además comprende:

un dispositivo de señalización para transmitir señales desde la superficie de la tierra hacia dicha pistola de perforación, donde dicho dispositivo de señalización está posicionado por fuera de dicha carcaza.

43. Un sistema de completamiento que comprende:

una carcaza; y

al menos una pistola perforadora conectada al exterior de dicha carcaza y que tiene al menos una carga explosiva mirando en la dirección de dicha carcaza.

44. El sistema de completamiento de la reivindicación 43 que además comprende:

al menos dos pistolas perforadoras conectadas al exterior de dicha carcaza, donde cada una de dichas al menos dos pistolas perforadoras tienen al menos una carga explosiva mirando en la dirección de dicha carcaza.

45. El sistema de completamiento de la reivindicación 44 que además comprende:

un dispositivo de zona de aislamiento posicionado entre dichas al menos dos pistolas perforadoras para cortar selectivamente el flujo a través de dicha carcaza.

46. El sistema de completamiento de la reivindicación 45 en donde dicho dispositivo de zona de aislamiento es una válvula de aletas.

47. El sistema de completamiento de la reivindicación 46 en donde dicha válvula de aletas está

construida de un material destructible.

48. El sistema de completamiento de la reivindicación 43 que además comprende:

un ensamble para proporcionar señales a dicha al menos una pistola perforadora el cual está conectado a dicha pistola perforadora y está posicionado por fuera de dicha carcasa.

49. El sistema de completamiento de la reivindicación 48 en donde dicho ensamble está hidráulicamente conectado a dicha pistola perforadora.

50. El sistema de completamiento de la reivindicación 48 en donde dicho ensamble está eléctricamente conectado a dicha pistola perforadora.

51. El sistema de completamiento de la reivindicación 48 en donde dicho ensamble está conectado a dicha pistola perforadora por transmisión de ondas.

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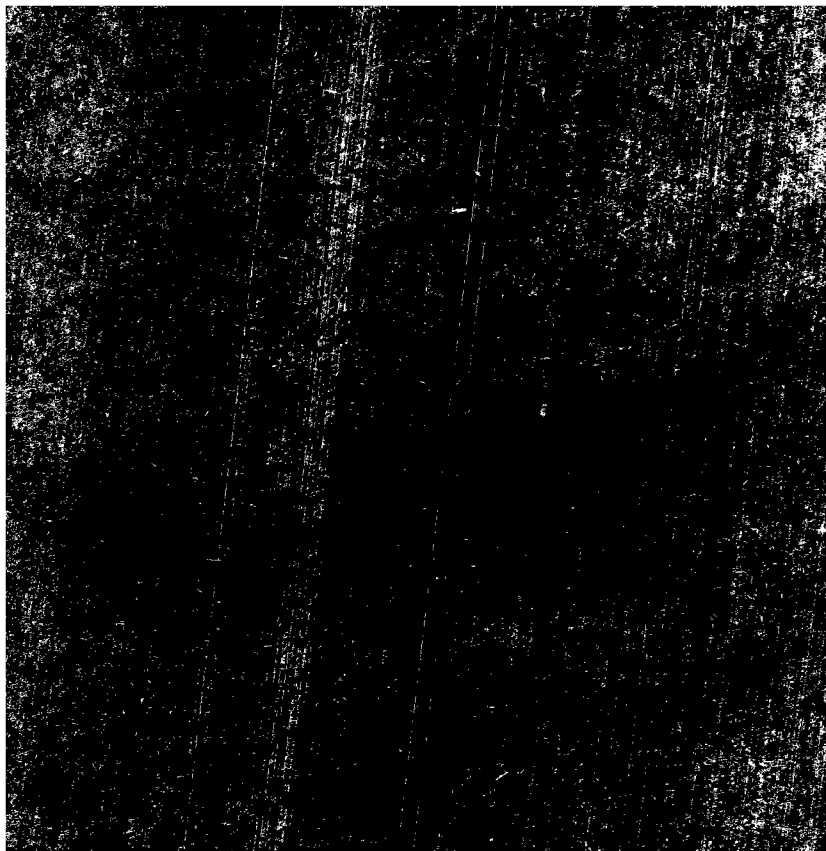
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| 2             | DVD                        |             |
| 3             | REVISTA                    |             |
| 4             | LIBRO                      |             |
| 5             | PERIODICO                  |             |
| 6             | DISQUETES                  |             |
| 7             | SOBRE DE MANILA X          |             |
| 8             | SOBRE BLANCO TAMAÑO CARTA  |             |
| 9             | SOBRE BLANCO TAMAÑO OFICIO |             |
| 10            | OTROS:                     |             |

Observaciones: Arte Final

196



2do. EXAMEN DE FORMA PATENTE DE INVENCION

Folio 200

Radicación no 00-30399

Concepto Técnico no 1459

Clasificación Internacional de Patentes E21B 29/02; 43/263

Practicado el examen de acuerdo a lo establecido en el Art. 38 de la Decisión 486 se determinó que esta solicitud de **Patente de Invención**:

- SI [☒] NO [ ] Contiene un resumen de la invención (Art.26-e).
- SI [☒] NO [ ] Contiene el título o nombre de la invención (Art.27-d).
- SI [☒] NO [ ] Contiene la descripción de la invención (Art.26-b).
- SI [☒] NO [ ] NO ES APLICABLE [ ] Contiene los dibujos necesarios para comprender la invención (Art.26-d)
- SI [☒] NO [ ] Contiene una o más reivindicaciones. (Art.26-c).
- SI [ ] NO [ ] NO ES APLICABLE [☒] Han sido desarrollados los productos y/o procedimientos a partir de recursos genéticos o de sus productos derivados de los que cualquiera de los Países Miembros es país de origen. (Art. 26- h).
- SI [ ] NO [ ] NO ES APLICABLE [☒] Los productos y/o procedimientos han sido obtenidos o desarrollados a partir de los conocimientos tradicionales de las comunidades indígenas, afroamericanas, o locales de los países miembros, de acuerdo a lo establecido en la Decisión 391 y sus modificaciones y reglamentaciones vigentes.(Art.26-i).
- SI [ ] NO [☒] La invención se refiere a un producto relativo a un material biológico. (Art.26-J).
- SI [☒] NO [ ] La prioridad coincide con la materia reivindicada.
- SI [☒] NO [ ] **CUMPLE LOS REQUISITOS TÉCNICOS**

OBSERVACIONES Y OTROS: SI [ ] NO [☒] ver hoja(s) anexa(s)

Nuevas paginas 4, 20, 27, 28, 34, y 36 a 40 del capitulo descriptivo, folios 104 a 113

Nuevas figuras, folios 114 a 119

Arte final 12 cm x 12 cm y 6 cm x 6 cm, folio 199

EXAMINADOR TÉCNICO  
202030

Bogotá D. C., 24-09-2002

2020  
Bogotá DC

Doctor(a)  
EMILIO FERRERO  
Apoderado(a)

|                    |                |          |
|--------------------|----------------|----------|
| <b>REFERENCIA:</b> | Radicación No. | 00-30399 |
|                    | Trámite        | 002      |
|                    | Evento         | 001      |
|                    | Actuación      | 416      |
|                    | Oficio No.     | 1949     |
|                    | Folios         | 001      |

Teniendo en cuenta que la solicitud de privilegio de patente que se tramita bajo el expediente indicado en la referencia, reúne los requisitos de forma establecidos en los artículos 26 y 27 de la Decisión 486 de la Comisión de la Comunidad Andina, y en las demás disposiciones vigentes sobre la materia, se envía el extracto de la solicitud a la Oficina de Comunicaciones para efecto de su publicación en la Gaceta de Propiedad Industrial, conforme lo establece el artículo 40 de la misma Decisión.

**Cúmplase**

Dado en Bogotá DC, a los

30 de mayo de 2002

**ALIX CARMENZA CÉSPEDES DE VERGEL**  
Jefe de la División de Nuevas Creaciones

Bogotá, DC, *Diciembre* El extracto de esta solicitud fue publicado en el número de *524* la Gaceta de Propiedad Industrial, de fecha *31-01-03*. El término hábil señalado por la ley expiró el *30-04-03* y SI ☐ NO ☒ se presentaron oposiciones por parte de terceros.