

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO	
RAD: 14-84477- -2	FECHA: 2015-05-16 23:03:35
DEP: 2020 DIRECCION DE NUEVAS CREACIONES	EVE: 378 FASE NACIONAL INCLUIDO CAPITULO I
TRA: 11 PCT-PATENTE DE INVENCION CAPITULOS I Y II	FOLIOS: 6
ACT: 430 REQUERSOLICITA	

DIRECCIÓN DE NUEVAS CREACIONES

2020
Bogotá, D.C.,

Abogado(a)/Señor(a)
SILVANA MARÍA LÓPEZ DÍAZ

Asunto: Radicación: 14-84477- -2
 Trámite: 11
 Evento: 378
 Actuación: 430
 Oficio: 5204
 Folios: 6

Patente de Invención	X			Patente de Modelo de Utilidad	
Vía Nacional					
Vía PCT (Fase Nacional)	X	Capítulo I	X	Capítulo II	
No. Solicitud Internacional	PCT/US2011/59354				
Fecha de Presentación Internacional	07/11/2011				

Como resultado del examen de fondo realizado, con fundamento en el Artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se comunica:

1. Documentos estudiados

Descripción:	Rad. N° 14-084477-00000-0000	21/Abril/2014
Reivindicaciones:	Rad. N° 14-084477-00000-0000	21/Abril/2014
Dibujos:	Rad. N° 14-084477-00000-0000	21/Abril/2014

2. Objeto de la invención

De acuerdo con lo establecido en el numeral 1.2.2.2 del Capítulo Primero del Título X de la Circular Única para efectos del examen de patentabilidad, se tendrá en cuenta la tasa pagada por el solicitante al momento de comenzar el examen para las reivindicaciones adicionales; esto es que cuando la solicitud contenga más de diez (10) reivindicaciones y no se haya pagado la tasa complementaria, sólo se estudiarán las cubiertas por la tasa pagada. Por lo tanto, se estudiarán las reivindicaciones 1 a 35.

Título de la solicitud: “Discriminación de fluidos para uso con un pozo subterráneo” (Fl. 1).

El problema planteado en esta solicitud consiste en lograr un discriminador y un método para la discriminación de fluidos para uso con un pozo subterráneo, con los que se logre la separación de fluido, control de fluidos producidos, control sobre el origen de fluidos producidos, prevención de daños de formación, entre otros.

Para resolver este problema técnico, la solicitud en estudio propone un sistema y un método de discriminación de fluido para uso con un pozo subterráneo que comprende un discriminador de fluido que selecciona a través de cual múltiples rutas de flujo de salida fluye una composición de fluido.

El objeto de la presente solicitud se relaciona con la Clasificación Internacional de Patentes (CIP): E 21 B 34/06, 43/12.

3. De la solicitud de patente

Reivindicaciones (Art 30 D 486, Art 22 PCT)

El capítulo reivindicatorio no es claro porque:

- En general, las reivindicaciones se centran en exponer funciones, ventajas, efectos o resultados a alcanzar, los cuales son aspectos que no pueden ser objeto de patente. Lo anterior, debido a que el examen de patentabilidad se realiza con base en las características estructurales (tangibles) del producto para el cual se solicita protección.

En el capítulo reivindicatorio, todas las reivindicaciones 1 a 35 comprenden los aspectos mencionados anteriormente, por lo que es difícil identificar las características a ser comparadas con el estado de la técnica. A manera de ejemplo, expresiones como: *“...que selecciona a través de cuál de las múltiples rutas de flujo de salida fluye una composición de fluido (...) la dirección es dependiente de por lo menos un tipo de fluido en la composición de fluido.”* (reivindicación 1), *“...selecciona una primera ruta de flujo de salida en respuesta a un aumento en una relación de fluido (...) en respuesta a una reducción en la relación de fluido deseado con no deseado.”* (reivindicación 2), *“...selecciona una primera ruta de flujo de salida (...) en respuesta a la dirección de flujo (...) en respuesta a la dirección de flujo que es más rotacional.”* (reivindicación 3), *“...que se desplaza en respuesta a un flujo de una composición de fluido (...) en una relación de fluidos en la composición de fluido.”* (reivindicación 12), *“...que por lo menos bloquea parcialmente el flujo (...) segunda rutas de flujo de entrada.”*, (reivindicación 22), *“...que selecciona a través de cual de las múltiples rutas de flujo de salida (...) y la dirección es dependiente de una relación de los fluidos en la composición de fluido.”* (reivindicación 25); son las que no pueden tenerse en cuenta al realizar el examen de patentabilidad y tampoco pueden definir la invención para la cual se solicita protección.

Se sugiere al solicitante que al replantear el capítulo reivindicatorio no incluya estos aspectos, sino exponga su invención por medio de sus características constructivas.

4. Determinación del Estado de la Técnica

El estado de la técnica se determinó con base en la fecha de presentación de la solicitud de patente nacional: noviembre 7 de 2011, y se encontraron los siguientes documentos que anticipan el objeto de esta solicitud:

Ítem	Documento	Título	Fecha de Publicación
D1	US 2011/0214876	'Flow path control based on fluid characteristics to thereby variably resist flow in a subterranean well'	08/Septiembre/2011
D2	US 3'566.900	'Fuel control system and viscosity sensor used therewith'	02/Marzo/1971
D3	US 2011/0042092	'Alternating flow resistance increases and decreases for propagating pressure pulses in a subterranean well'	24/Febrero/2011
D4	US 3'754.576	'Flap – equipped power fluid amplifier'	28/Agosto/1973

El documento D1¹ divulga un sistema de resistencia variable de flujo que trae mejoras al arte de regular el flujo de fluido en un pozo ([Párr. 0006])

El documento D2² divulga un sensor de viscosidad de combustible incorporado en un sistema de control de combustible para una turbina de gas (resumen).

El documento D3³ divulga un método para propagar pulsos de presión en un pozo que puede incluir un sistema de resistencia variable de flujo que incluye una cámara de vórtice teniendo por lo menos una entrada y una salida (resumen).

El documento D4⁴ divulga un amplificador de fluido que comprende una entrada, un par de salidas de flujo, una entrada de control de flujo de fluido y un miembro triangular en el punto de derivación de las salidas del flujo de fluido (resumen).

5. Examen de Patentabilidad (Art 14 D486)

El examen de patentabilidad se realizó con base en lo expuesto en el numeral 3 de la presente comunicación y en las características constructivas que se encuentran incluidas en el capítulo reivindicatorio.

Novedad (Art 16 D486)

La reivindicación 1 consiste en: “*Un sistema de discriminación de fluido para uso con un pozo subterráneo, el sistema comprende: un discriminador de fluido...*” (Ver página 65 del radicado N° 14-084477-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D1	D2	D3	D4
Un sistema de discriminación	Control de recorrido de fluido	Sistema de control de combustible	Control de recorrido de fluido	Amplificador de fluido

1 <https://docs.google.com/viewer?url=patentimages.storage.googleapis.com/pdfs/US20110214876.pdf>

2 <https://docs.google.com/viewer?url=patentimages.storage.googleapis.com/pdfs/US3566900.pdf>

3 <https://docs.google.com/viewer?url=patentimages.storage.googleapis.com/pdfs/US20110042092.pdf>

4 <https://docs.google.com/viewer?url=patentimages.storage.googleapis.com/pdfs/US3754576.pdf>

de fluido que comprende:	caracterizado por:	caracterizado por:	caracterizado por:	caracterizado por:
Un discriminador de fluido con múltiples rutas.	Un discriminador de fluido (25) con múltiples rutas (Fig. 3; Párrs. [0042 a 0071]).	Un discriminador de fluido (66) con múltiples rutas (Fig. 1).	Un discriminador de fluido (25) con múltiples rutas (Figs. 3 a 5).	Un discriminador de fluido con múltiples rutas (Figs. 1 a 3).

De acuerdo con la tabla anterior, las características esenciales del sistema de la reivindicación 1 habían sido divulgadas previamente en los documentos D1 a D4, por lo tanto, la materia reivindicada no es nueva.

La reivindicación 12 consiste en: “*Un discriminador de fluido para uso con un pozo subterráneo, el discriminador de fluido comprende: una estructura que se desplaza en respuesta a un flujo...*” (Ver página 67 del radicado N° 14-084477-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D4
Un discriminador de fluido que comprende:	Un discriminador de fluido caracterizado por:
Una estructura.	Una estructura (1), (1a), (1b) (Figs. 1 a 5).

De acuerdo con la tabla anterior, las características esenciales del discriminador de la reivindicación 12 habían sido divulgadas previamente en el documento D4, por lo tanto, la materia reivindicada no es nueva.

Asimismo, el documento D4 divulga las características de las reivindicaciones dependientes así:

- Reivindicación 22: Un interruptor de fluido (Figs. 1 a 5).

La reivindicación 25 consiste en: “*Un método de discriminación entre fluidos que fluyen en un pozo subterráneo, el método comprende: proporcionar un discriminador de fluido...*” (Ver página 70 del radicado N° 14-084477-00000-0000).

Comparación de las características técnicas esenciales, con las del estado de la técnica:

Características esenciales	D1	D2	D3	D4
Un método de discriminación entre fluidos caracterizado por:	Control de recorrido de fluido caracterizado por:	Sistema de control de combustible caracterizado por:	Control de recorrido de fluido caracterizado por:	Amplificador de fluido caracterizado por:
Proporcionar un discriminador de fluido con múltiples rutas.	Un discriminador de fluido (25) con múltiples rutas (Fig. 3; Párrs. [0042 a 0071]).	Un discriminador de fluido (66) con múltiples rutas (Fig. 1).	Un discriminador de fluido (25) con múltiples rutas (Figs. 3 a 5).	Un discriminador de fluido con múltiples rutas (Figs. 1 a 3).

De acuerdo con la tabla anterior, las características esenciales del método de la reivindicación 25 habían sido divulgadas previamente en los documentos D1 a D4, por lo tanto, la materia reivindicada no es nueva.

Las reivindicaciones 1 a 35 fueron afectadas en el numeral 3 del presente requerimiento.

6. Conclusión

Los requisitos de Patentabilidad de la presente solicitud están afectados así:

Ítem	Documento	Reivindicaciones afectadas	Requisito que afecta
D1	US 2011/0214876	1, 12, 25	Novedad/Nivel Inventivo
D2	US 3'566.900	1, 12, 25	Novedad/Nivel Inventivo
D3	US 2011/0042092	1, 12, 25	Novedad/Nivel Inventivo
D4	US 3'754.576	1, 12, 22, 25	Novedad/Nivel Inventivo

En cumplimiento del artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le indica que debe dar respuesta dentro del término de sesenta (60) días contados a partir del día siguiente de la fecha de notificación de la presente comunicación. En caso de no dar respuesta al presente requerimiento, o si a pesar de la respuesta subsistieran los impedimentos para la concesión, se denegará la patente.

Se invita al solicitante se sirva indicar, si así lo considera, su renuncia al término faltante de sesenta (60) días para dar respuesta a este requerimiento y presentarla por escrito.

Finalmente, se le recuerda al solicitante que si como respuesta a este requerimiento llegara a modificar el capítulo reivindicatorio y éste contenga más de diez (10) reivindicaciones, no pagará la tasa de modificación voluntaria pero sí la correspondiente al pago por reivindicación adicional.

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única No. 10 de 2001.



JOSÉ LUIS SALAZAR LÓPEZ
Director de Nuevas Creaciones (c)

El anterior requerimiento fue notificado por fijación en lista, de fecha 2015-05-19

Elaboró: Monica Andrea Gutierrez Almonacid
Revisó: Sonia Andrea Diaz Pirazan



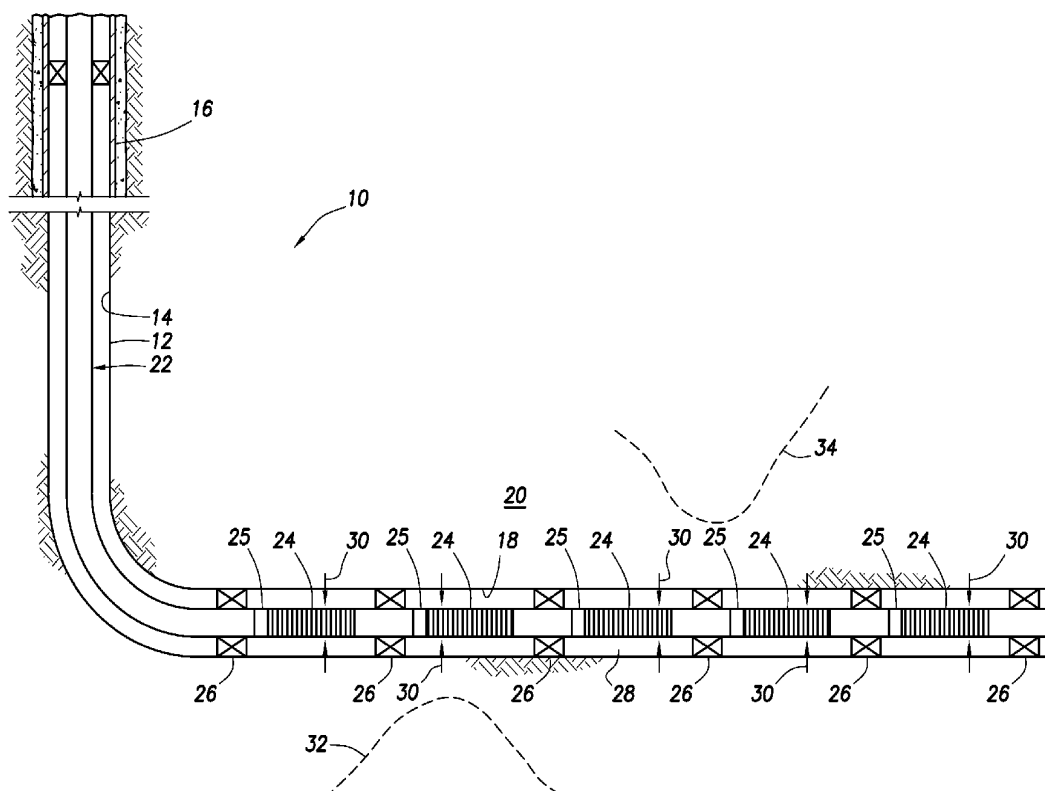
US 20110214876A1

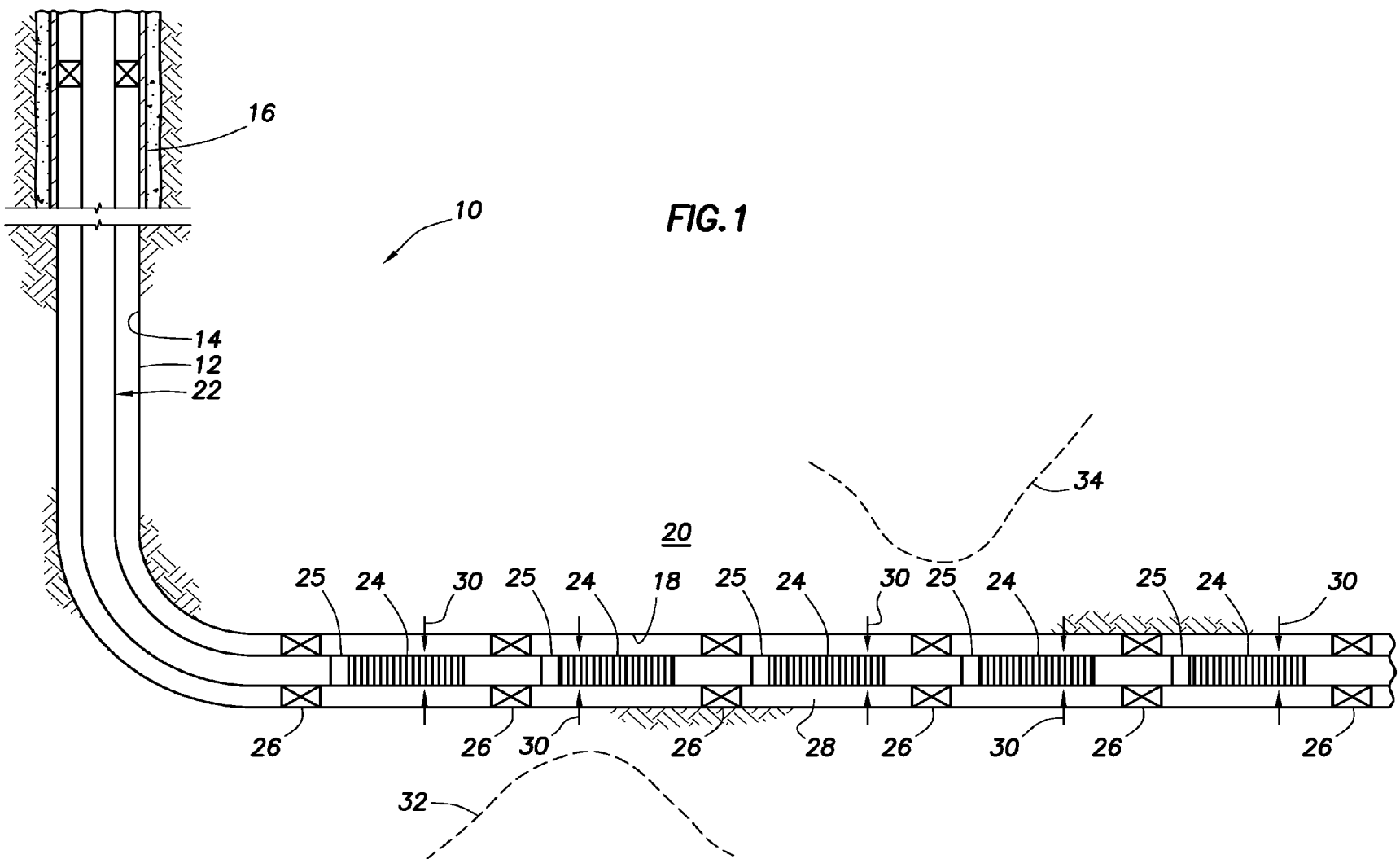
(19) **United States**(12) **Patent Application Publication**
DYKSTRA et al.(10) **Pub. No.: US 2011/0214876 A1**(43) **Pub. Date: Sep. 8, 2011**(54) **FLOW PATH CONTROL BASED ON FLUID CHARACTERISTICS TO THEREBY VARIABLY RESIST FLOW IN A SUBTERRANEAN WELL****Publication Classification**(51) **Int. Cl.**
E21B 34/06 (2006.01)(52) **U.S. Cl.** **166/316**(75) **Inventors:** **Jason D. DYKSTRA**, Carrollton, TX (US); **Michael L. FRIPP**, Carrollton, TX (US); **Syed HAMID**, Dallas, TX (US)(73) **Assignee:** **HALLIBURTON ENERGY SERVICES, INC.**, Houston, TX (US)(21) **Appl. No.:** **13/111,169**(22) **Filed:** **May 19, 2011****Related U.S. Application Data**

(63) Continuation of application No. 12/791,993, filed on Jun. 2, 2010, which is a continuation-in-part of application No. 12/700,685, filed on Feb. 4, 2010, which is a continuation-in-part of application No. 12/542,695, filed on Aug. 18, 2009, now abandoned.

(57) **ABSTRACT**

A system for variably resisting flow of a fluid composition can include a flow passage and a set of one or more branch passages which intersect the flow passage, whereby a proportion of the fluid composition diverted from the passage to the set of branch passages varies based on at least one of a) viscosity of the fluid composition, and b) velocity of the fluid composition in the flow passage. Another variable flow resistance system can include a flow path selection device that selects which of multiple flow paths a majority of fluid flows through from the device, based on a ratio of desired fluid to undesired fluid in the fluid composition. Yet another variable flow resistance system can include a flow chamber, with a majority of the fluid composition entering the chamber in a direction which changes based on a ratio of desired fluid to undesired fluid in the fluid composition.





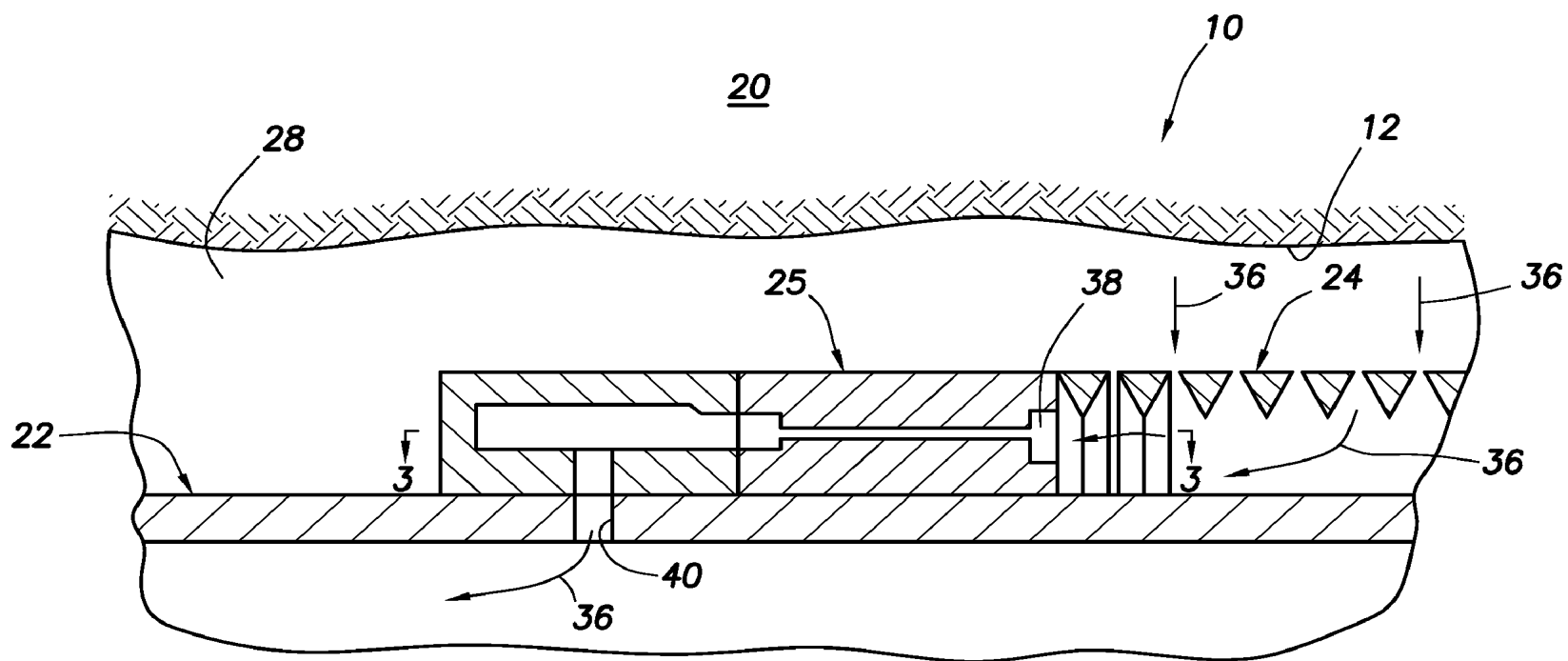


FIG.2

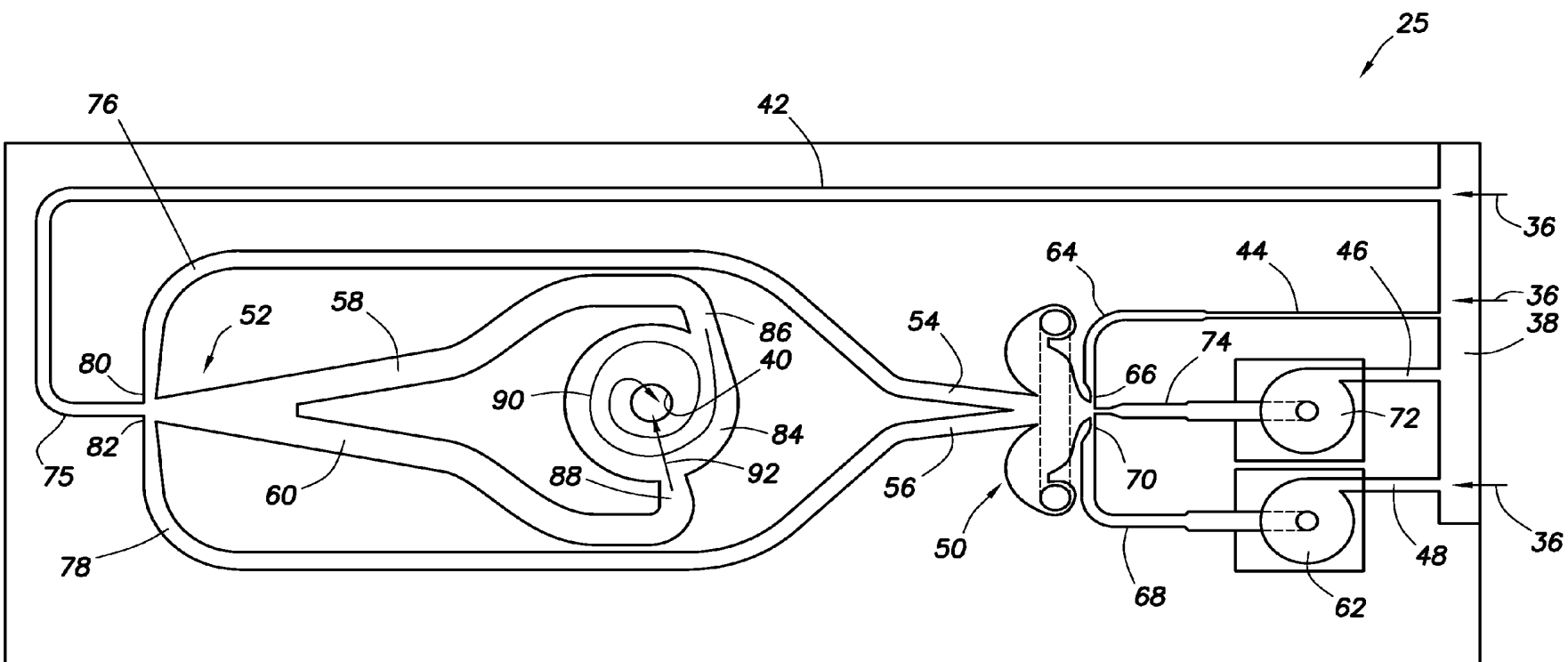


FIG. 3

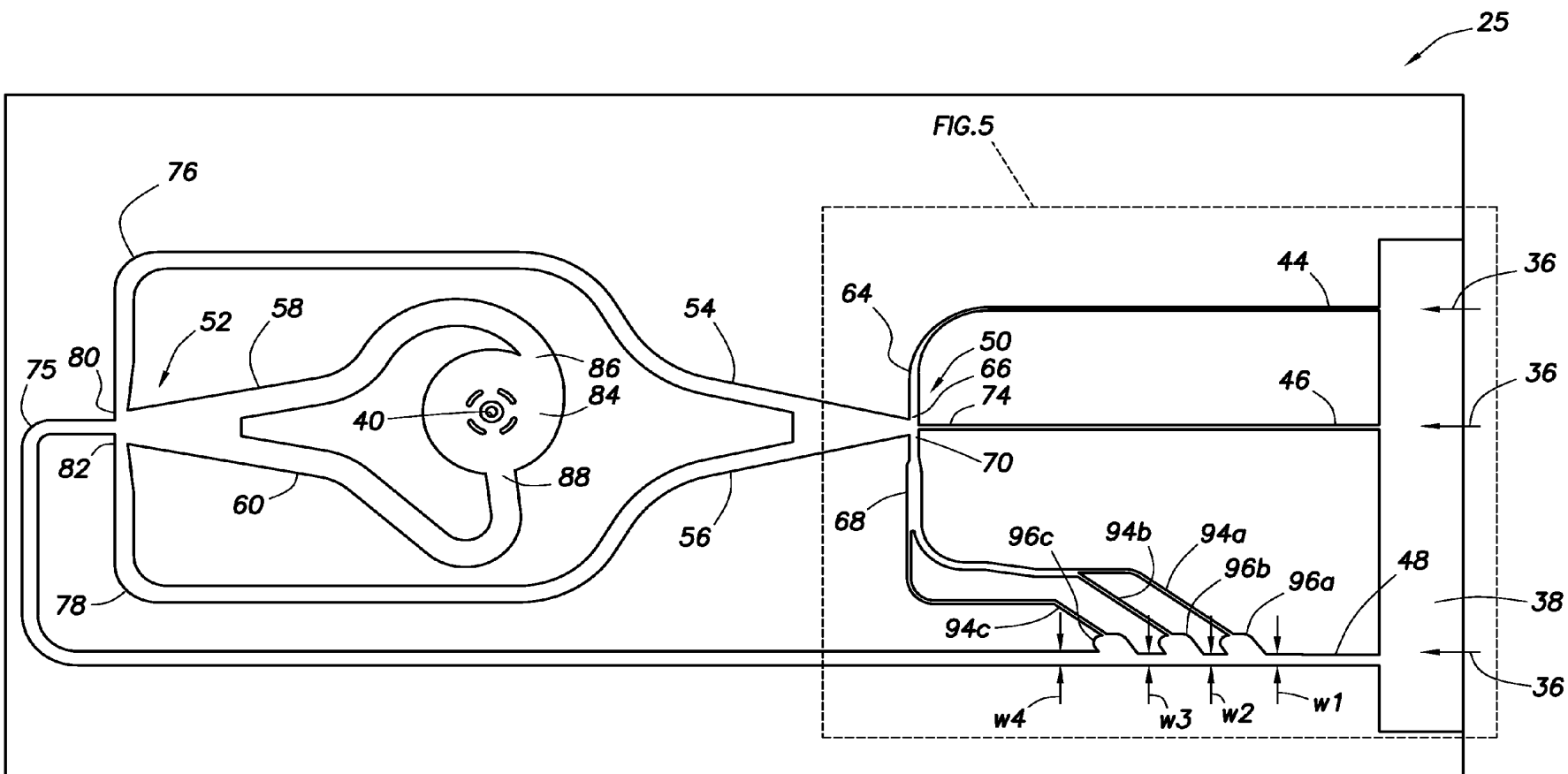


FIG. 4

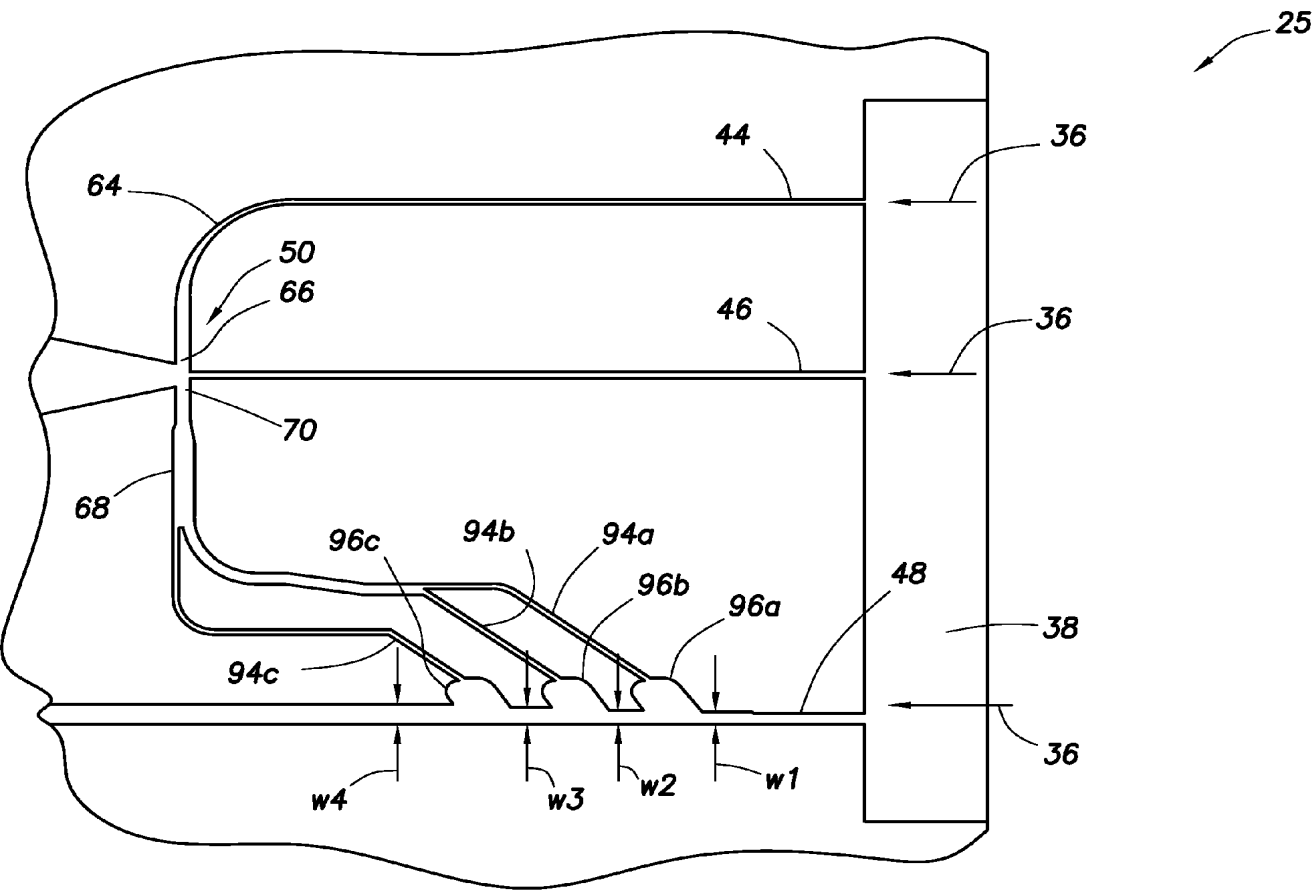


FIG.5

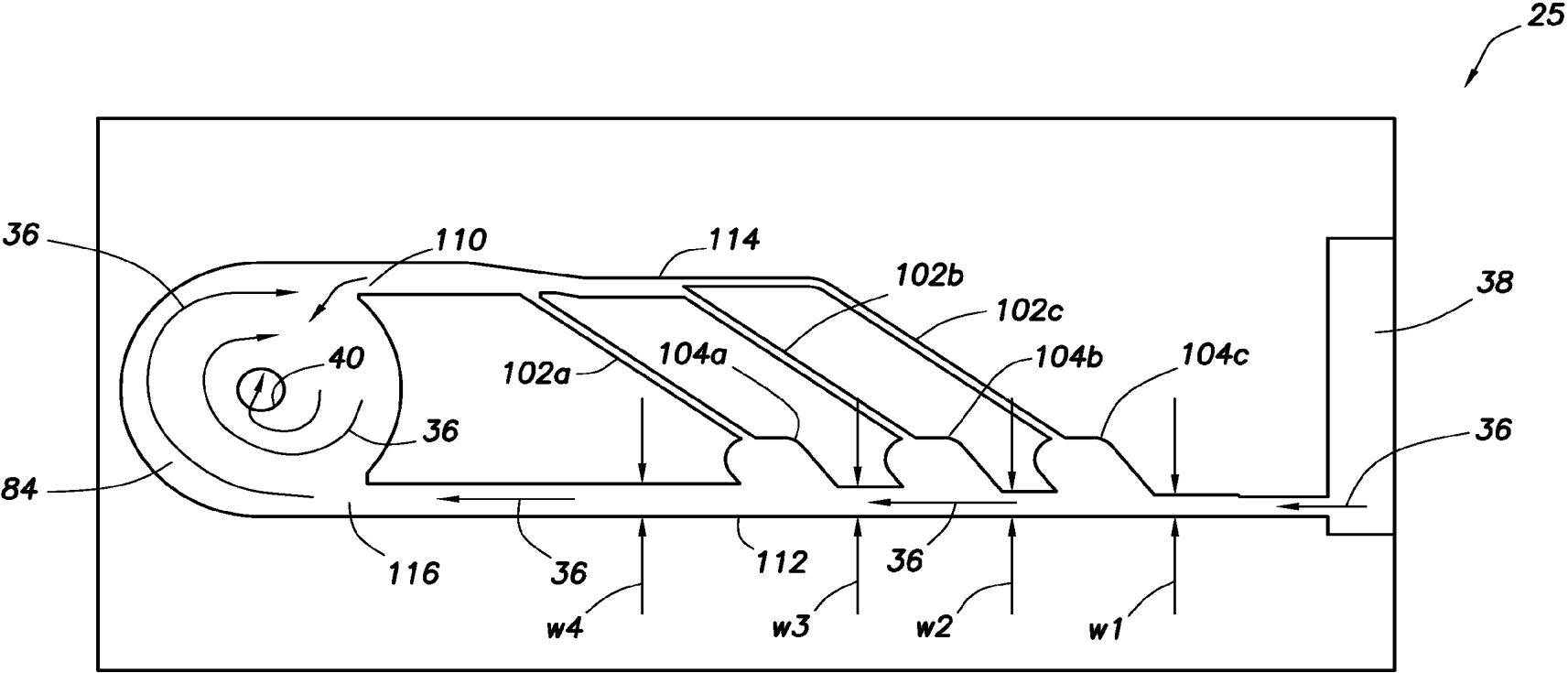


FIG. 7A

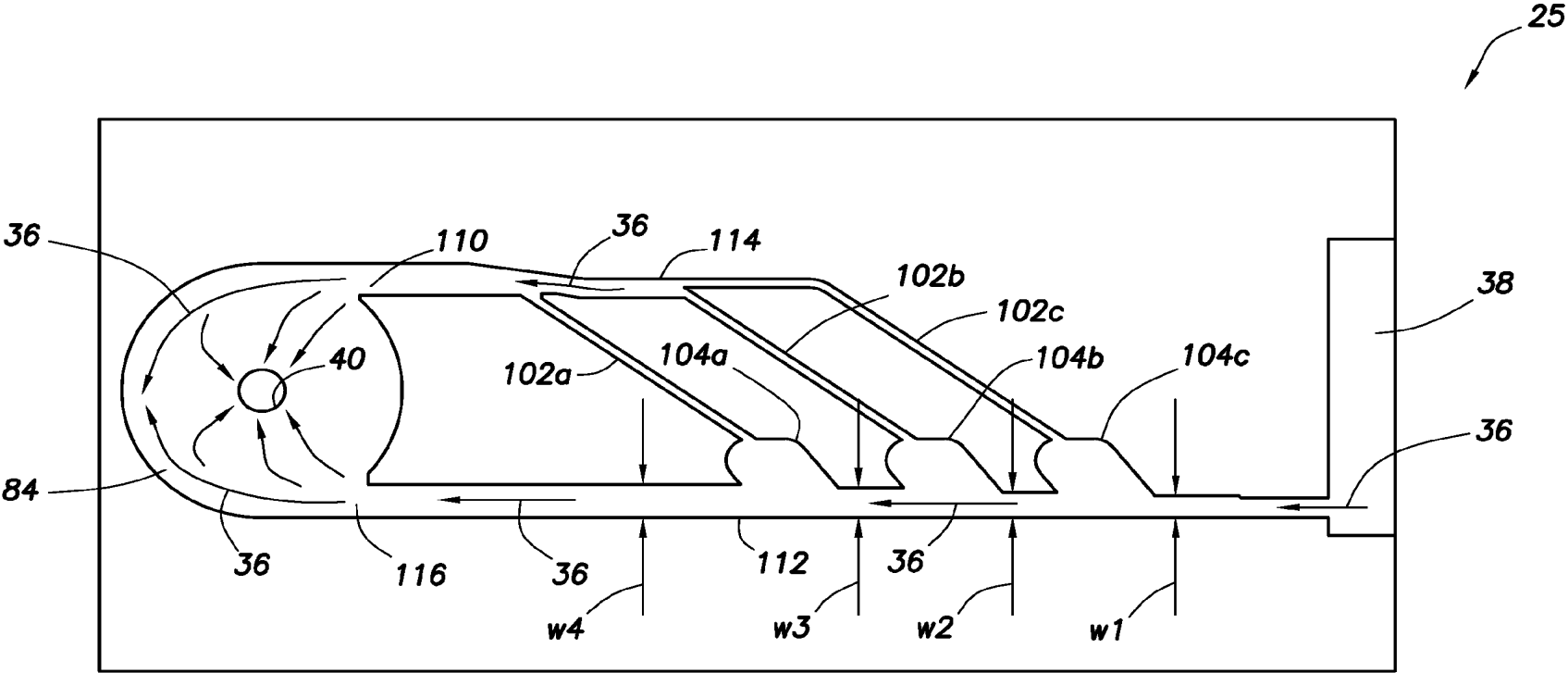


FIG. 7B

FIG. 8B

**FLOW PATH CONTROL BASED ON FLUID
CHARACTERISTICS TO THEREBY
VARIABLY RESIST FLOW IN A
SUBTERRANEAN WELL**

CROSS-REFERENCE TO RELATED
APPLICATIONS

[0001] This application is a continuation-in-part of prior application Ser. No. 12/700,685 filed on 4 Feb. 2010, which is a continuation-in-part of application Ser. No. 12/542695 filed on 18 Aug. 2009. The entire disclosures of these prior applications are incorporated herein by this reference for all purposes.

BACKGROUND

[0002] This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in an example described below, more particularly provides for flow path control based on fluid characteristics to thereby variably resist flow in a subterranean well.

[0003] In a hydrocarbon production well, it is many times beneficial to be able to regulate flow of fluids from an earth formation into a wellbore. A variety of purposes may be served by such regulation, including prevention of water or gas coning, minimizing sand production, minimizing water and/or gas production, maximizing oil and/or gas production, balancing production among zones, etc.

[0004] In an injection well, it is typically desirable to evenly inject water, steam, gas, etc., into multiple zones, so that hydrocarbons are displaced evenly through an earth formation, without the injected fluid prematurely breaking through to a production wellbore. Thus, the ability to regulate flow of fluids from a wellbore into an earth formation can also be beneficial for injection wells.

[0005] Therefore, it will be appreciated that advancements in the art of variably restricting fluid flow in a well would be desirable in the circumstances mentioned above, and such advancements would also be beneficial in a wide variety of other circumstances.

SUMMARY

[0006] In the disclosure below, a variable flow resistance system is provided which brings improvements to the art of regulating fluid flow in a well. One example is described below in which a fluid composition is made to flow along a more resistive flow path if the fluid composition has a threshold level (or more than the threshold level) of an undesirable characteristic. Another example is described below in which a resistance to flow through the system increases as a ratio of desired fluid to undesired fluid in the fluid composition decreases.

[0007] In one aspect, a system for variably resisting flow of a fluid composition in a subterranean well is provided by the disclosure. The system can include a flow passage and a set of one or more branch passages which intersect the flow passage. In this manner, a proportion of the fluid composition diverted from the flow passage to the set of branch passages varies based on at least one of a) viscosity of the fluid composition, and b) velocity of the fluid composition in the flow passage.

[0008] In another aspect, a system for variably resisting flow of a fluid composition in a subterranean well is

described. The system can include a flow path selection device that selects which of multiple flow paths a majority of fluid flows through from the device, based on a ratio of desired fluid to undesired fluid in the fluid composition.

[0009] In yet another aspect, a system for variably resisting flow of a fluid composition can include a flow chamber. A majority of the fluid composition enters the chamber in a direction which changes based on a ratio of desired fluid to undesired fluid in the fluid composition.

[0010] In a further aspect, the present disclosure provides a system for variably resisting flow of a fluid composition in a subterranean well. The system can include a flow chamber, and a majority of the fluid composition can enter the chamber in a direction which changes based on a velocity of the fluid composition.

[0011] In a still further aspect, a variable flow resistance system for use in a subterranean well can include a flow chamber having an outlet, and at least first and second inlets.

A fluid composition which enters the flow chamber via the second inlet can oppose flow of the fluid composition which enters the flow chamber via the first inlet, whereby a resistance to flow of the fluid composition through the flow chamber can vary with a ratio of flows through the first and second inlets.

[0012] These and other features, advantages and benefits will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of representative examples below and the accompanying drawings, in which similar elements are indicated in the various figures using the same reference numbers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic partially cross-sectional view of a well system which can embody principles of the present disclosure.

[0014] FIG. 2 is an enlarged scale schematic cross-sectional view of a well screen and a variable flow resistance system which may be used in the well system of FIG. 1.

[0015] FIG. 3 is a schematic "unrolled" plan view of one configuration of the variable flow resistance system, taken along line 3-3 of FIG. 2.

[0016] FIG. 4 is a schematic plan view of another configuration of the variable flow resistance system.

[0017] FIG. 5 is an enlarged scale schematic plan view of a portion of the variable flow resistance system of FIG. 4.

[0018] FIG. 6 is a schematic plan view of yet another configuration of the variable flow resistance system.

[0019] FIGS. 7A & B are schematic plan views of a further configuration of the variable flow resistance system.

[0020] FIGS. 8A & B are schematic plan views of another configuration of the variable flow resistance system.

DETAILED DESCRIPTION

[0021] Representatively illustrated in FIG. 1 is a well system 10 which can embody principles of this disclosure.

[0022] As depicted in FIG. 1, a wellbore 12 has a generally vertical uncased section 14 extending downwardly from casing 16, as well as a generally horizontal uncased section 18 extending through an earth formation 20.

[0023] A tubular string 22 (such as a production tubing string) is installed in the wellbore 12. Interconnected in the tubular string 22 are multiple well screens 24, variable flow resistance systems 25 and packers 26.

[0024] The packers **26** seal off an annulus **28** formed radially between the tubular string **22** and the wellbore section **18**. In this manner, fluids **30** may be produced from multiple intervals or zones of the formation **20** via isolated portions of the annulus **28** between adjacent pairs of the packers **26**.

[0025] Positioned between each adjacent pair of the packers **26**, a well screen **24** and a variable flow resistance system **25** are interconnected in the tubular string **22**. The well screen **24** filters the fluids **30** flowing into the tubular string **22** from the annulus **28**. The variable flow resistance system **25** variably restricts flow of the fluids **30** into the tubular string **22**, based on certain characteristics of the fluids.

[0026] At this point, it should be noted that the well system **10** is illustrated in the drawings and is described herein as merely one example of a wide variety of well systems in which the principles of this disclosure can be utilized. It should be clearly understood that the principles of this disclosure are not limited at all to any of the details of the well system **10**, or components thereof, depicted in the drawings or described herein.

[0027] For example, it is not necessary in keeping with the principles of this disclosure for the wellbore **12** to include a generally vertical wellbore section **14** or a generally horizontal wellbore section **18**. It is not necessary for fluids **30** to be only produced from the formation **20** since, in other examples, fluids could be injected into a formation, fluids could be both injected into and produced from a formation, etc.

[0028] It is not necessary for one each of the well screen **24** and variable flow resistance system **25** to be positioned between each adjacent pair of the packers **26**. It is not necessary for a single variable flow resistance system **25** to be used in conjunction with a single well screen **24**. Any number, arrangement and/or combination of these components may be used.

[0029] It is not necessary for any variable flow resistance system **25** to be used with a well screen **24**. For example, in injection operations, the injected fluid could be flowed through a variable flow resistance system **25**, without also flowing through a well screen **24**.

[0030] It is not necessary for the well screens **24**, variable flow resistance systems **25**, packers **26** or any other components of the tubular string **22** to be positioned in uncased sections **14**, **18** of the wellbore **12**. Any section of the wellbore **12** may be cased or uncased, and any portion of the tubular string **22** may be positioned in an uncased or cased section of the wellbore, in keeping with the principles of this disclosure.

[0031] It should be clearly understood, therefore, that this disclosure describes how to make and use certain examples, but the principles of the disclosure are not limited to any details of those examples. Instead, the principles of this disclosure can be applied to a variety of other examples using the knowledge obtained from this disclosure.

[0032] It will be appreciated by those skilled in the art that it would be beneficial to be able to regulate flow of the fluids **30** into the tubular string **22** from each zone of the formation **20**, for example, to prevent water coning **32** or gas coning **34** in the formation. Other uses for flow regulation in a well include, but are not limited to, balancing production from (or injection into) multiple zones, minimizing production or injection of undesired fluids, maximizing production or injection of desired fluids, etc.

[0033] Examples of the variable flow resistance systems **25** described more fully below can provide these benefits by

increasing resistance to flow if a fluid velocity increases beyond a selected level (e.g., to thereby balance flow among zones, prevent water or gas coning, etc.), increasing resistance to flow if a fluid viscosity decreases below a selected level or if a fluid density increases above a selected level (e.g., to thereby restrict flow of an undesired fluid, such as water or gas, in an oil producing well), and/or increasing resistance to flow if a fluid viscosity or density increases above a selected level (e.g., to thereby minimize injection of water in a steam injection well).

[0034] Whether a fluid is a desired or an undesired fluid depends on the purpose of the production or injection operation being conducted. For example, if it is desired to produce oil from a well, but not to produce water or gas, then oil is a desired fluid and water and gas are undesired fluids. If it is desired to produce gas from a well, but not to produce water or oil, the gas is a desired fluid, and water and oil are undesired fluids. If it is desired to inject steam into a formation, but not to inject water, then steam is a desired fluid and water is an undesired fluid in a fluid composition.

[0035] Note that, at downhole temperatures and pressures, hydrocarbon gas can actually be completely or partially in liquid phase. Thus, it should be understood that when the term "gas" is used herein, supercritical, liquid and/or gaseous phases are included within the scope of that term.

[0036] Referring additionally now to FIG. 2, an enlarged scale cross-sectional view of one of the variable flow resistance systems **25** and a portion of one of the well screens **24** is representatively illustrated. In this example, a fluid composition **36** (which can include one or more fluids, such as oil and water, liquid water and steam, oil and gas, gas and water, oil, water and gas, etc.) flows into the well screen **24**, is thereby filtered, and then flows into an inlet **38** of the variable flow resistance system **25**.

[0037] A fluid composition can include one or more undesired or desired fluids. Both steam and water can be combined in a fluid composition. As another example, oil, water and/or gas can be combined in a fluid composition.

[0038] Flow of the fluid composition **36** through the variable flow resistance system **25** is resisted based on one or more characteristics (such as density, viscosity, velocity, etc.) of the fluid composition. The fluid composition **36** is then discharged from the variable flow resistance system **25** to an interior of the tubular string **22** via an outlet **40**.

[0039] In other examples, the well screen **24** may not be used in conjunction with the variable flow resistance system **25** (e.g., in injection operations), the fluid composition **36** could flow in an opposite direction through the various elements of the well system **10** (e.g., in injection operations), a single variable flow resistance system could be used in conjunction with multiple well screens, multiple variable flow resistance systems could be used with one or more well screens, the fluid composition could be received from or discharged into regions of a well other than an annulus or a tubular string, the fluid composition could flow through the variable flow resistance system prior to flowing through the well screen, any other components could be interconnected upstream or downstream of the well screen and/or variable flow resistance system, etc. Thus, it will be appreciated that the principles of this disclosure are not limited at all to the details of the example depicted in FIG. 2 and described herein.

[0040] Although the well screen **24** depicted in FIG. 2 is of the type known to those skilled in the art as a wire-wrapped

well screen, any other types or combinations of well screens (such as sintered, expanded, pre-packed, wire mesh, etc.) may be used in other examples. Additional components (such as shrouds, shunt tubes, lines, instrumentation, sensors, inflow control devices, etc.) may also be used, if desired.

[0041] The variable flow resistance system 25 is depicted in simplified form in FIG. 2, but in a preferred example, the system can include various passages and devices for performing various functions, as described more fully below. In addition, the system 25 preferably at least partially extends circumferentially about the tubular string 22, or the system may be formed in a wall of a tubular structure interconnected as part of the tubular string.

[0042] In other examples, the system 25 may not extend circumferentially about a tubular string or be formed in a wall of a tubular structure. For example, the system 25 could be formed in a flat structure, etc. The system 25 could be in a separate housing that is attached to the tubular string 22, or it could be oriented so that the axis of the outlet 40 is parallel to the axis of the tubular string. The system 25 could be on a logging string or attached to a device that is not tubular in shape. Any orientation or configuration of the system 25 may be used in keeping with the principles of this disclosure.

[0043] Referring additionally now to FIG. 3, a more detailed cross-sectional view of one example of the system 25 is representatively illustrated. The system 25 is depicted in FIG. 3 as if it is “unrolled” from its circumferentially extending configuration to a generally planar configuration.

[0044] As described above, the fluid composition 36 enters the system 25 via the inlet 38, and exits the system via the outlet 40. A resistance to flow of the fluid composition 36 through the system 25 varies based on one or more characteristics of the fluid composition. The system 25 depicted in FIG. 3 is similar in most respects to that illustrated in FIG. 23 of the prior application Ser. No. 12/700,685 incorporated herein by reference above.

[0045] In the example of FIG. 3, the fluid composition 36 initially flows into multiple flow passages 42, 44, 46, 48. The flow passages 42, 44, 46, 48 direct the fluid composition 36 to two flow path selection devices 50, 52. The device 50 selects which of two flow paths 54, 56 a majority of the flow from the passages 44, 46, 48 will enter, and the other device 52 selects which of two flow paths 58, 60 a majority of the flow from the passages 42, 44, 46, 48 will enter.

[0046] The flow passage 44 is configured to be more restrictive to flow of fluids having higher viscosity. Flow of increased viscosity fluids will be increasingly restricted through the flow passage 44.

[0047] As used herein, the term “viscosity” is used to encompass both Newtonian and non-Newtonian rheological behaviors. Related rheological properties include kinematic viscosity, yield strength, viscoplasticity, surface tension, wettability, etc. For example, a desired fluid can have a desired range of kinematic viscosity, yield strength, viscoplasticity, surface tension, wettability, etc.

[0048] The flow passage 44 may have a relatively small flow area, the flow passage may require the fluid flowing therethrough to follow a tortuous path, surface roughness or flow impeding structures may be used to provide an increased resistance to flow of higher viscosity fluid, etc. Relatively low viscosity fluid, however, can flow through the flow passage 44 with relatively low resistance to such flow.

[0049] A control passage 64 of the flow path selection device 50 receives the fluid which flows through the flow

passage 44. A control port 66 at an end of the control passage 64 has a reduced flow area to thereby increase a velocity of the fluid exiting the control passage.

[0050] The flow passage 48 is configured to have a flow resistance which is relatively insensitive to viscosity of fluids flowing therethrough, but which may be increasingly resistant to flow of higher velocity or higher density fluids. Flow of increased viscosity fluids may be increasingly resisted through the flow passage 48, but not to as great an extent as flow of such fluids would be resisted through the flow passage 44.

[0051] In the example depicted in FIG. 3, fluid flowing through the flow passage 48 must flow through a “vortex” chamber 62 prior to being discharged into a control passage 68 of the flow path selection device 50. Since the chamber 62 in this example has a cylindrical shape with a central outlet, and the fluid composition 36 spirals about the chamber, increasing in velocity as it nears the outlet, driven by a pressure differential from the inlet to the outlet, the chamber is referred to as a “vortex” chamber. In other examples, one or more orifices, venturis, nozzles, etc. may be used.

[0052] The control passage 68 terminates at a control port 70. The control port 70 has a reduced flow area, in order to increase the velocity of the fluid exiting the control passage 68.

[0053] It will be appreciated that, as a viscosity of the fluid composition 36 increases, a greater proportion of the fluid composition will flow through the flow passage 48, control passage 68 and control port 70 (due to the flow passage 44 resisting flow of higher viscosity fluid more than the flow passage 48 and vortex chamber 62). Conversely, as a viscosity of the fluid composition 36 decreases, a greater proportion of the fluid composition will flow through the flow passage 44, control passage 64 and control port 66.

[0054] Fluid which flows through the flow passage 46 also flows through a vortex chamber 72, which may be similar to the vortex chamber 62 (although the vortex chamber 72 in a preferred example provides less resistance to flow therethrough than the vortex chamber 62), and is discharged into a central passage 74. The vortex chamber 72 is used for “resistance matching” to achieve a desired balance of flows through the flow passages 44, 46, 48.

[0055] Note that dimensions and other characteristics of the various components of the system 25 will need to be selected appropriately, so that desired outcomes are achieved. In the example of FIG. 3, one desired outcome of the flow path selection device 50 is that flow of a majority of the fluid composition 36 which flows through the flow passages 44, 46, 48 is directed into the flow path 54 when the fluid composition has a sufficiently high ratio of desired fluid to undesired fluid therein.

[0056] In this example, the desired fluid is oil, which has a higher viscosity than water or gas, and so when a sufficiently high proportion of the fluid composition 36 is oil, a majority (or at least a greater proportion) of the fluid composition 36 which enters the flow path selection device 50 will be directed to flow into the flow path 54, instead of into the flow path 56. This result is achieved due to the fluid exiting the control port 70 at a greater rate, higher velocity and/or greater momentum than fluid exiting the other control port 66, thereby influencing the fluid flowing from the passages 64, 68, 74 to flow more toward the flow path 54.

[0057] If the viscosity of the fluid composition 36 is not sufficiently high (and thus a ratio of desired fluid to undesired

fluid is below a selected level), a majority (or at least a greater proportion) of the fluid composition which enters the flow path selection device 50 will be directed to flow into the flow path 56, instead of into the flow path 54. This will be due to the fluid exiting the control port 66 at a greater rate, higher velocity and/or greater momentum than fluid exiting the other control port 70, thereby influencing the fluid flowing from the passages 64, 68, 74 to flow more toward the flow path 56.

[0058] It will be appreciated that, by appropriately configuring the flow passages 44, 46, 48, control passages 64, 68, control ports 66, 70, vortex chambers 62, 72, etc., the ratio of desired to undesired fluid in the fluid composition 36 at which the device 50 selects either the flow passage 54 or 56 for flow of a majority of fluid from the device can be set to various different levels.

[0059] The flow paths 54, 56 direct fluid to respective control passages 76, 78 of the other flow path selection device 52. The control passages 76, 78 terminate at respective control ports 80, 82. A central passage 75 receives fluid from the flow passage 42.

[0060] The flow path selection device 52 operates similar to the flow path selection device 50, in that a majority of fluid which flows into the device 52 via the passages 75, 76, 78 is directed toward one of the flow paths 58, 60, and the flow path selection depends on a ratio of fluid discharged from the control ports 80, 82. If fluid flows through the control port 80 at a greater rate, velocity and/or momentum as compared to fluid flowing through the control port 82, then a majority (or at least a greater proportion) of the fluid composition 36 will be directed to flow through the flow path 60. If fluid flows through the control port 82 at a greater rate, velocity and/or momentum as compared to fluid flowing through the control port 80, then a majority (or at least a greater proportion) of the fluid composition 36 will be directed to flow through the flow path 58.

[0061] Although two of the flow path selection devices 50, 52 are depicted in the example of the system 25 in FIG. 3, it will be appreciated that any number (including one) of flow path selection devices may be used in keeping with the principles of this disclosure. The devices 50, 52 illustrated in FIG. 3 are of the type known to those skilled in the art as jet-type fluid ratio amplifiers, but other types of flow path selection devices (e.g., pressure-type fluid ratio amplifiers, bi-stable fluid switches, proportional fluid ratio amplifiers, etc.) may be used in keeping with the principles of this disclosure.

[0062] Fluid which flows through the flow path 58 enters a flow chamber 84 via an inlet 86 which directs the fluid to enter the chamber generally tangentially (e.g., the chamber 84 is shaped similar to a cylinder, and the inlet 86 is aligned with a tangent to a circumference of the cylinder). As a result, the fluid will spiral about the chamber 84, until it eventually exits via the outlet 40, as indicated schematically by arrow 90 in FIG. 3.

[0063] Fluid which flows through the flow path 60 enters the flow chamber 84 via an inlet 88 which directs the fluid to flow more directly toward the outlet 40 (e.g., in a radial direction, as indicated schematically by arrow 92 in FIG. 3). As will be readily appreciated, much less energy is consumed at the same flow rate when the fluid flows more directly toward the outlet 40 as compared to when the fluid flows less directly toward the outlet.

[0064] Thus, less resistance to flow is experienced when the fluid composition 36 flows more directly toward the outlet 40 and, conversely, more resistance to flow is experienced when

the fluid composition flows less directly toward the outlet. Accordingly, working upstream from the outlet 40, less resistance to flow is experienced when a majority of the fluid composition 36 flows into the chamber 84 from the inlet 88, and through the flow path 60.

[0065] A majority of the fluid composition 36 flows through the flow path 60 when fluid exits the control port 80 at a greater rate, velocity and/or momentum as compared to fluid exiting the control port 82. More fluid exits the control port 80 when a majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 54.

[0066] A majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 54 when fluid exits the control port 70 at a greater rate, velocity and/or momentum as compared to fluid exiting the control port 66. More fluid exits the control port 70 when a viscosity of the fluid composition 36 is above a selected level.

[0067] Thus, flow through the system 25 is resisted less when the fluid composition 36 has an increased viscosity (and a greater ratio of desired to undesired fluid therein). Flow through the system 25 is resisted more when the fluid composition 36 has a decreased viscosity.

[0068] More resistance to flow is experienced when the fluid composition 36 flows less directly toward the outlet 40 (e.g., as indicated by arrow 90). Thus, more resistance to flow is experienced when a majority of the fluid composition 36 flows into the chamber 84 from the inlet 86, and through the flow path 58.

[0069] A majority of the fluid composition 36 flows through the flow path 58 when fluid exits the control port 82 at a greater rate, velocity and/or momentum as compared to fluid exiting the control port 80. More fluid exits the control port 82 when a majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 56, instead of through the flow path 54.

[0070] A majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 56 when fluid exits the control port 66 at a greater rate, velocity and/or momentum as compared to fluid exiting the control port 70. More fluid exits the control port 66 when a viscosity of the fluid composition 36 is below a selected level.

[0071] As described above, the system 25 is configured to provide less resistance to flow when the fluid composition 36 has an increased viscosity, and more resistance to flow when the fluid composition has a decreased viscosity. This is beneficial when it is desired to flow more of a higher viscosity fluid, and less of a lower viscosity fluid (e.g., in order to produce more oil and less water or gas).

[0072] If it is desired to flow more of a lower viscosity fluid, and less of a higher viscosity fluid (e.g., in order to produce more gas and less water, or to inject more steam and less water), then the system 25 may be readily reconfigured for this purpose. For example, the inlets 86, 88 could conveniently be reversed, so that fluid which flows through the flow path 58 is directed to the inlet 88, and fluid which flows through the flow path 60 is directed to the inlet 86.

[0073] Referring additionally now to FIG. 4, another configuration of the variable flow resistance system 25 is representatively illustrated. The configuration of FIG. 4 is similar in some respects to the configuration of FIG. 3, but differs somewhat, in that the vortex chambers 62, 72 are not used for the flow passages 46, 48, and the separate flow passage 42 connecting the inlet 38 to the flow path selection device 52 is

not used in the configuration of FIG. 4. Instead, the flow passage 48 connects the inlet 38 to the central passage 75 of the device 52.

[0074] A series of spaced apart branch passages 94a-c intersect the flow passage 48 and provide fluid communication between the flow passage and the control passage 68. Chambers 96a-c are provided at the respective intersections between the branch passages 94a-c and the flow passage 48.

[0075] A greater proportion of the fluid composition 36 which flows through the flow passage 48 will be diverted into the branch passages 94a-c as the viscosity of the fluid composition increases, or as the velocity of the fluid composition decreases. Thus, fluid will flow at a greater rate, velocity and/or momentum through the control port 70 of the device 50 (compared to the rate, velocity and/or momentum of fluid flow through the control port 66) as the viscosity of the fluid composition increases, or as the velocity of the fluid composition in the flow passage 48 decreases.

[0076] Preferably, the system 25 of FIG. 4 is appropriately configured so that the ratio of flows through the control ports 66, 70 has a linear or monotonic relationship to a proportion of a desired fluid in the fluid composition 36. For example, if the desired fluid is oil, then the ratio of flow through the control port 70 to flow through the control port 66 can vary with the percentage of oil in the fluid composition 36.

[0077] The chambers 96a-c are not strictly necessary, but are provided to enhance the effect of viscosity on the diversion of fluid into the branch passages 94a-c. The chambers 96a-c can be considered "eddy" chambers, since they provide a volume in which the fluid composition 36 can act upon itself, thereby increasing diversion of the fluid as its viscosity increases. Various different shapes, volumes, surface treatments, surface topographies, etc. may be used for the chambers 96a-c to further enhance the effect of viscosity on diversion of fluid into the branch passages 94a-c.

[0078] Although three of the branch passages 94a-c are depicted in FIG. 4, any number (including one) of the branch passages may be used in keeping with the principles of this disclosure. The branch passages 94a-c are linearly spaced apart on one side of the flow passage 48 as depicted in FIG. 4, but in other examples they could be radially, helically or otherwise spaced apart, and they could be on any side(s) of the flow passage 48, in keeping with the principles of this disclosure.

[0079] As is more clearly viewed in FIG. 5, the flow passage 48 preferably increases in width (and, thus, flow area) at each of the intersections between the branch passages 94a-c and the flow passage. Thus, a width w2 of the flow passage 48 is greater than a width w1 of the flow passage, width w3 is greater than width w2, and width w4 is greater than width w3. Each increase in width is preferably on the side of the flow passage 48 intersected by the respective one of the branch passages 94a-c.

[0080] The width of the flow passage 48 increases at each intersection with the branch passages 94a-c, in order to compensate for spreading of the flow of the fluid composition 36 through the flow passage. Preferably a jet-type flow of the fluid composition 36 is maintained as it traverses each of the intersections. In this manner, higher velocity and lower viscosity fluids are less influenced to be diverted into the branch passages 94a-c.

[0081] The intersections of the branch passages 94a-c with the flow passage 48 may be evenly spaced apart (as depicted in FIGS. 4 & 5) or unevenly spaced apart. The spacing of the

branch passages 94a-c is preferably selected to maintain the jet-type flow of the fluid composition 36 through the flow passage 48 as it traverses each intersection, as mentioned above.

[0082] In the configuration of FIGS. 4 & 5, the desired fluid has a higher viscosity as compared to the undesired fluid, and so the various elements of the system 25 (e.g., flow passages 44, 48, control passages 64, 68, control ports 66, 70, branch passages 94a-c, chambers 96a-c, etc.) are appropriately configured so that the device 50 directs a majority (or at least a greater proportion) of the fluid flowing through the passages 44, 46, 48 into the flow path 54 when the fluid composition 36 has a sufficiently high viscosity. If the viscosity of the fluid composition 36 is not sufficiently high, then the device 50 directs a majority (or at least a greater proportion) of the fluid into the flow path 56.

[0083] If a majority of the fluid has been directed into the flow path 54 (i.e., if the fluid composition 36 has a sufficiently high viscosity), then the device 52 will direct a majority of the fluid composition to flow into the flow path 60. Thus, a substantial majority of the fluid composition 36 will flow into the chamber 84 via the inlet 88, and will follow a relatively direct, less resistant path to the outlet 40.

[0084] If a majority of the fluid has been directed by the device 50 into the flow path 56 (i.e., if the fluid composition 36 has a relatively low viscosity), then the device 52 will direct a majority of the fluid composition to flow into the flow path 58. Thus, a substantial majority of the fluid composition 36 will flow into the chamber 84 via the inlet 86, and will follow a relatively circuitous, more resistant path to the outlet 40.

[0085] It will, therefore, be appreciated that the system 25 of FIGS. 4 & 5 increases resistance to flow of relatively low viscosity fluid compositions, and decreases resistance to flow of relatively high viscosity fluid compositions. The level of viscosity at which resistance to flow through the system 25 increases or decreases above or below certain levels can be determined by appropriately configuring the various elements of the system.

[0086] Similarly, if the fluid flowing through the flow passage 48 has a relatively low velocity, proportionately more of the fluid will be diverted from the flow passage and into the branch passages 94a-c, resulting in a greater ratio of fluid flow through the control port 70 to fluid flow through the control port 66. As a result, a majority (or at least a greater proportion) of the fluid composition will flow through the inlet 88 into the chamber 84, and the fluid composition will follow a relatively direct, less resistant path to the outlet 40.

[0087] Conversely, if the fluid flowing through the flow passage 48 has a relatively high velocity, proportionately less of the fluid will be diverted from the flow passage and into the branch passages 94a-c, resulting in a decreased ratio of fluid flow through the control port 70 to fluid flow through the control port 66. As a result, a majority (or at least a greater proportion) of the fluid composition 36 will flow through the inlet 86 into the chamber 84, and the fluid composition will follow a relatively circuitous, more resistant path to the outlet 40.

[0088] It will, therefore, be appreciated that the system 25 of FIGS. 4 & 5 increases resistance to flow of relatively high velocity fluid compositions, and decreases resistance to flow of relatively low velocity fluid compositions. The level of velocity at which resistance to flow through the system 25

increases or decreases above or below a certain level can be determined by appropriately configuring the various elements of the system.

[0089] In one preferred example of the system 25, the flow of a relatively low viscosity fluid (such as the fluid composition 36 having a high proportion of gas therein) is resisted by the system, no matter its velocity (above a minimum threshold velocity). However, the flow of a relatively high viscosity fluid (such as the fluid composition 36 having a high proportion of oil therein) is resisted by the system only when its velocity is above a selected level. Again, these characteristics of the system 25 can be determined by appropriately configuring the various elements of the system.

[0090] Referring additionally now to FIG. 6, another configuration of the system 25 is representatively illustrated. The configuration of FIG. 6 is similar in many respects to the configuration of FIGS. 4 & 5, but differs somewhat, in that fluid from both of the flow passages 44, 48 is communicated to the central passage 75 of the device 52, and a spaced apart series of branch passages 98a-c intersect the flow passage 44, with chambers 100a-c at the intersections. Any number (including one), spacing, size, configuration, etc., of the branch passages 98a-c and chambers 100a-c may be used in keeping with the principles of this disclosure.

[0091] Similar to the branch passages 94a-c and chambers 96a-c described above, the branch passages 98a-c and chambers 100a-c operate to divert proportionately more fluid from the flow passage 44 (and to the central passage 75 of the device 52) as the viscosity of the fluid composition 36 increases, or as the velocity of the fluid composition decreases in the flow passage. Thus, proportionately less fluid is delivered to the control port 66 as the viscosity of the fluid composition 36 increases, or as the velocity of the fluid composition decreases in the flow passage 44.

[0092] Since more fluid is delivered to the control port 70 as the viscosity of the fluid composition 36 increases, or as the velocity of the fluid composition decreases in the flow passage 48 (as described above in relation to the configuration of FIGS. 4 & 5), the ratio of fluid flow through the control port 70 to fluid flow through the control port 66 increases substantially more when the viscosity of the fluid composition 36 increases, or when the velocity of the fluid composition decreases in the configuration of FIG. 6, as compared to the configuration of FIGS. 4 & 5.

[0093] Conversely, the ratio of fluid flow through the control port 70 to fluid flow through the control port 66 decreases substantially more when the viscosity of the fluid composition 36 decreases, or when the velocity of the fluid composition increases in the configuration of FIG. 6, as compared to the configuration of FIGS. 4 & 5. Thus, the system 25 of FIG. 6 is more responsive to changes in viscosity or velocity of the fluid composition 36, as compared to the system of FIGS. 4 & 5.

[0094] Another difference in the configuration of FIG. 6 is that the chambers 96a-c and the chambers 100a-c decrease in volume stepwise in a downstream direction along the respective flow passages 48, 44. Thus, the chamber 96b has a smaller volume than the chamber 96a, and the chamber 96c has a smaller volume than the chamber 96b. Similarly, the chamber 100b has a smaller volume than the chamber 100a, and the chamber 100c has a smaller volume than the chamber 100b.

[0095] The changes in volume of the chambers 96a-c and 100a-c can help to compensate for changes in flow rate, velocity, etc. of the fluid composition 36 through the respec-

tive passages 48, 44. For example, at each successive intersection between the branch passages 94a-c and the flow passage 48, the velocity of the fluid through the flow passage 48 will decrease, and the volume of the respective one of the chambers 96a-c decreases accordingly. Similarly, at each successive intersection between the branch passages 98a-c and the flow passage 44, the velocity of the fluid through the flow passage 44 will decrease, and the volume of the respective one of the chambers 100a-c decreases accordingly.

[0096] One advantage of the configurations of FIGS. 4-6 over the configuration of FIG. 3 is that all of the flow passages, flow paths, control passages, branch passages, etc. in the configurations of FIGS. 4-6 are preferably in a single plane (as viewed in the drawings). Of course, when the system 25 extends circumferentially about, or in, a tubular structure, the passages, flow paths, etc. would preferably be at a same radial distance in or on the tubular structure. This makes the system 25 less difficult and expensive to construct.

[0097] Referring additionally now to FIGS. 7A & B, another configuration of the variable flow resistance system 25 is representatively illustrated. The system 25 of FIGS. 7A & B is much less complex as compared to the systems of FIGS. 3-5, at least in part because it does not include the flow path selection devices 50, 52.

[0098] The flow chamber 84 of FIGS. 7A & B is also somewhat different, in that two inlets 116, 110 to the chamber are supplied with flow of the fluid composition 36 via two flow passages 110, 112 which direct the fluid composition to flow in opposing directions about the outlet 40. As depicted in FIGS. 7A & B, fluid which enters the chamber 84 via the inlet 116 is directed to flow in a clockwise direction about the outlet 40, and fluid which enters the chamber via the inlet 110 is directed to flow in a counter-clockwise direction about the outlet.

[0099] In FIG. 7A, the system 25 is depicted in a situation in which an increased velocity and/or reduced viscosity of the fluid composition 36 results in a majority of the fluid composition flowing into the chamber 84 via the inlet 116. The fluid composition 36, thus spirals about the outlet 40 in the chamber 84, and a resistance to flow through the system 25 increases. The reduced viscosity could result from a relatively low ratio of desired fluid to undesired fluid in the fluid composition 36.

[0100] Relatively little of the fluid composition 36 flows into the chamber 84 via the inlet 110 in FIG. 7A, because the flow passage 114 is connected to branch passages 102a-c which branch from the flow passage 112 at eddy chambers 104a-c. At relatively high velocities and/or low viscosities, the fluid composition 36 tends to flow past the eddy chambers 104a-c, without a substantial amount of the fluid composition flowing through the eddy chambers and branch passages 102a-c to the flow passage 114.

[0101] In FIG. 7B, a velocity of the fluid composition 36 has decreased and/or a viscosity of the fluid composition has increased, and as a result, proportionately more of the fluid composition flows from the passage 112 into the branch passages 102a-c and via the passage 114 to the inlet 110. Since the flows into the chamber 84 from the two inlets 116, 110 are in opposing directions, they counteract each other, resulting in a disruption of the vortex 90 in the chamber.

[0102] As depicted in FIG. 7B, the fluid composition 36 flows less spirally about the outlet 40, and more directly to the outlet, thereby reducing the resistance to flow through the system 25. Thus, resistance to flow through the system 25 is

decreased when the velocity of the fluid composition 36 decreases, when the viscosity of the fluid composition increases, or when a ratio of desired fluid to undesired fluid in the fluid composition increases.

[0103] Referring additionally now to FIGS. 8A & B, another configuration of the variable flow resistance system 25 is representatively illustrated. The system 25 of FIGS. 8A & B is similar in many respects to the system of FIGS. 7A & B, but differs at least in that the branch passages 102a-c and eddy chambers 104a-c are not necessarily used in the FIGS. 8A & B configuration. Instead, the flow passage 114 itself branches off of the flow passage 112.

[0104] Another difference is that circular flow inducing structures 106 are used in the chamber 84 in the configuration of FIGS. 8A & B. The structures 106 operate to maintain circular flow of the fluid composition 36 about the outlet 40, or at least to impede inward flow of the fluid composition toward the outlet, when the fluid composition does flow circularly about the outlet. Openings 108 in the structures 106 permit the fluid composition 36 to eventually flow inward to the outlet 40.

[0105] The structures 106 are an example of how the configuration of the system 25 can be altered to produce a desired flow resistance (e.g., when the fluid composition 36 has a predetermined viscosity, velocity, density, ratio of desired to undesired fluid therein, etc.). The manner in which the flow passage 114 is branched off of the flow passage 112 is yet another example of how the configuration of the system 25 can be altered to produce a desired flow resistance.

[0106] In FIG. 8A, the system 25 is depicted in a situation in which an increased velocity and/or reduced viscosity of the fluid composition 36 results in a majority of the fluid composition flowing into the chamber 84 via the inlet 116. The fluid composition 36, thus, spirals about the outlet 40 in the chamber 84, and a resistance to flow through the system 25 increases. The reduced viscosity can be due to a relatively low ratio of desired fluid to undesired fluid in the fluid composition 36.

[0107] Relatively little of the fluid composition 36 flows into the chamber 84 via the inlet 110 in FIG. 8A, because the flow passage 114 is branched from the flow passage 112 in a manner such that most of the fluid composition remains in the flow passage 112. At relatively high velocities and/or low viscosities, the fluid composition 36 tends to flow past the flow passage 114.

[0108] In FIG. 8B, a velocity of the fluid composition 36 has decreased and/or a viscosity of the fluid composition has increased, and as a result, proportionately more of the fluid composition flows from the passage 112 and via the passage 114 to the inlet 110. The increased viscosity of the fluid composition 36 may be due to an increased ratio of desired to undesired fluids in the fluid composition.

[0109] Since the flows into the chamber 84 from the two inlets 116, 110 are oppositely directed (or at least the flow of the fluid composition through the inlet 110 opposes the flow through the inlet 116), they counteract each other, resulting in a disruption of the vortex 90 in the chamber. Thus, the fluid composition 36 flows more directly to the outlet 40 and a resistance to flow through the system 25 is decreased.

[0110] Note that any of the features of any of the configurations of the system 25 described above may be included in any of the other configurations of the system and, thus, it should be understood that these features are not exclusive to any one particular configuration of the system. The system 25

can be used in any type of well system (e.g., not only in the well system 10), and for accomplishing various purposes in various well operations, including but not limited to injection, stimulation, completion, production, conformance, drilling operations, etc.

[0111] It may now be fully appreciated that the above disclosure provides substantial advancements to the art of controlling fluid flow in a well. Fluid flow can be variably resisted based on various characteristics (e.g., viscosity, density, velocity, etc.) of a fluid composition which flows through a variable flow resistance system.

[0112] In particular, the above disclosure provides to the art a system 25 for variably resisting flow of a fluid composition 36 in a subterranean well. The system 25 can include a first flow passage 48, 112 and a first set of one or more branch passages 94a-c, 100, 102a-c which intersect the first flow passage 48, 112. In this manner, a proportion of the fluid composition 36 diverted from the first flow passage 48, 112 to the first set of branch passages 94a-c, 100, 102a-c varies based on at least one of a) viscosity of the fluid composition 36, and b) velocity of the fluid composition 36 in the first flow passage 48, 98.

[0113] The proportion of the fluid composition 36 diverted from the first flow passage 48, 112 to the first set of branch passages 94a-c, 100, 102a-c preferably increases in response to increased viscosity of the fluid composition 36.

[0114] The proportion of the fluid composition 36 diverted from the first flow passage 48, 112 to the first set of branch passages 94a-c, 100, 102a-c preferably increases in response to decreased velocity of the fluid composition 36 in the first flow passage 48, 112.

[0115] The first set of branch passages 94a-c can direct the fluid composition 36 to a first control passage 68 of a flow path selection device 50. The flow path selection device 50 can select which of multiple flow paths 54, 56 a majority of fluid flows through from the device 50, based at least partially on the proportion of the fluid composition 36 diverted to the first control passage 68.

[0116] The system 25 can include a second flow passage 44 with a second set of one or more branch passages 98a-c which intersect the second flow passage 44. In this configuration, a proportion of the fluid composition 36 diverted from the second flow passage 44 to the second set of branch passages 98a-c preferably increases with increased viscosity of the fluid composition 36, and increases with decreased velocity of the fluid composition 36 in the second flow passage 44.

[0117] The second flow passage 44 can direct the fluid composition 36 to a second control passage 64 of the flow path selection device 50. The flow path selection device 50 can select which of the multiple flow paths 54, 56 the majority of fluid flows through from the device 50, based on a ratio of flow rates of the fluid composition 36 through the first and second control passages 64, 68. The ratio of the flow rates through the first and second control passages 64, 68 preferably varies with respect to a ratio of desired fluid to undesired fluid in the fluid composition 36.

[0118] The first set of branch passages 94a-c, 100, 102a-c can include multiple branch passages spaced apart along the first flow passage 48, 112. A chamber 96a-c, 104a-c may be provided at each of multiple intersections between the first flow passage 48, 112 and the branch passages 94a-c, 102a-c.

[0119] Each of the chambers 96a-c, 104a-c has a fluid volume, and the volumes may decrease in a direction of flow of the fluid composition 36 through the first flow passage 48,

112. A flow area of the first flow passage **48, 112** may increase at each of multiple intersections between the first flow passage **48, 112** and the first set of branch passages **94a-c, 102a-c**.

[0120] Also described above is a system **25** for variably resisting flow of a fluid composition **36** in a subterranean well, with the system **25** including a flow path selection device **50** that selects which of multiple flow paths **54, 56** a majority of fluid flows through from the device, based on a ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0121] The flow path selection device **50** can include a first control port **70**. A flow rate of the fluid composition **36** through the first control port **70** affects which of the multiple flow paths the majority of fluid flows through from the device **50**. The flow rate of the fluid composition **36** through the first control port **70** preferably varies based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0122] The flow path selection device **50** can also include a second control port **66**. The flow path selection device **50** can select which of multiple flow paths **54, 56** the majority of fluid flows through from the device **50**, based on a ratio of a) the flow rate of the fluid composition **36** through the first control port **70** to b) a flow rate of the fluid composition **36** through the second control port **66**. The ratio of the flow rates through the first and second control ports **70, 66** preferably varies with respect to the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0123] The fluid composition **36** can flow to the first control port **70** via at least one control passage **68** which connects to a flow passage **48** through which the fluid composition **36** flows. A flow rate of the fluid composition **36** from the flow passage **48** to the control passage **68** can vary based on the ratio of desired fluid to undesired fluid in the fluid composition **36**. A proportion of the fluid composition **36** which flows from the flow passage **48** to the control passage **68** can increase when a viscosity of the fluid composition **36** increases, and/or decrease when a velocity of the fluid composition **36** in the flow passage **48** increases.

[0124] The flow path selection device **50** can include a second control port **66**. A flow rate of the fluid composition **36** through the second control port **66** affects which of the multiple flow paths **54, 56** the majority of fluid flows through from the device **50**.

[0125] The fluid composition **36** flows to the second control port **66** via at least one control passage **64** through which the fluid composition **36** flows. The control passage **64** connects to at least one flow passage **44**, and a flow rate of the fluid composition **36** from the flow passage **44** to the control passage **64** can vary based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0126] A proportion of the fluid composition **36** which flows from the flow passage **44** to the control passage **64** can decrease when a viscosity of the fluid composition **36** increases, and/or increase when a velocity of the fluid composition **36** in the flow passage **44** increases.

[0127] The above disclosure also provides to the art a system **25** for variably resisting flow of a fluid composition **36** in a subterranean well, with the system **25** including a flow chamber **84**. A majority of the fluid composition **36** enters the chamber **84** in a direction which changes based on a ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0128] The fluid composition **36** can more directly flow through the chamber **84** to an outlet **40** of the chamber **84** in

response to an increase in the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0129] The majority of the fluid composition **36** enters the chamber **84** via one of multiple inlets **86, 88**. The one of the multiple inlets **86, 88** which the majority of the fluid composition **36** enters is selected based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0130] A first inlet **88** directs the fluid composition **36** to flow more directly toward an outlet **40** of the chamber **84** as compared to a second inlet **86**. The first inlet **88** may direct the fluid composition **36** to flow more radially relative to the outlet **40** as compared to the second inlet **86**. The second inlet **86** may direct the fluid composition **36** to spiral more about the outlet **40** as compared to the first inlet **88**.

[0131] The chamber **84** can be generally cylindrical-shaped, and the fluid composition **36** may spiral more within the chamber **84** as the ratio of desired fluid to undesired fluid in the fluid composition **36** decreases.

[0132] The system **25** preferably includes a flow path selection device **50** that selects which of multiple flow paths **54, 56** a majority of fluid flows through from the device, based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0133] The flow path selection device **50** includes a first control port **70**. A flow rate of the fluid composition **36** through the first control port **70** affects which of the multiple flow paths **54, 56** the majority of fluid flows through from the device. The flow rate of the fluid composition **36** through the first control port **70** varies based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0134] The flow path selection device **50** can also include a second control port **66**. A ratio of a) the flow rate of the fluid composition **36** through the first control port **70** to b) a flow rate of the fluid composition **36** through the second control port **66** affects which of the multiple flow paths the majority of fluid flows through from the device. The ratio of the flow rates through the first and second control ports **70, 66** preferably varies with respect to the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0135] The fluid composition **36** can flow to the first control port **70** via at least one control passage **68** which connects to a flow passage **48** through which the fluid composition **36** flows. A flow rate of the fluid composition **36** from the flow passage **48** to the control passage **68** can vary based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0136] The flow path selection device **50** can include a second control port **66**. A flow rate of the fluid composition **36** through the second control port **66** affects which of the multiple flow paths **54, 56** the majority of fluid flows through from the device **50**. The fluid composition **36** flows to the second control port **66** via at least one control passage **64** through which the fluid composition **36** flows.

[0137] The control passage **64** connects to at least one flow passage **44**. A flow rate of the fluid composition **36** from the flow passage **44** to the control passage **64** varies based on the ratio of desired fluid to undesired fluid in the fluid composition **36**.

[0138] Also described above is system **25** for variably resisting flow of a fluid composition **36** in a subterranean well, with the system **25** including a flow chamber **84**. A majority of the fluid composition **36** enters the chamber **84** in a direction which changes based on a velocity of the fluid composition **36**.

[0139] The fluid composition 36 can more directly flow through the chamber 84 to an outlet 40 of the chamber 84 in response to a decrease in the velocity.

[0140] The majority of the fluid composition 36 can enter the chamber 84 via one of multiple inlets 86, 88. The one of the multiple inlets 86, 88 is selected based on the velocity. A first one 88 of the multiple inlets may direct the fluid composition 36 to flow more directly toward an outlet 40 of the chamber 84 as compared to a second one 86 of the multiple inlets.

[0141] The first inlet 88 may direct the fluid composition 86 to flow more radially relative to the outlet 40 as compared to the second inlet 86. The second inlet 86 may direct the fluid composition 36 to spiral more about the outlet 40 as compared to the first inlet 88.

[0142] The chamber 84 may be generally cylindrical-shaped, and the fluid composition 36 may spiral more within the chamber 84 as the velocity increases.

[0143] The system 25 can also include a flow path selection device 52 that selects which of multiple flow paths 58, 60 the majority of the fluid composition 36 flows through from the device 52, based on the velocity of the fluid composition 36.

[0144] The above disclosure also describes a variable flow resistance system 25 for use in a subterranean well, with the variable flow resistance system 25 comprising a flow chamber 84 having an outlet 40, and at least first and second inlets 116, 110. A fluid composition 36 which enters the flow chamber 84 via the second inlet 110 opposes flow of the fluid composition 36 which enters the flow chamber 84 via the first inlet 116, whereby a resistance to flow of the fluid composition 36 through the flow chamber 84 varies with a ratio of flows through the first and second inlets 116, 110.

[0145] A resistance to flow of the fluid composition 36 through the flow chamber 84 may decrease as flow through the first and second inlets 116, 110 becomes more equal. Flow through the first and second inlets 116, 110 may become more equal as a viscosity of the fluid composition 36 increases, as a velocity of the fluid composition 36 decreases, as a density of the fluid composition 36 decreases, and/or as a ratio of desired fluid to undesired fluid in the fluid composition 36 increases.

[0146] A resistance to flow of the fluid composition 36 through the flow chamber 84 may increase as flow through the first and second inlets 116, 110 becomes less equal.

[0147] The fluid composition 36 may flow to the first inlet 116 via a first flow passage 112 which is oriented generally tangential to the flow chamber 84. The fluid composition 36 may flow to the second inlet 110 via a second flow passage 114 which is oriented generally tangential to the flow chamber 84, and the second passage 114 may receive the fluid composition 36 from a branch of the first flow passage 112.

[0148] It is to be understood that the various examples described above may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present disclosure. The embodiments illustrated in the drawings are depicted and described merely as examples of useful applications of the principles of the disclosure, which are not limited to any specific details of these embodiments.

[0149] Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such

changes are within the scope of the principles of the present disclosure. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims and their equivalents.

1. A system for variably resisting flow of a fluid composition in a subterranean well, the system comprising:

a first flow passage; and

a first set of one or more branch passages which intersect the first flow passage, whereby a proportion of the fluid composition diverted from the first flow passage to the first set of branch passages varies based on at least one of a) viscosity of the fluid composition, and b) velocity of the fluid composition in the first flow passage.

2. The system of claim 1, wherein the proportion increases in response to increased viscosity of the fluid composition.

3. The system of claim 1, wherein the proportion increases in response to decreased velocity of the fluid composition in the first flow passage.

4. The system of claim 1, wherein the first set of branch passages direct the fluid composition to a first control passage of a flow path selection device, and wherein the flow path selection device selects which of multiple flow paths a majority of fluid flows through from the device, based at least partially on the proportion of the fluid composition diverted to the first control passage.

5. The system of claim 4, further comprising a second flow passage, and a second set of one or more branch passages which intersect the second flow passage, whereby a proportion of the fluid composition diverted from the second flow passage to the second set of branch passages increases with increased viscosity of the fluid composition, and increases with decreased velocity of the fluid composition in the second flow passage.

6. The system of claim 5, wherein the second flow passage directs the fluid composition to a second control passage of the flow path selection device, and wherein the flow path selection device selects which of the multiple flow paths the majority of fluid flows through from the device, based on a ratio of flow rates of the fluid composition through the first and second control passages.

7. The system of claim 6, wherein the ratio of the flow rates through the first and second control passages varies with respect to a ratio of desired fluid to undesired fluid in the fluid composition.

8. The system of claim 4, further comprising a second flow passage, wherein the second flow passage directs the fluid composition to a second control passage of the flow path selection device, and wherein the flow path selection device selects which of the multiple flow paths the majority of fluid flows through from the device, based on a ratio of flow rates of the fluid composition through the first and second control passages.

9. The system of claim 1, wherein the first set of branch passages includes multiple branch passages spaced apart along the first flow passage.

10. The system of claim 9, further comprising a chamber at each of multiple intersections between the first flow passage and the branch passages.

11. The system of claim 10, wherein each of the chambers has a fluid volume, and wherein the volumes decrease in a direction of flow of the fluid composition through the first flow passage.

12. The system of claim 9, wherein a flow area of the first flow passage increases at each of multiple intersections between the first flow passage and the first set of branch passages.

13-23. (canceled)

24. A system for variably resisting flow of a fluid composition in a subterranean well, the system comprising:
a flow chamber, and

wherein a majority of the fluid composition enters the chamber in a direction which changes based on a ratio of desired fluid to undesired fluid in the fluid composition.

25. The system of claim 24, wherein the fluid composition more directly flows through the chamber to an outlet of the chamber in response to an increase in the ratio.

26. The system of claim 24, wherein the majority of the fluid composition enters the chamber via one of multiple inlets, and wherein the one of the multiple inlets is selected based on the ratio.

27. The system of claim 26, wherein a first one of the multiple inlets directs the fluid composition to flow more directly toward an outlet of the chamber as compared to a second one of the multiple inlets.

28. The system of claim 27, wherein the first inlet directs the fluid composition to flow more radially relative to the outlet as compared to the second inlet.

29. The system of claim 27, wherein the second inlet directs the fluid composition to spiral more about the outlet as compared to the first inlet.

30. The system of claim 24, wherein the chamber is generally cylindrical-shaped, and wherein the fluid composition spirals more within the chamber as the ratio decreases.

31. The system of claim 24, further comprising a flow path selection device that selects which of multiple flow paths the majority of the fluid composition flows through from the device, based on the ratio of desired fluid to undesired fluid in the fluid composition.

32. The system of claim 31, wherein the flow path selection device includes a first control port, and wherein a flow rate of the fluid composition through the first control port affects which of the multiple flow paths the majority of the fluid composition flows through.

33. The system of claim 32, wherein the flow rate of the fluid composition through the first control port varies based on the ratio of desired fluid to undesired fluid in the fluid composition.

34. The system of claim 32, wherein the flow path selection device further includes a second control port, and wherein a ratio of the flow rates of the fluid composition through the first and second control ports affects which of the multiple flow paths the majority of fluid composition flows through from the device.

35. The system of claim 34, wherein the ratio of the flow rates through the first and second control ports varies with respect to the ratio of desired fluid to undesired fluid in the fluid composition.

36. The system of claim 32, wherein the fluid composition flows to the first control port via at least one control passage which connects to a flow passage through which the fluid composition flows, and wherein a flow rate of the fluid composition from the flow passage to the control passage varies based on the ratio of desired fluid to undesired fluid in the fluid composition.

37. The system of claim 32, wherein the flow path selection device includes a second control port, wherein a flow rate of the fluid composition through the second control port affects which of the multiple flow paths the majority of the fluid composition flows through from the device, wherein the fluid composition flows to the second control port via at least one control passage through which the fluid composition flows, wherein the control passage connects to at least one flow passage, and wherein a flow rate of the fluid composition from the flow passage to the control passage varies based on the ratio of desired fluid to undesired fluid in the fluid composition.

38. A system for variably resisting flow of a fluid composition in a subterranean well, the system comprising:

a flow chamber, and

wherein a majority of the fluid composition enters the chamber in a direction which changes based on a velocity of the fluid composition.

39. The system of claim 38, wherein the fluid composition more directly flows through the chamber to an outlet of the chamber in response to a decrease in the velocity.

40. The system of claim 38, wherein the majority of the fluid composition enters the chamber via one of multiple inlets, and wherein the one of the multiple inlets is selected based on the velocity.

41. The system of claim 40, wherein a first one of the multiple inlets directs the fluid composition to flow more directly toward an outlet of the chamber as compared to a second one of the multiple inlets.

42. The system of claim 41, wherein the first inlet directs the fluid composition to flow more radially relative to the outlet as compared to the second inlet.

43. The system of claim 41, wherein the second inlet directs the fluid composition to spiral more about the outlet as compared to the first inlet.

44. The system of claim 38, wherein the chamber is generally cylindrical-shaped, and wherein the fluid composition spirals more within the chamber as the velocity increases.

45. The system of claim 38, further comprising a flow path selection device that selects which of multiple flow paths the majority of the fluid composition flows through from the device, based on the velocity of the fluid composition.

46. A variable flow resistance system for use in a subterranean well, the variable flow resistance system comprising:

a flow chamber having an outlet, and at least first and second inlets, wherein a fluid composition which enters the flow chamber via the second inlet opposes flow of the fluid composition which enters the flow chamber via the first inlet, whereby a resistance to flow of the fluid composition through the flow chamber varies with a ratio of flows through the first and second inlets.

47. The system of claim 46, wherein a resistance to flow of the fluid composition through the flow chamber decreases as flow through the first and second inlets becomes more equal.

48. The system of claim 47, wherein flow through the first and second inlets becomes more equal as a viscosity of the fluid composition increases.

49. The system of claim 47, wherein flow through the first and second inlets becomes more equal as a velocity of the fluid composition decreases.

50. The system of claim 47, wherein flow through the first and second inlets becomes more equal as a density of the fluid composition decreases.

51. The system of claim **47**, wherein flow through the first and second inlets becomes more equal as a ratio of desired fluid to undesired fluid in the fluid composition increases.

52. The system of claim **46**, wherein a resistance to flow of the fluid composition through the flow chamber increases as flow through the first and second inlets becomes less equal.

53. The system of claim **46**, wherein the fluid composition flows to the first inlet via a first flow passage which is oriented

generally tangential to the flow chamber, and wherein the fluid composition flows to the second inlet via a second flow passage which is oriented generally tangential to the flow chamber.

54. The system of claim **53**, wherein the second passage receives the fluid composition from a branch of the first flow passage.

* * * * *

United States Patent

[11] 3,566,900

[72]	Inventor	Jay I. Black Orange, Conn.
[21]	Appl. No.	803,758
[22]	Filed	Mar. 3, 1969
[45]	Patented	Mar. 2, 1971
[73]	Assignee	Avco Corporation Stratford, Conn.

[56]

References Cited

UNITED STATES PATENTS

3,314,294	4/1967	Colston	137/81.5X
3,403,842	10/1968	Roche	137/81.5X
3,488,948	1/1970	Cornett et al.....	137/81.5X

Primary Examiner—William R. Cline
Attorneys—Charles M. Hogan and Gary M. Gron

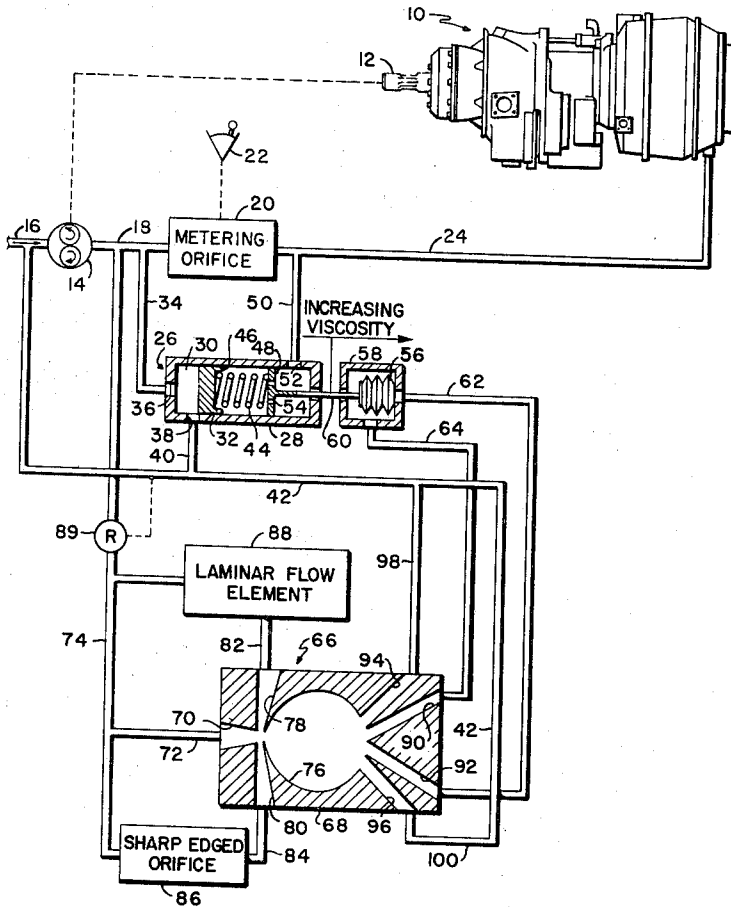
**[54] FUEL CONTROL SYSTEM AND VISCOSITY
SENSOR USED THEREWITH
6 Claims, 1 Drawing Fig.**

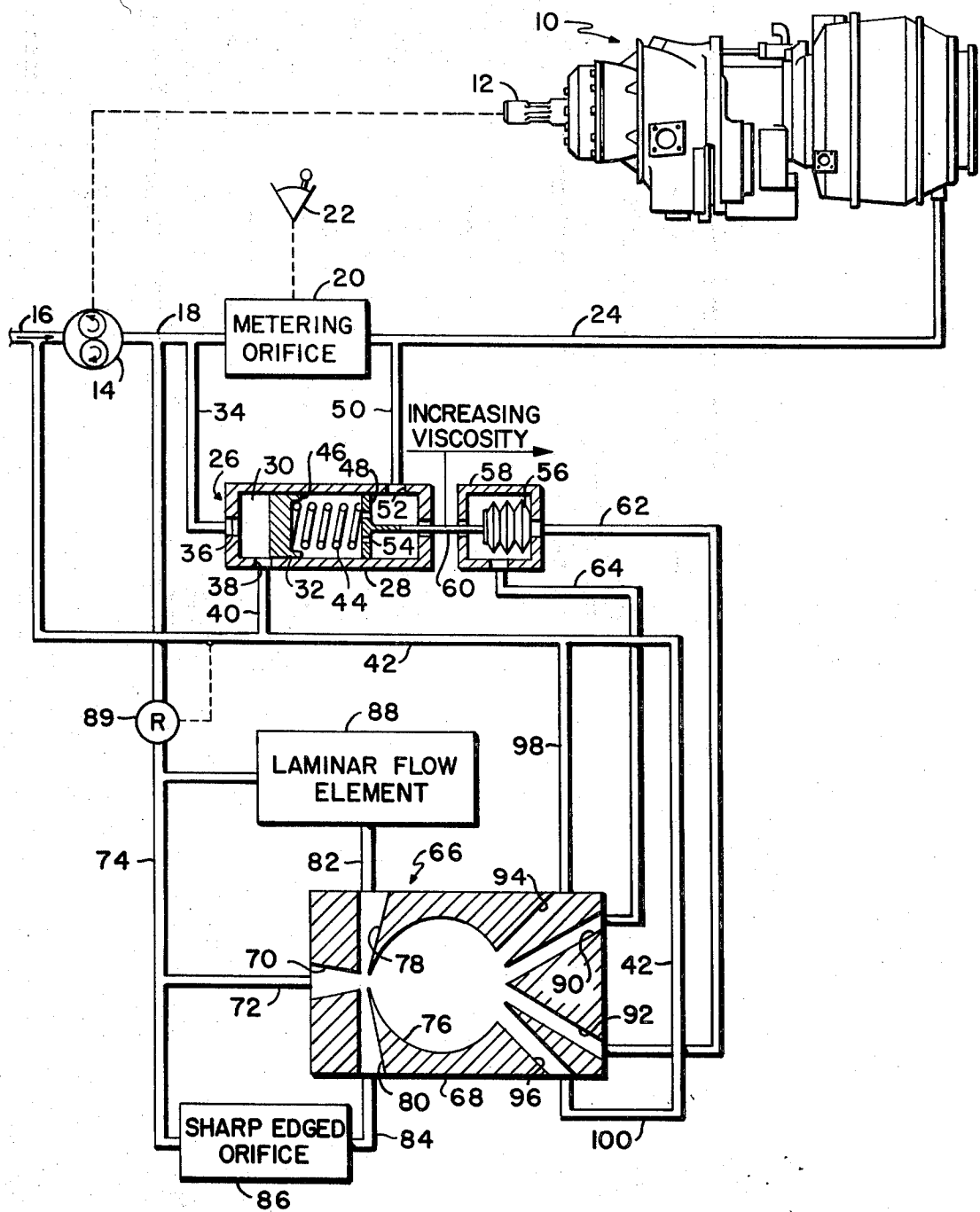
[52] U.S. Cl..... 137/83,
137/81.5, 60/243, 60/39.28

[51] **Int. Cl.**..... **F15c 1/04**
[50] **Field of Search**.....

[50] **Field of Search**..... FISC 1/04
..... 137/81.5,
83; 73/55, 205 (L), 357; 60/243, 39.28

ABSTRACT: The disclosure illustrates a fuel viscosity sensor incorporated in a fuel control system for a gas turbine engine to assure a constant engine power output irrespective of fuel viscosity changes. The viscosity sensor comprises a proportional fluidic amplifier having a laminar flow element, series connected with one control jet. The fluidic amplifier is connected to the pressurized fuel supply and its output is proportional to the fuel viscosity. The pressure output from this amplifier is used to correct a flow-metering device for viscosity changes.





INVENTOR.

JAY I. BLACK

BY *Charles M. Hogan*
Gary M. Iron
ATTORNEYS.

FUEL CONTROL SYSTEM AND VISCOSITY SENSOR USED THEREWITH

The present invention relates to viscosity sensing devices and more specifically to flow control systems used in combination with this type of device.

In recent years there have been significant design improvements that enable gas turbine fuel control systems to maintain the selected power output of an engine at a level practically independent of uncontrolled parameters. One parameter that has not yet been effectively compensated for is the variation in the energy content of the fuel used by the engine. A variation in this parameter has an immediate and substantial effect on the power output of the engine. It has been found that this characteristic of the fuel is a direct function of the fuel viscosity, which is affected by the fuel type and fuel temperature.

While many present-day fuel controls provide a manual adjustment for fuel type, practically none automatically compensate for fuel type and fuel temperature. The net result is that an engine will have a different power output for different fuel types and fuel temperatures. There have been a few attempts to automatically compensate for fuel temperature but temperature accounts for only about 50 percent of the metered fuel flow error.

Therefore, it is an object of the present invention to provide a fuel control system for an engine of the above general type which efficiently, economically and effectively compensates for changes of fuel viscosity to provide a uniform controlled power output.

It is a further and more specific object of the present invention to provide a simplified and effective viscosity sensor for use with the above system or other types of liquid flow systems.

The objects of the invention are achieved in one aspect by providing a fluidic viscosity-sensing device comprising a power stream discharge means adapted to be connected to a supply of the pressurized fuel or liquid whose viscosity is to be measured. A means, also connected to the pressurized liquid, is provided for discharging at least one control jet against the discharge means power stream. The control jet deflects the power stream proportional to the flow of the control jet. A means is provided to receive the power stream and provide a pressure output proportional to the deflection of the power stream. A flow element means, such as a laminar flow element, is series connected between the control jet and the pressurized fuel to vary the flow to the control jet discharge means responsive to the changes in viscosity of the fuel. As a result, the pressure output of the fluidic device is proportional to the viscosity of the liquid. 3

In another aspect of the present invention, other objects outlined above are achieved by providing the fluidic viscosity sensor in a fuel control system and connecting the fuel supply to the fluidic device so that the fuel metered to an engine is varied as a function of the fuel viscosity to compensate for the effects of viscosity on the fuel energy content.

The above and other related objects and features of the present invention will be apparent from a reading of the following description of the disclosure found in the accompanying drawing and the novelty thereof pointed out in the appended claims.

The single FIGURE of the drawing is a diagrammatic illustration of a viscosity sensor embodying the present invention, along with a gas turbine engine and fuel control system in which the invention may be used.

Referring now to the drawing, there is shown a gas turbine engine 10 of the turboshaft type that may be used in propeller-driven aircraft, rotary-wing aircraft, or marine vehicles. The details of such an engine are well known to those skilled in the art so that it is not necessary for a clear understanding of the present invention to explain the components and functions of the engine in detail.

It is sufficient for the present purposes to say that the engine has a series of fuel nozzles for injecting a metered amount of

fuel into a combustion chamber where the fuel is mixed with pressurized air and ignited to provide a propulsive gas stream. This stream is discharged to drive, among other things, a power turbine (not shown) that drives a power output shaft 12.

The fuel nozzles of the engine 10 receive a supply of fuel from a fuel control system comprising an engine-driven main fuel pump 14, receiving a suitable supply of fuel from an inlet conduit 16 and pressurizing it for delivery through conduit 18 to a metering orifice 20. The metering orifice 20 has a variable area primarily determined by an operator-controlled power lever 22 to vary the flow through the metering orifice to a nozzle supply conduit 24, extending to the engine nozzles. The power lever 22 input to the fuel metering orifice 20 is modified by a number of engine operating parameters to provide proper transient and steady state operating conditions for the engine 10. These inputs are apparent to those skilled in the art and need not be outlined in this discussion of the present invention.

A pressure-regulating device 26 is provided to maintain a constant pressure differential across the orifice 20 in order to have the flow through the orifice 20 a direct function of its area. The pressure-regulating device 26 comprises a housing 28, having an internal chamber 30, in which a piston valve element 32 is displaceable. A conduit 34 is connected to conduit 18 and extends to a port 36 at one end of chamber 30 to expose the outer face of valve element 32 to fuel pressure upstream of orifice 20. An outlet port 38, at the same end of chamber 30, connects with a discharge conduit 40 that extends to a main low-pressure discharge conduit 42, thereby providing a bypass flow path upstream of metering orifice 20.

The valve element 32 is urged toward a position restricting the bypass flow through port 39 by a spring 44 acting on a recess 46 of valve element 32 and a flanged plate 48 positioned in the opposite end of chamber 30. The opposite end of chamber 30 is connected to the nozzle supply conduit 24 downstream of metering orifice 20 by a conduit 50 and a port 52. A series of ports 54 in plate 48 enable the metering orifice downstream pressure to be applied to the inner face of valve element 32.

The valve element 32 is displaced to vary the bypass flow upstream of the metering orifice 20 until the pressure in conduit 18 is a predetermined pressure above the level in conduit 24. This pressure differential is automatically maintained at the level of force with which the spring 44 acts against the valve element 32.

As stated previously, it is necessary to compensate the flow of the fuel to the engine 10 to maintain a given power output, irrespective of fuel viscosity changes. For this purpose, the force with which the spring 44 acts against the valve element 32 is varied by a bellows 56 housed in a chamber 58 and having an output shaft 60 connected to the plate 48. The bellows 56 expands and contracts in response to liquid pressure signals from a pair of output pressure conduits 62 and 64 of a fluidic viscosity sensor 66 embodying the present invention.

The viscosity sensor 66 comprises a housing 68 having a power stream nozzle 70 supplied with fuel or other liquid from a supply conduit 72. The supply conduit 72 is connected to a main viscosity sensor supply conduit 74 extending to pump discharge conduit 18. The nozzle 70 discharges a power stream into a chamber 76. The power stream, thus discharged, is deflected in response to the resultant flow of control jets discharged from a pair of oppositely positioned control ports 78 and 80. The ports 78, 80 are respectively supplied with pressurized fuel or other liquid from conduits 82, 84 extending to the main supply conduit 74. The flow from port 80 is controlled by a sharp-edged orifice 86, series connected with the port 80. As described later, the sharp-edged orifice 86 may have an adjustable variable area. The flow from port 78 is controlled by a laminar flow element 88, series connected between port 78 and the main supply conduit 74. A suitable regulator 89 is positioned upstream of conduit 74 to maintain a constant pressure above the pressure in return conduit 42 thereby maintaining a constant pressure across the sensor.

The power stream, discharged from nozzle 70, impinges on a pair of receiver ports 90, 92 respectively connected to the conduits 64 and 62. The receiver ports 90, 92 are positioned so that when the power stream from nozzle 70 is undeflected, equal pressures are experienced in the ports. When the stream is deflected by varying flows from the control ports 78, 80, the pressure in one of the receiver ports will be higher than in the other. A pair of drain ports 94, 96 are respectively positioned adjacent the receiver ports 90, 92. These ports connect with discharge conduits 98, 100 extending to the main low-pressure discharge conduit 42.

The viscosity sensor 66 operates in the following manner. When fuel pump 14 pressurizes fuel, the viscosity sensor supply conduit 74 provides a flow path for fuel to power stream nozzle 70, thereby causing a power stream to be discharged into chamber 76. At the same time, fuel is caused to flow through the laminar flow element 88 and the sharp-edged orifice 86 to the control ports 78, 80. The regulator 89 maintains a constant pressure differential across the viscosity sensor 66 and the fuel will flow through the laminar element as a direct function of density and as an inverse function of the fuel viscosity. For the sharp-edged orifice, the flow therethrough is a direct function of density. Accordingly, the relative flow through the elements and from the control ports 78, 80 is an inverse function of fuel viscosity times a constant which reflects the sizes of the flow elements. Therefore, as fuel viscosity increases, the flow through the laminar flow element 88 is decreased relative to orifice 86. As a result, the power stream is deflected toward receiver port 90, thereby increasing the pressure on conduit 64 relative to the pressure on conduit 62. This in turn causes the bellows 56 to contract and pull plate 48 away from the valve element 32. The force of spring 44 then decreases, thereby permitting a smaller pressure differential across the metering orifice 20 and a resultant smaller flow.

The net result then is that the flow set by the area of the metering orifice 20 is corrected by variations in fuel viscosity. Since the fuel energy level increases with increasing viscosity, the viscosity-sensing device 66 and the pressure-regulating device 26 are connected to correct flow in a decreasing direction for an increase in fuel viscosity. Therefore, fuel with a constant selected energy level is delivered to the engine 10 to maintain a given power output irrespective of fuel viscosity changes. It is apparent to those skilled in the art that the pressure-regulating device 26 and the viscosity-sensing device 66 may be adjusted to achieve this result. One way to adjust the device is to provide the sharp-edged orifice 86 with a variable area so that the relative flows from the control ports 78, 80 may be adjusted to give pressure outputs for a given level of fuel viscosity.

The viscosity sensor incorporated in the fuel control system illustrated above provides a highly simplified and effective means of compensating for fuel viscosity in that it receives its power directly from the fuel supply to be compensated and has a minimum of working parts. However, the viscosity sensor 66 is not limited to such a use but may be used in many control systems to sense the viscosity of a pressurized liquid.

I claim:

1. In a gas turbine engine having a power output proportional to the rate of flow of fuel supplied to the engine and including:

- means for pressurizing a source of fuel;
- means for providing a flow path from the fuel pressurizing means to said engine;
- a fuel metering orifice interposed in said flow path and having a variable area for varying the fuel flow rate to said engine and the power output thereof;
- means for maintaining a constant predetermined pressure

differential across the orifice, whereby fuel flow through said fuel metering orifice is proportional to the area thereof;

the improvement comprising:

- a fluidic device comprising a nozzle and a means for connecting said nozzle to said fuel flow path means whereby a power stream is discharged from said nozzle, receiver means positioned so that said power stream impinges on said receiver means, and a control jet means connected to said fuel flow path means and adapted to deflect said power stream responsive to flow through said control jet means, said control jet means including a means responsive to at least the viscosity parameter of said fuel for varying the flow through said control jet means; and
- means connected to said receiver means and responsive to the pressure output of said fluidic device for compensating said pressure differential means to vary the predetermined pressure differential across said orifice;
- whereby the power output of said engine is maintained at a level proportional to the area of said fuel metering orifice irrespective of the variation in said fuel parameter.

2. Apparatus as in claim 1 wherein the flow-varying means of said fluidic device comprises a laminar flow element through which said fuel is passed whereby fuel flow from said control jet means is proportional to the viscosity of said fuel.

3. Apparatus as in claim 1 wherein:

the control jet means of said fluidic device comprises a pair of control jet discharge ports on opposite sides of said power stream and means for forming flow paths from said ports to said fuel flow path means so that the power jet is deflected as a function of the relative flow from said control jet discharge ports;

said flow-varying means comprises a laminar flow element interposed in one of said control jet flow paths whereby the power stream is deflected in response to changes in viscosity of said fuel.

4. Apparatus as in claim 3 wherein said flow-varying means further comprises a sharp-edged orifice interposed in the other of said control jet flow paths.

5. Apparatus as in claim 4 wherein said sharp-edged orifice has an adjustable variable area whereby the power stream from said fluidic device may be set in an undeflected position for a given level of viscosity.

6. Apparatus as in claim 5 wherein said means for maintaining a constant predetermined pressure differential across said fuel metering orifice comprises:

means for providing a bypass flow path from said fuel flow path means upstream of said fuel metering orifice to a low pressure discharge point;

a valve element interposed in said flow path for varying the bypass flow as a function of the displacement of said valve element;

means for applying the fuel flow path pressure upstream of said fuel metering orifice to one face of said valve element whereby the valve element is urged in a direction to increase bypass flow;

means for applying the fuel flow path pressure downstream from said fuel metering orifice to the opposite face of said valve element;

means for yieldably urging said opposite face of the valve element with a predetermined force whereby the valve element controls the bypass flow to maintain said predetermined pressure level across the fuel metering orifice;

said compensating means comprises a means responsive to said received pressure for varying the predetermined force which said yieldable urging means exerts on said valve element.



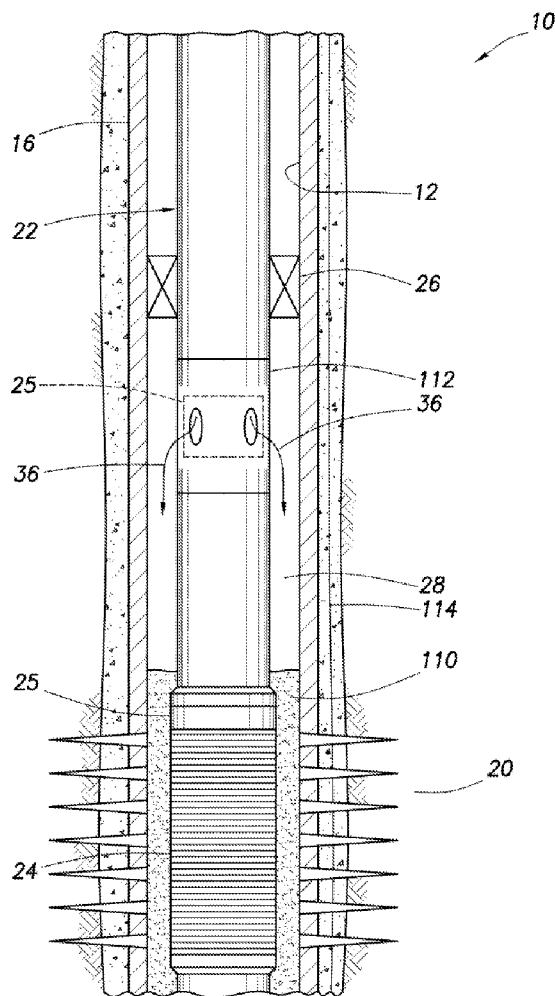
US 20110042092A1

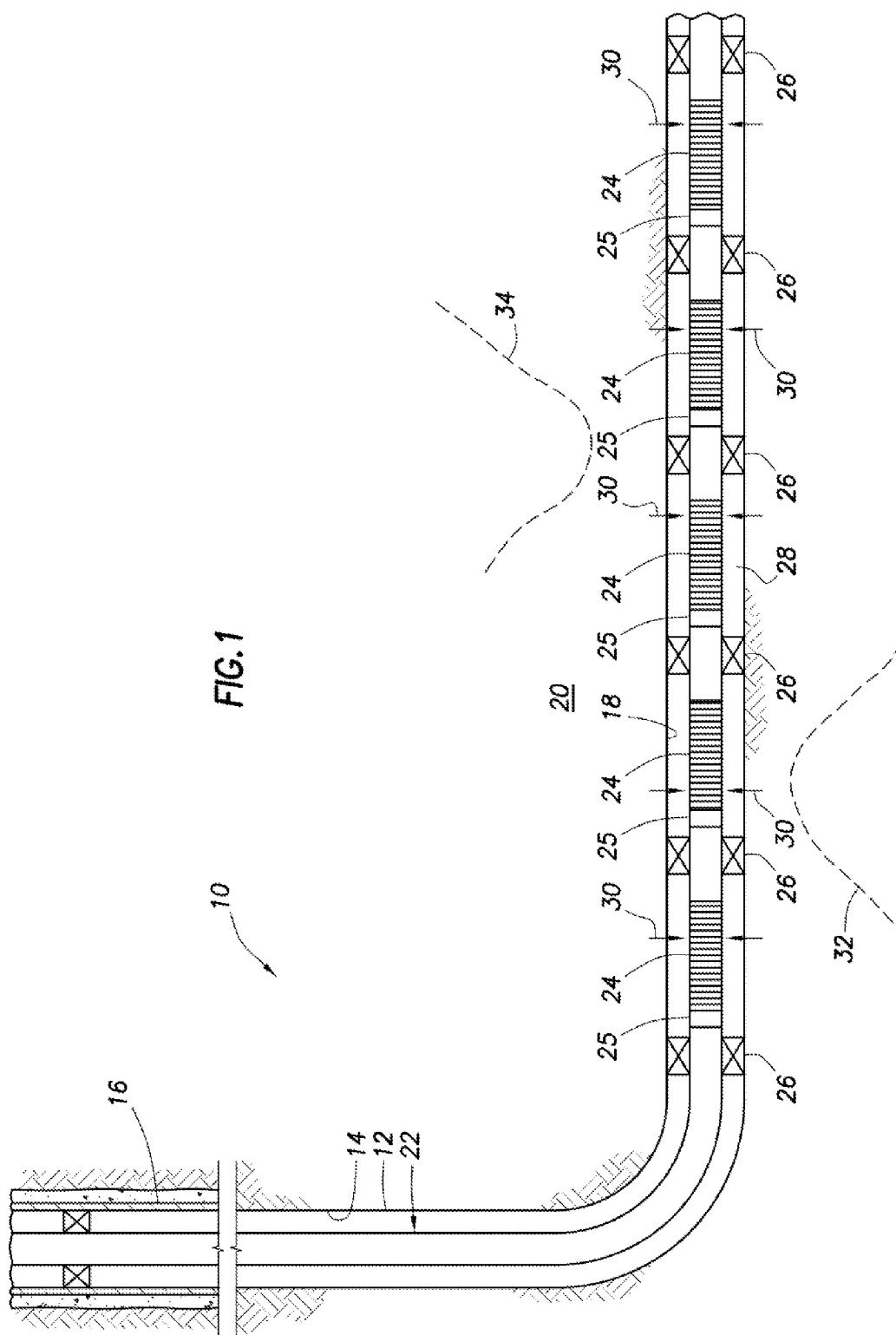
(19) **United States**(12) **Patent Application Publication**
FRIPP et al.(10) **Pub. No.: US 2011/0042092 A1**(43) **Pub. Date: Feb. 24, 2011**(54) **ALTERNATING FLOW RESISTANCE
INCREASES AND DECREASES FOR
PROPAGATING PRESSURE PULSES IN A
SUBTERRANEAN WELL****Related U.S. Application Data**

(63) Continuation-in-part of application No. 12/700,685, filed on Feb. 4, 2010, which is a continuation-in-part of application No. 12/542,695, filed on Aug. 18, 2009, now abandoned.

(75) Inventors: **Michael L. FRIPP**, Carrollton, TX
(US); **Jason D. DYKSTRA**,
Carrollton, TX (US)**Publication Classification**(51) **Int. Cl.**
E21B 34/06 (2006.01)
F16L 55/027 (2006.01)
(52) **U.S. Cl.** **166/319**; 166/373; 138/42
(57) **ABSTRACT**Correspondence Address:
SMITH IP SERVICES, P.C.
P.O. Box 997
Rockwall, TX 75087 (US)(73) Assignee: **HALLIBURTON ENERGY
SERVICES, INC.**, Houston, TX
(US)(21) Appl. No.: **12/792,095**(22) Filed: **Jun. 2, 2010**

A method of propagating pressure pulses in a well can include flowing a fluid composition through a variable flow resistance system which includes a vortex chamber having at least one inlet and an outlet, a vortex being created when the fluid composition spirals about the outlet, and a resistance to flow of the fluid composition alternately increasing and decreasing. The vortex can be alternately created and dissipated in response to flowing the fluid composition through the system. A well system can include a variable flow resistance system which propagates pressure pulses into a formation in response to flow of a fluid composition from the formation.





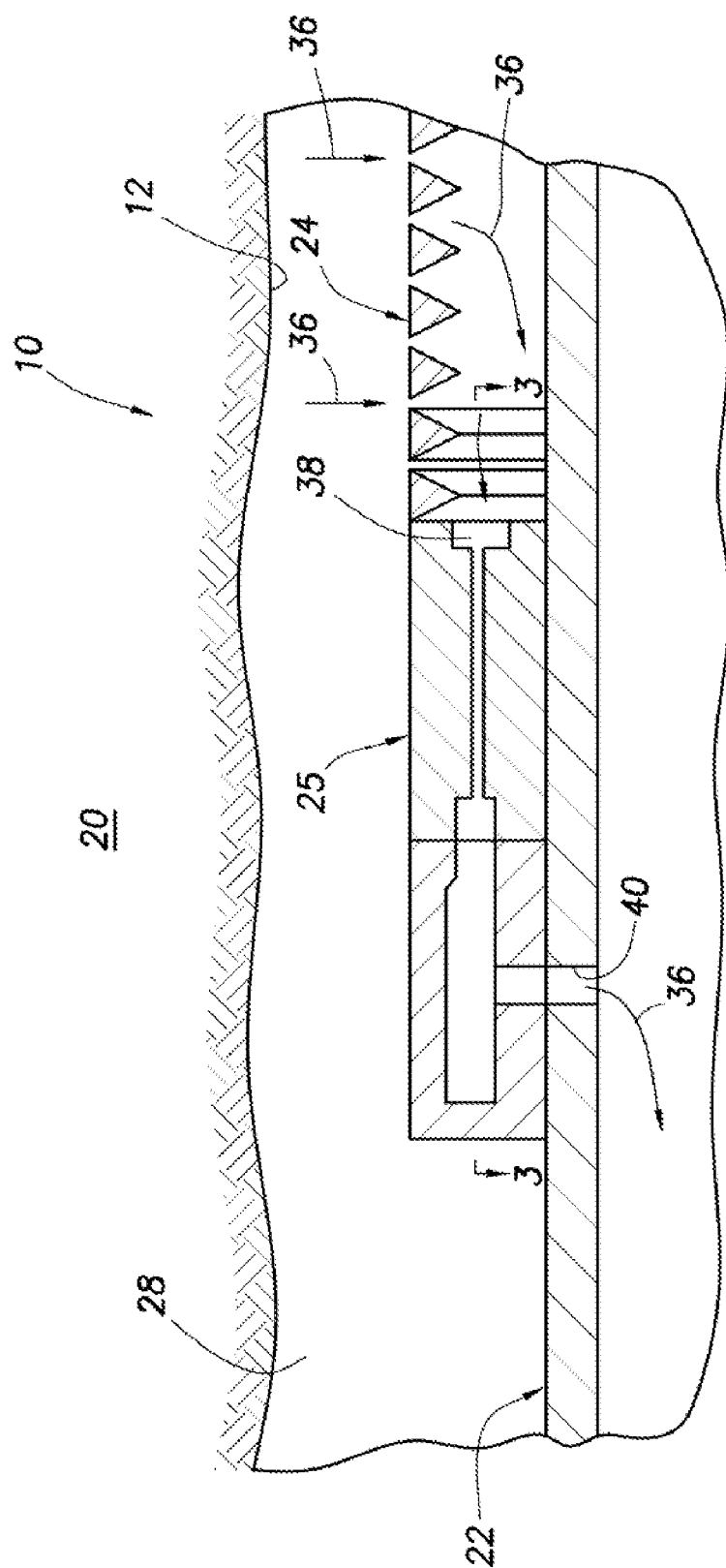


FIG. 2

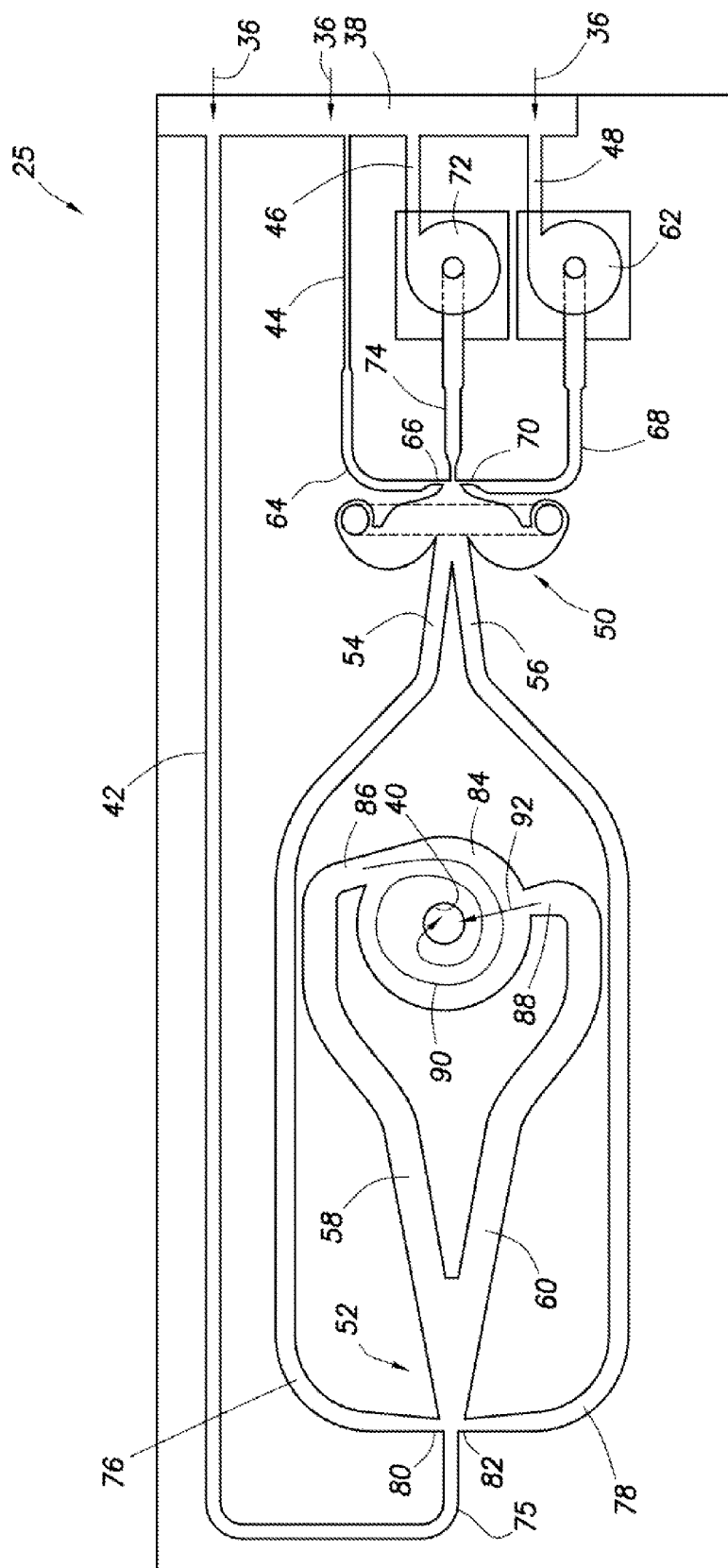


FIG. 3

25

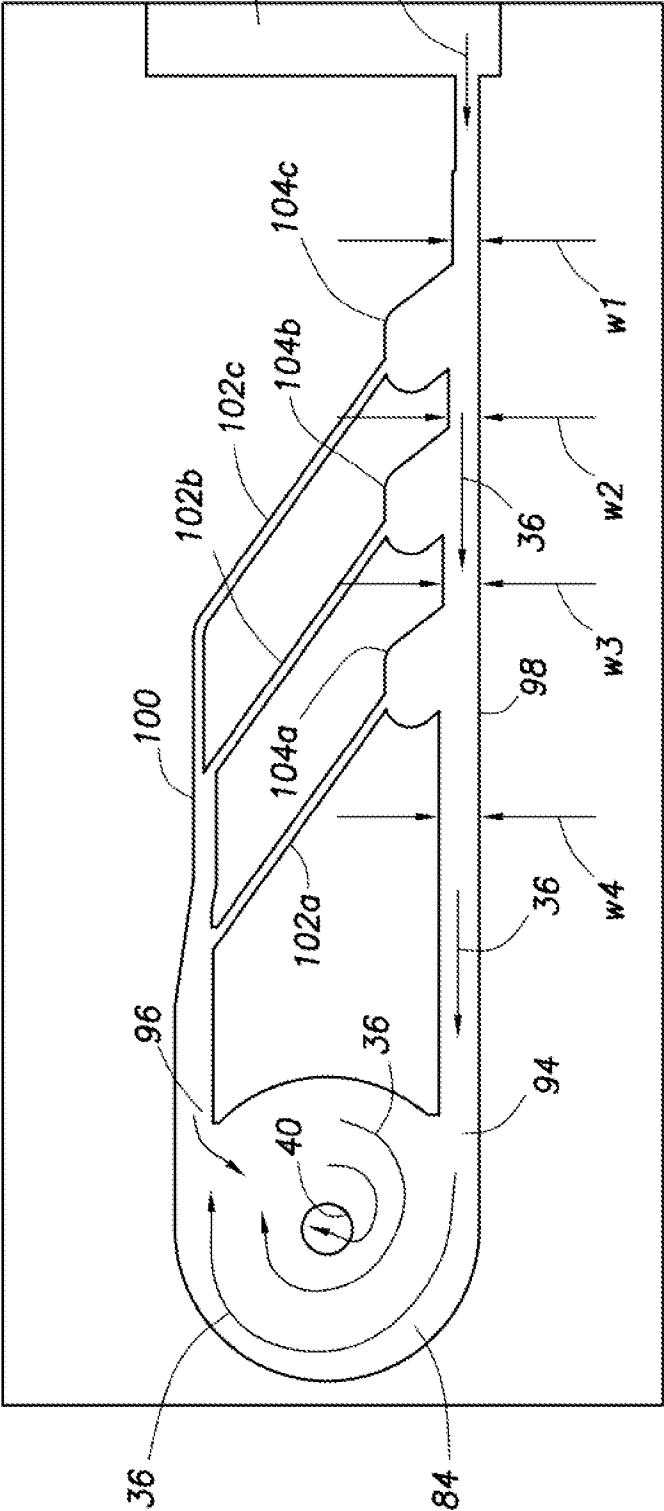


FIG. 4A

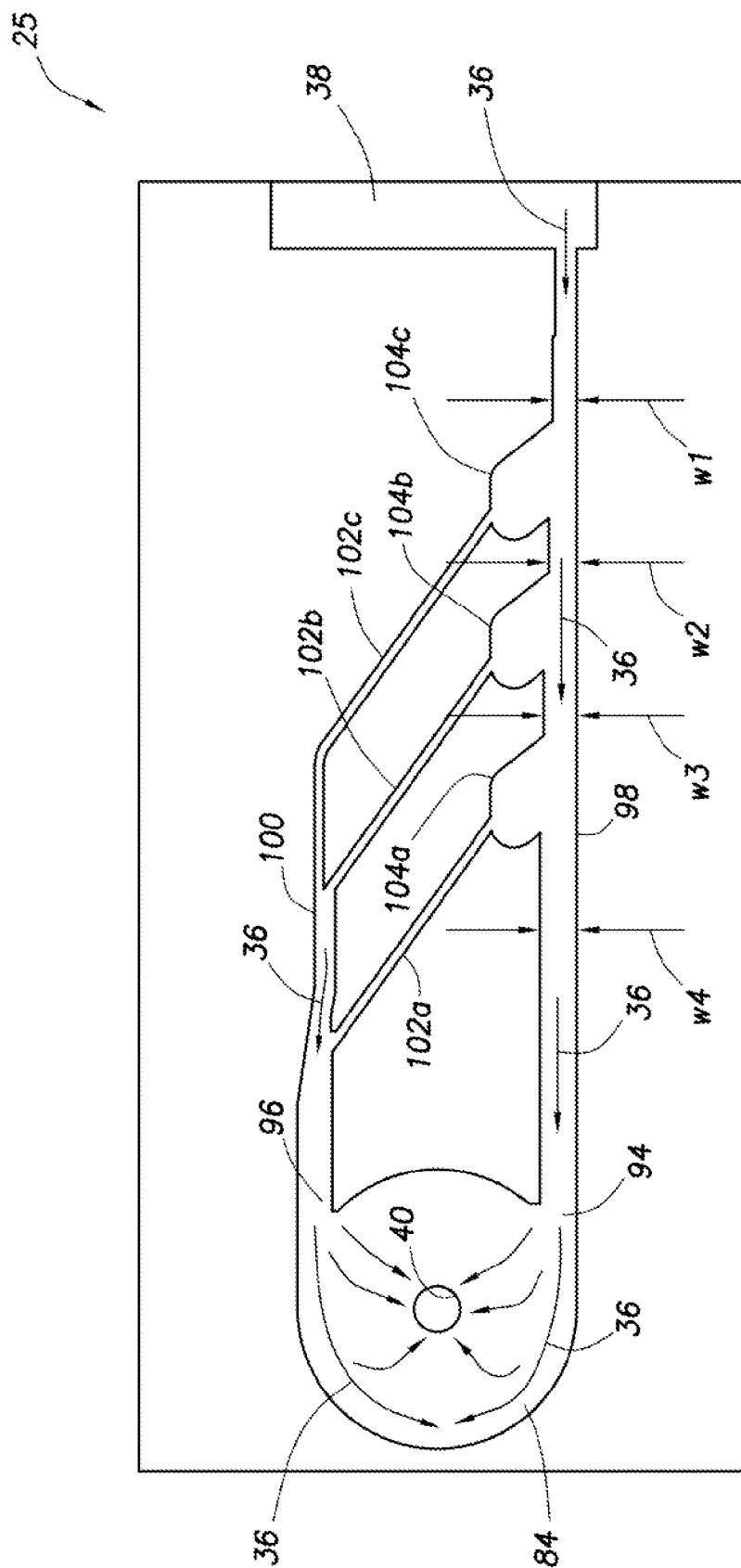


FIG. 4B

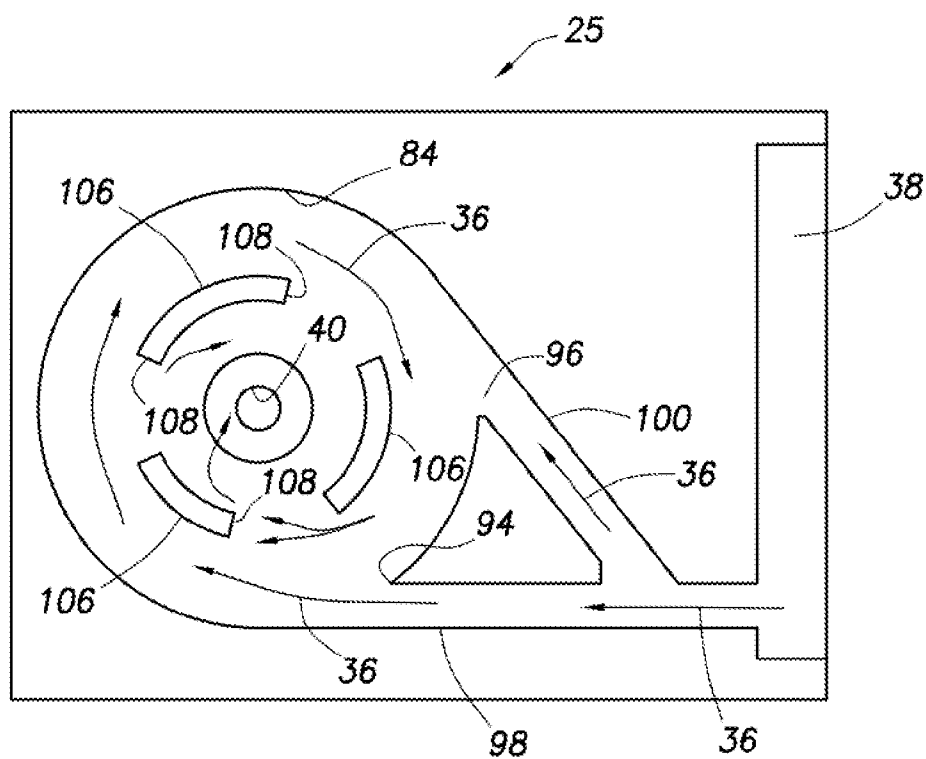


FIG. 5A

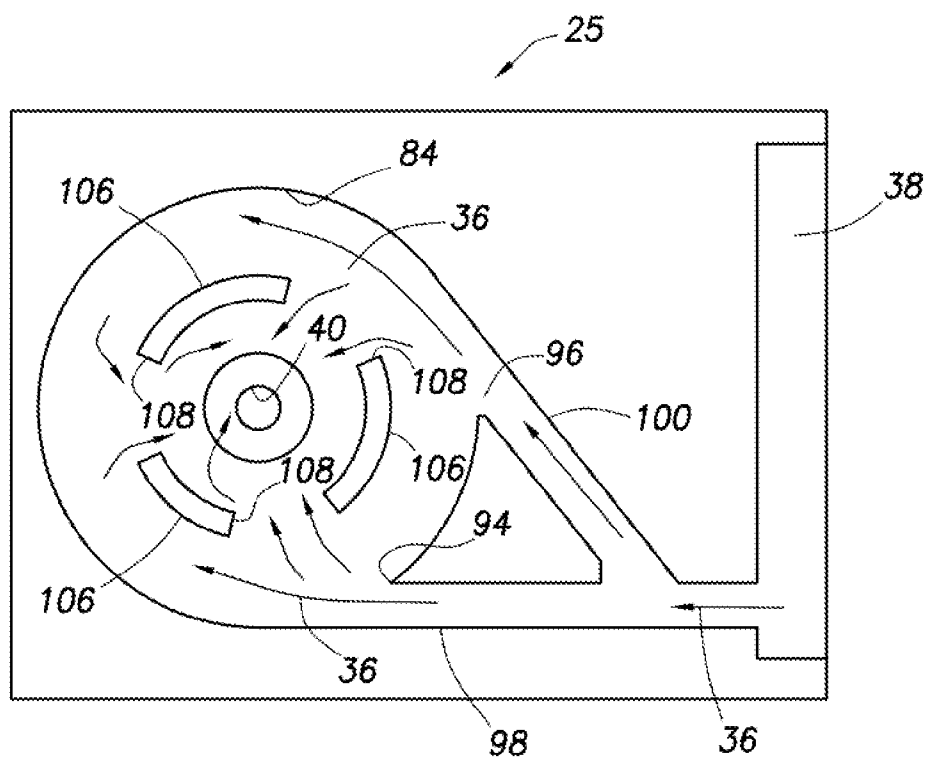


FIG. 5B

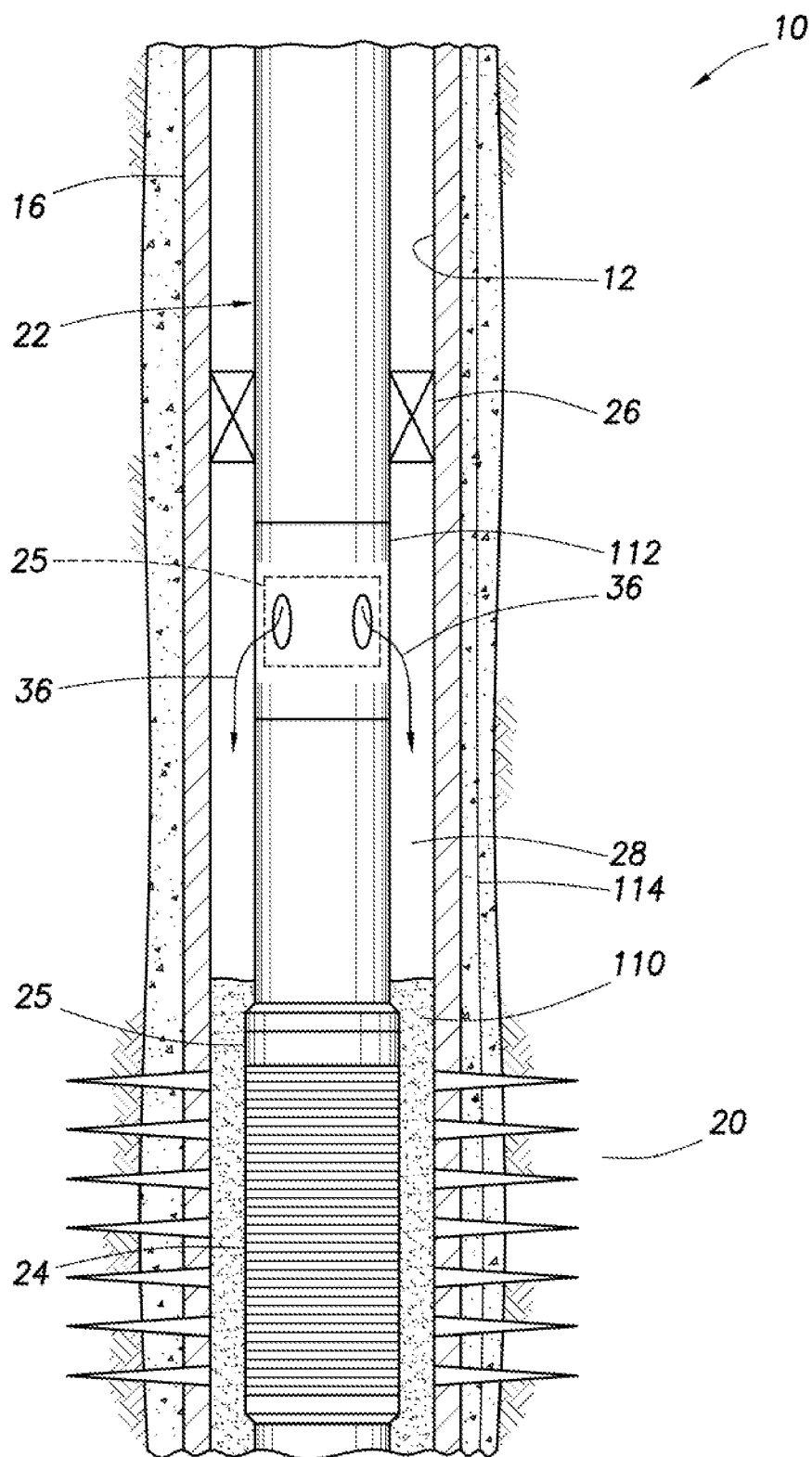


FIG. 6

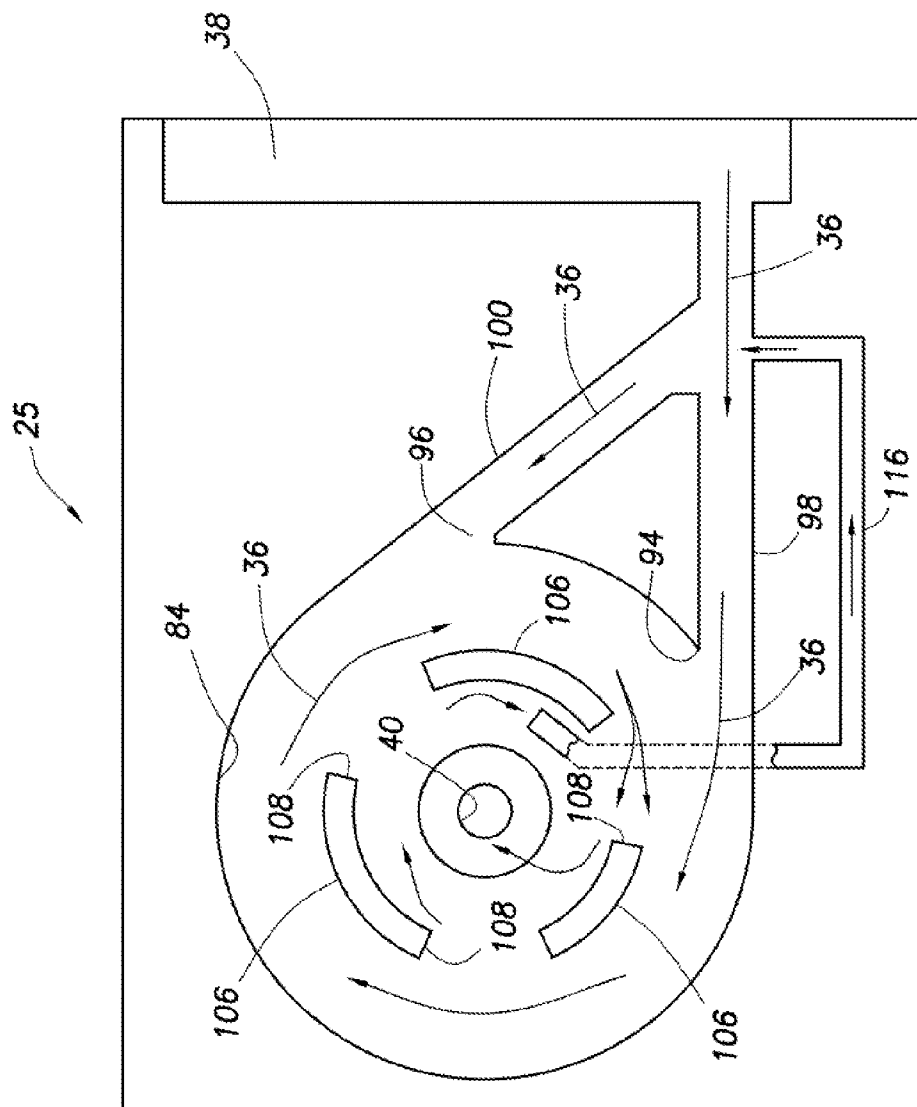
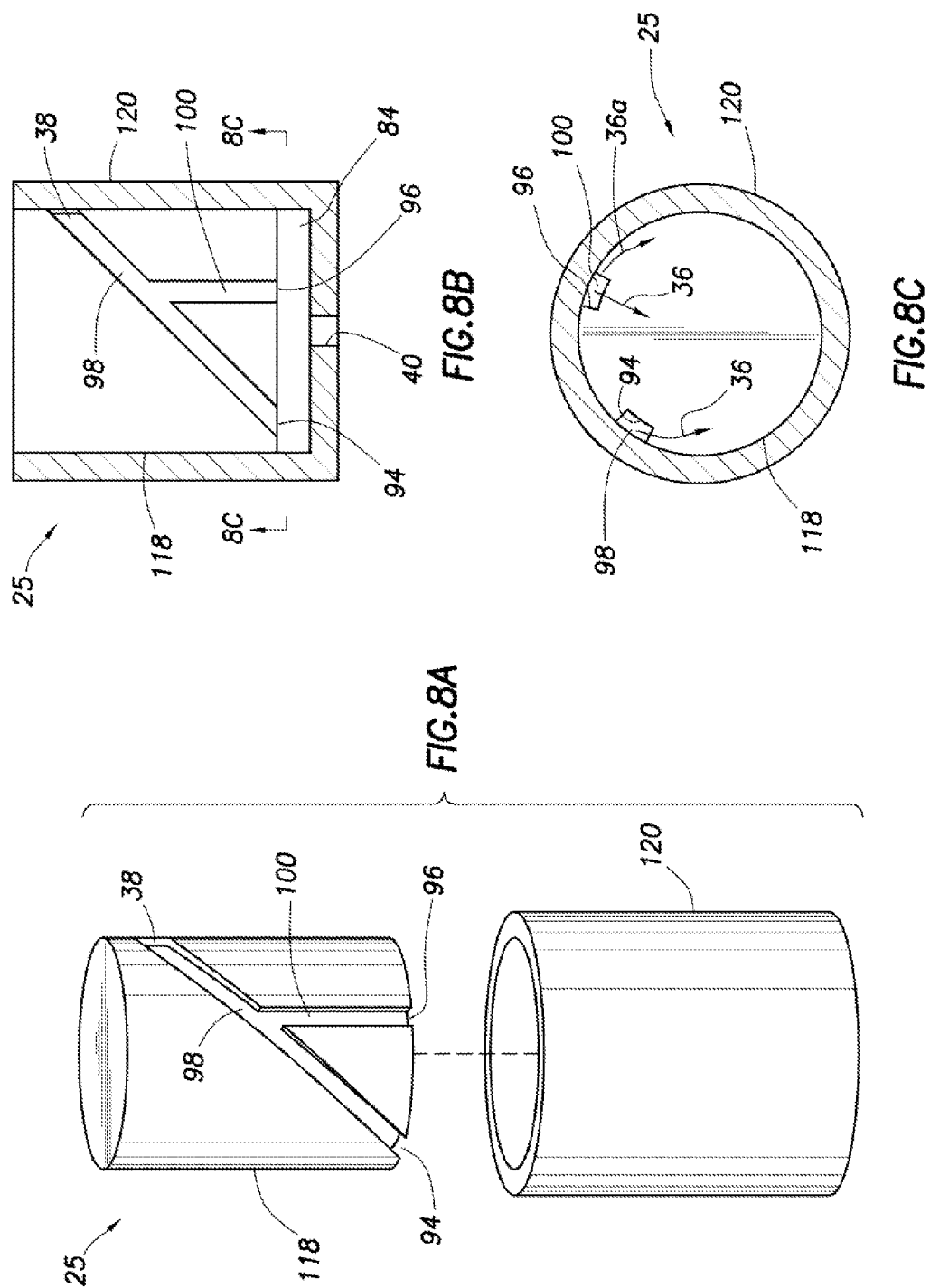


FIG. 7



**ALTERNATING FLOW RESISTANCE
INCREASES AND DECREASES FOR
PROPAGATING PRESSURE PULSES IN A
SUBTERRANEAN WELL**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

[0001] This application is a continuation-in-part of prior application Ser. No. 12/700685 filed on 4 Feb. 2010, which is a continuation-in-part of application Ser. No. 12/542695 filed on 18 Aug. 2009. The entire disclosures of these prior applications are incorporated herein by this reference for all purposes.

BACKGROUND

[0002] This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in an example described below, more particularly provides for propagating pressure pulses in a subterranean well.

[0003] In an injection well, hydrocarbon production well, or other type of well, it is many times beneficial to be able to propagate pressure pulses into a subterranean formation. Such pressure pulses can enhance mobility of fluids in the formation. For example, injected fluids can more readily flow into and spread through the formation in injection operations, and produced fluids can more readily flow from the formation into a wellbore in production operations.

[0004] Therefore, it will be appreciated that advancements in the art of propagating pressure pulses in a well would be desirable in the circumstances mentioned above, and such advancements would also be beneficial in a wide variety of other circumstances.

SUMMARY

[0005] In the disclosure below, a variable flow resistance system and associated methods are provided which bring improvements to the art of propagating pressure pulses in a well. An example is described below in which resistance to flow of a fluid composition is alternately increased and decreased as the fluid composition flows through a variable flow resistance system.

[0006] In one aspect, a method of propagating pressure pulses in a subterranean well is provided to the art by the present disclosure. The method can include flowing a fluid composition through at least one variable flow resistance system. The variable flow resistance system includes a vortex chamber having at least one inlet and an outlet. A vortex is created when the fluid composition flows spirally about the outlet. A resistance to flow of the fluid composition through the vortex chamber alternately increases and decreases.

[0007] In another aspect, the vortex is alternately created and dissipated in the vortex chamber, in response to flowing the fluid composition through the variable flow resistance system.

[0008] In yet another aspect, a subterranean well system can comprise at least one variable flow resistance system which propagates pressure pulses into a subterranean formation in response to flow of a fluid composition from the formation.

[0009] These and other features, advantages and benefits will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of represen-

tative examples below and the accompanying drawings, in which similar elements are indicated in the various figures using the same reference numbers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic partially cross-sectional view of a well system and associated method which can embody principles of the present disclosure.

[0011] FIG. 2 is an enlarged scale schematic cross-sectional view of a well screen and a variable flow resistance system which may be used in the well system of FIG. 1.

[0012] FIG. 3 is a schematic "unrolled" plan view of one configuration of the variable flow resistance system, taken along line 3-3 of FIG. 2.

[0013] FIGS. 4A & B are schematic plan views of another configuration of the variable flow resistance system.

[0014] FIGS. 5A & B are schematic plan views of another configuration of the variable flow resistance system.

[0015] FIG. 6 is a schematic cross-sectional view of another configuration of the well system and method of FIG. 1.

[0016] FIG. 7 is a schematic plan view of another configuration of the variable flow resistance system.

[0017] FIGS. 8A-C are schematic perspective, partially cross-sectional and cross-sectional views, respectively, of yet another configuration of the variable flow resistance system.

DETAILED DESCRIPTION

[0018] Representatively illustrated in FIG. 1 is a well system 10 which can embody principles of this disclosure. As depicted in FIG. 1, a wellbore 12 has a generally vertical uncased section 14 extending downwardly from casing 16, as well as a generally horizontal uncased section 18 extending through an earth formation 20.

[0019] A tubular string 22 (such as a production tubing string) is installed in the wellbore 12. Interconnected in the tubular string 22 are multiple well screens 24, variable flow resistance systems 25 and packers 26.

[0020] The packers 26 seal off an annulus 28 formed radially between the tubular string 22 and the wellbore section 18. In this manner, fluids 30 may be produced from multiple intervals or zones of the formation 20 via isolated portions of the annulus 28 between adjacent pairs of the packers 26.

[0021] Positioned between each adjacent pair of the packers 26, a well screen 24 and a variable flow resistance system 25 are interconnected in the tubular string 22. The well screen 24 filters the fluids 30 flowing into the tubular string 22 from the annulus 28. The variable flow resistance system 25 variably restricts flow of the fluids 30 into the tubular string 22, based on certain characteristics of the fluids.

[0022] At this point, it should be noted that the well system 10 is illustrated in the drawings and is described herein as merely one example of a wide variety of well systems in which the principles of this disclosure can be utilized. It should be clearly understood that the principles of this disclosure are not limited at all to any of the details of the well system 10, or components thereof, depicted in the drawings or described herein.

[0023] For example, it is not necessary in keeping with the principles of this disclosure for the wellbore 12 to include a generally vertical wellbore section 14 or a generally horizontal wellbore section 18. It is not necessary for fluids 30 to be only produced from the formation 20 since, in other

examples, fluids could be injected into a formation, fluids could be both injected into and produced from a formation, etc.

[0024] It is not necessary for one each of the well screen **24** and variable flow resistance system **25** to be positioned between each adjacent pair of the packers **26**. It is not necessary for a single variable flow resistance system **25** to be used in conjunction with a single well screen **24**. Any number, arrangement and/or combination of these components may be used.

[0025] It is not necessary for any variable flow resistance system **25** to be used with a well screen **24**. For example, in injection operations, the injected fluid could be flowed through a variable flow resistance system **25**, without also flowing through a well screen **24**.

[0026] It is not necessary for the well screens **24**, variable flow resistance systems **25**, packers **26** or any other components of the tubular string **22** to be positioned in uncased sections **14**, **18** of the wellbore **12**. Any section of the wellbore **12** may be cased or uncased, and any portion of the tubular string **22** may be positioned in an uncased or cased section of the wellbore, in keeping with the principles of this disclosure.

[0027] It should be clearly understood, therefore, that this disclosure describes how to make and use certain examples, but the principles of the disclosure are not limited to any details of those examples. Instead, the principles of this disclosure can be applied to a variety of other examples using the knowledge obtained from this disclosure.

[0028] It will be appreciated by those skilled in the art that it would be beneficial to be able to regulate flow of the fluids **30** into the tubular string **22** from each zone of the formation **20**, for example, to prevent water coning **32** or gas coning **34** in the formation. Other uses for flow regulation in a well include, but are not limited to, balancing production from (or injection into) multiple zones, minimizing production or injection of undesired fluids, maximizing production or injection of desired fluids, etc.

[0029] Examples of the variable flow resistance systems **25** described more fully below can provide these benefits by increasing resistance to flow if a fluid velocity increases beyond a selected level (e.g., to thereby balance flow among zones, prevent water or gas coning, etc.), increasing resistance to flow if a fluid viscosity decreases below a selected level or if a fluid density increases above a selected level (e.g., to thereby restrict flow of an undesired fluid, such as water or gas, in an oil producing well), and/or increasing resistance to flow if a fluid viscosity or density increases above a selected level (e.g., to thereby minimize injection of water in a steam injection well).

[0030] Whether a fluid is a desired or an undesired fluid depends on the purpose of the production or injection operation being conducted. For example, if it is desired to produce oil from a well, but not to produce water or gas, then oil is a desired fluid and water and gas are undesired fluids. If it is desired to produce gas from a well, but not to produce water or oil, the gas is a desired fluid, and water and oil are undesired fluids. If it is desired to inject steam into a formation, but not to inject water, then steam is a desired fluid and water is an undesired fluid in a fluid composition.

[0031] Note that, at downhole temperatures and pressures, hydrocarbon gas can actually be completely or partially in liquid phase. Thus, it should be understood that when the term "gas" is used herein, supercritical, liquid and/or gaseous phases are included within the scope of that term.

[0032] Referring additionally now to FIG. 2, an enlarged cross-sectional view of one of the variable flow resistance systems **25** and a portion of one of the well screens **24** is representatively illustrated. In this example, a fluid composition **36** (which can include one or more fluids, such as oil and water, liquid water and steam, oil and gas, gas and water, oil, water and gas, etc.) flows into the well screen **24**, is thereby filtered, and then flows into an inlet **38** of the variable flow resistance system **25**.

[0033] A fluid composition can include one or more undesired or desired fluids. Both steam and water can be combined in a fluid composition. As another example, oil, water and/or gas can be combined in a fluid composition.

[0034] Flow of the fluid composition **36** through the variable flow resistance system **25** is resisted based on one or more characteristics (such as density, viscosity, velocity, etc.) of the fluid composition. The fluid composition **36** is then discharged from the variable flow resistance system **25** to an interior of the tubular string **22** via an outlet **40**.

[0035] In other examples, the well screen **24** may not be used in conjunction with the variable flow resistance system **25** (e.g., in injection operations), the fluid composition **36** could flow in an opposite direction through the various elements of the well system **10** (e.g., in injection operations), a single variable flow resistance system could be used in conjunction with multiple well screens, multiple variable flow resistance systems could be used with one or more well screens, the fluid composition could be received from or discharged into regions of a well other than an annulus or a tubular string, the fluid composition could flow through the variable flow resistance system prior to flowing through the well screen, any other components could be interconnected upstream or downstream of the well screen and/or variable flow resistance system, etc. Thus, it will be appreciated that the principles of this disclosure are not limited at all to the details of the example depicted in FIG. 2 and described herein.

[0036] Although the well screen **24** depicted in FIG. 2 is of the type known to those skilled in the art as a wire-wrapped well screen, any other types or combinations of well screens (such as sintered, expanded, pre-packed, wire mesh, etc.) may be used in other examples. Additional components (such as shrouds, shunt tubes, lines, instrumentation, sensors, inflow control devices, etc.) may also be used, if desired.

[0037] The variable flow resistance system **25** is depicted in simplified form in FIG. 2, but in a preferred example, the system can include various passages and devices for performing various functions, as described more fully below. In addition, the system **25** preferably at least partially extends circumferentially about the tubular string **22**, or the system may be formed in a wall of a tubular structure interconnected as part of the tubular string.

[0038] In other examples, the system **25** may not extend circumferentially about a tubular string or be formed in a wall of a tubular structure. For example, the system **25** could be formed in a flat structure, etc. The system **25** could be in a separate housing that is attached to the tubular string **22**, or it could be oriented so that the axis of the outlet **40** is parallel to the axis of the tubular string. The system **25** could be on a logging string or attached to a tubular that is not tubular in shape. Any orientation or configuration of the system **25** may be used in keeping with the principles of this disclosure.

[0039] Referring additionally now to FIG. 3, a more detailed cross-sectional view of one example of the system **25**

is representatively illustrated. The system 25 is depicted in FIG. 3 as if it is “unrolled” from its circumferentially extending configuration to a generally planar configuration.

[0040] As described above, the fluid composition 36 enters the system 25 via the inlet 38, and exits the system via the outlet 40. A resistance to flow of the fluid composition 36 through the system 25 varies based on one or more characteristics of the fluid composition. The system 25 depicted in FIG. 3 is similar in most respects to that illustrated in FIG. 23 of the prior application Ser. No. 12/700685 incorporated herein by reference above.

[0041] In the example of FIG. 3, the fluid composition 36 initially flows into multiple flow passages 42, 44, 46, 48. The flow passages 42, 44, 46, 48 direct the fluid composition 36 to two flow path selection devices 50, 52. The device 50 selects which of two flow paths 54, 56 a majority of the flow from the passages 44, 46, 48 will enter, and the other device 52 selects which of two flow paths 58, 60 a majority of the flow from the passages 42, 44, 46, 48 will enter.

[0042] The flow passage 44 is configured to be more restrictive to flow of fluids having higher viscosity. Flow of increased viscosity fluids will be increasingly restricted through the flow passage 44.

[0043] As used herein, the term “viscosity” is used to indicate any of the related rheological properties including kinematic viscosity, yield strength, viscoplasticity, surface tension, wettability, etc.

[0044] For example, the flow passage 44 may have a relatively small flow area, the flow passage may require the fluid flowing therethrough to follow a tortuous path, surface roughness or flow impeding structures may be used to provide an increased resistance to flow of higher viscosity fluid, etc. Relatively low viscosity fluid, however, can flow through the flow passage 44 with relatively low resistance to such flow.

[0045] A control passage 64 of the flow path selection device 50 receives the fluid which flows through the flow passage 44. A control port 66 at an end of the control passage 64 has a reduced flow area to thereby increase a velocity of the fluid exiting the control passage.

[0046] The flow passage 48 is configured to have a flow resistance which is relatively insensitive to viscosity of fluids flowing therethrough, but which may be increasingly resistant to flow of higher velocity or higher density fluids. Flow of increased viscosity fluids may be increasingly resisted through the flow passage 48, but not to as great an extent as flow of such fluids would be resisted through the flow passage 44.

[0047] In the example depicted in FIG. 3, fluid flowing through the flow passage 48 must flow through a “vortex” chamber 62 prior to being discharged into a control passage 68 of the flow path selection device 50. Since the chamber 62 in this example has a cylindrical shape with a central outlet, and the fluid composition 36 spirals about the chamber, increasing in velocity as it nears the outlet, driven by a pressure differential from the inlet to the outlet, the chamber is referred to as a “vortex” chamber. In other examples, one or more orifices, venturis, nozzles, etc. may be used.

[0048] The control passage 68 terminates at a control port 70. The control port 70 has a reduced flow area, in order to increase the velocity of the fluid exiting the control passage 68.

[0049] It will be appreciated that, as a viscosity of the fluid composition 36 increases, a greater proportion of the fluid composition will flow through the flow passage 48, control

passage 68 and control port 70 (due to the flow passage 44 resisting flow of higher viscosity fluid more than the flow passage 48 and vortex chamber 62). Conversely, as a viscosity of the fluid composition 36 decreases, a greater proportion of the fluid composition will flow through the flow passage 44, control passage 64 and control port 66.

[0050] Fluid which flows through the flow passage 46 also flows through a vortex chamber 72, which may be similar to the vortex chamber 62 (although the vortex chamber 72 in a preferred example provides less resistance to flow there-through than the vortex chamber 62), and is discharged into a central passage 74. The vortex chamber 72 is used for “impedance matching” to achieve a desired balance of flows through the flow passages 44, 46, 48.

[0051] Note that dimensions and other characteristics of the various components of the system 25 will need to be selected appropriately, so that desired outcomes are achieved. In the example of FIG. 3, one desired outcome of the flow path selection device 50 is that flow of a majority of the fluid composition 36 which flows through the flow passages 44, 46, 48 is directed into the flow path 54 when the fluid composition has a sufficiently high ratio of desired fluid to undesired fluid therein.

[0052] In this example, the desired fluid is oil, which has a higher viscosity than water or gas, and so when a sufficiently high proportion of the fluid composition 36 is oil, a majority (or at least a greater proportion) of the fluid composition 36 which enters the flow path selection device 50 will be directed to flow into the flow path 54, instead of into the flow path 56. This result is achieved due to the fluid exiting the control port 70 at a greater rate or at a higher velocity than fluid exiting the other control port 66, thereby influencing the fluid flowing from the passages 64, 68, 74 to flow more toward the flow path 54.

[0053] If the viscosity of the fluid composition 36 is not sufficiently high (and thus a ratio of desired fluid to undesired fluid is below a selected level), a majority (or at least a greater proportion) of the fluid composition which enters the flow path selection device 50 will be directed to flow into the flow path 56, instead of into the flow path 54. This will be due to the fluid exiting the control port 66 at a greater rate or at a higher velocity than fluid exiting the other control port 70, thereby influencing the fluid flowing from the passages 64, 68, 74 to flow more toward the flow path 56.

[0054] It will be appreciated that, by appropriately configuring the flow passages 44, 46, 48, control passages 64, 68, control ports 66, 70, vortex chambers 62, 72, etc., the ratio of desired to undesired fluid in the fluid composition 36 at which the device 50 selects either the flow passage 54 or 56 for flow of a majority of fluid from the device can be set to various different levels.

[0055] The flow paths 54, 56 direct fluid to respective control passages 76, 78 of the other flow path selection device 52. The control passages 76, 78 terminate at respective control ports 80, 82. A central passage 75 receives fluid from the flow passage 42.

[0056] The flow path selection device 52 operates similar to the flow path selection device 50, in that fluid which flows into the device 52 via the passages 75, 76, 78 is directed toward one of the flow paths 58, 60, and the flow path selection depends on a ratio of fluid discharged from the control ports 80, 82. If fluid flows through the control port 80 at a greater rate or velocity as compared to fluid flowing through the control port 82, then a majority (or at least a greater propor-

tion) of the fluid composition 36 will be directed to flow through the flow path 60. If fluid flows through the control port 82 at a greater rate or velocity as compared to fluid flowing through the control port 80, then a majority (or at least a greater proportion) of the fluid composition 36 will be directed to flow through the flow path 58.

[0057] Although two of the flow path selection devices 50, 52 are depicted in the example of the system 25 in FIG. 3, it will be appreciated that any number (including one) of flow path selection devices may be used in keeping with the principles of this disclosure. The devices 50, 52 illustrated in FIG. 3 are of the type known to those skilled in the art as jet-type fluid ratio amplifiers, but other types of flow path selection devices (e.g., pressure-type fluid ratio amplifiers, bi-stable fluid switches, proportional fluid ratio amplifiers, etc.) may be used in keeping with the principles of this disclosure.

[0058] Fluid which flows through the flow path 58 enters a flow chamber 84 via an inlet 86 which directs the fluid to enter the chamber generally tangentially (e.g., the chamber 84 is shaped similar to a cylinder, and the inlet 86 is aligned with a tangent to a circumference of the cylinder). As a result, the fluid will spiral about the chamber 84, until it eventually exits via the outlet 40, as indicated schematically by arrow 90 in FIG. 3.

[0059] Fluid which flows through the flow path 60 enters the flow chamber 84 via an inlet 88 which directs the fluid to flow more directly toward the outlet 40 (e.g., in a radial direction, as indicated schematically by arrow 92 in FIG. 3). As will be readily appreciated, much less energy is consumed when the fluid flows more directly toward the outlet 40 as compared to when the fluid flows less directly toward the outlet.

[0060] Thus, less resistance to flow is experienced when the fluid composition 36 flows more directly toward the outlet 40 and, conversely, more resistance to flow is experienced when the fluid composition flows less directly toward the outlet. Accordingly, working upstream from the outlet 40, less resistance to flow is experienced when a majority of the fluid composition 36 flows into the chamber 84 from the inlet 88, and through the flow path 60.

[0061] A majority of the fluid composition 36 flows through the flow path 60 when fluid exits the control port 80 at a greater rate or velocity as compared to fluid exiting the control port 82. More fluid exits the control port 80 when a majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 54.

[0062] A majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 54 when fluid exits the control port 70 at a greater rate or velocity as compared to fluid exiting the control port 66. More fluid exits the control port 70 when a viscosity of the fluid composition 36 is above a selected level.

[0063] Thus, flow through the system 25 is resisted less when the fluid composition 36 has an increased viscosity (and a greater ratio of desired to undesired fluid therein). Flow through the system 25 is resisted more when the fluid composition 36 has a decreased viscosity.

[0064] More resistance to flow is experienced when the fluid composition 36 flows less directly toward the outlet 40 (e.g., as indicated by arrow 90). Thus, more resistance to flow is experienced when a majority of the fluid composition 36 flows into the chamber 84 from the inlet 86, and through the flow path 58.

[0065] A majority of the fluid composition 36 flows through the flow path 58 when fluid exits the control port 82 at a greater rate or velocity as compared to fluid exiting the control port 80. More fluid exits the control port 82 when a majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 56, instead of through the flow path 54.

[0066] A majority of the fluid flowing from the passages 64, 68, 74 flows through the flow path 56 when fluid exits the control port 66 at a greater rate or velocity as compared to fluid exiting the control port 70. More fluid exits the control port 66 when a viscosity of the fluid composition 36 is below a selected level.

[0067] As described above, the system 25 is configured to provide less resistance to flow when the fluid composition 36 has an increased viscosity, and more resistance to flow when the fluid composition has a decreased viscosity. This is beneficial when it is desired to flow more of a higher viscosity fluid, and less of a lower viscosity fluid (e.g., in order to produce more oil and less water or gas).

[0068] If it is desired to flow more of a lower viscosity fluid, and less of a higher viscosity fluid (e.g., in order to produce more gas and less water, or to inject more steam and less water), then the system 25 may be readily reconfigured for this purpose. For example, the inlets 86, 88 could conveniently be reversed, so that fluid which flows through the flow path 58 is directed to the inlet 88, and fluid which flows through the flow path 60 is directed to the inlet 86.

[0069] Although, as described above, a majority of the fluid composition 36 may enter the chamber 84 via the inlet 86, thereby having an increased resistance to flow, and in other circumstances a majority of the fluid composition may enter the chamber via the inlet 88, thereby having a reduced resistance to flow, the variable flow resistance system 25 can be configured so that the resistance to flow through the vortex chamber alternately increases and decreases. This can be accomplished in one example by the vortex 90 alternately being created and dissipated in the vortex chamber 84.

[0070] The variable flow resistance system 25 can be configured so that, when resistance to flow through the system is increased, a backpressure is transmitted through the system to the inlet 38 (and to elements upstream of the inlet), and a velocity of the fluid composition through the system is decreased. At such decreased velocity, proportionately more of the fluid composition 36 will flow through the flow passage 48, and a majority of the fluid composition which flows through the passages 66, 70, 74 will thus flow into the flow path 54.

[0071] When more of the fluid composition 36 flows through the control passage 76 to the control port 80, a majority of the fluid composition 36 will be influenced to flow through the flow path 60 to the inlet 88. Thus, the fluid composition 36 will flow more directly to the outlet 40 (as indicated by the arrow 92) and the resistance to flow through the system 25 will decrease. A previous vortex in the chamber 84 (indicated by vortex 90) will dissipate as the fluid composition 36 flows more directly to the outlet 40.

[0072] The decrease in resistance to flow through the system 25 results in a reduction of the backpressure transmitted through the system to the inlet 38 (and to elements upstream of the inlet), and the velocity of the fluid composition through the system is increased. At such increased velocity, proportionately more of the fluid composition 36 will flow through

the flow passage 44, and a majority of the fluid composition which flows through the passage 66, 70, 74 will thus flow into the flow path 56.

[0073] When more of the fluid composition 36 flows through the control passage 78 to the control port 82, a majority of the fluid composition 36 will be influenced to flow through the flow path 58 to the inlet 86. Thus, the fluid composition 36 will flow more indirectly to the outlet 40 (as indicated by the vortex 90) and the resistance to flow through the system 25 will increase. The vortex 90 is created in the chamber 84 as the fluid composition 36 flows spirally about the outlet 40.

[0074] The flow resistance through the system 25 will alternately increase and decrease, causing the backpressure to alternately be increased and decreased in response. This backpressure can be useful, since in the well system 10 it will result in pressure pulses being propagated from the system 25 upstream into the annulus 28 and formation 20 surrounding the tubular string 22 and wellbore section 18.

[0075] Pressure pulses transmitted into the formation 20 can aid production of the fluids 30 from the formation, because the pressure pulses help to break down "skin effects" surrounding the wellbore 12, and otherwise enhance mobility of the fluids in the formation. By making it easier for the fluids 30 to flow from the formation 20 into the wellbore 12, the fluids can be more readily produced (e.g., the same fluid production rate will require less pressure differential from the formation to the wellbore, or more fluids can be produced at the same pressure differential, etc.).

[0076] The alternating increases and decreases in flow resistance through the system 25 can also cause pressure pulses to be transmitted downstream of the outlet 40. These pressure pulses downstream of the outlet 40 can be useful, for example, in circumstances in which the system 25 is used for injecting the fluid composition 36 into a formation.

[0077] In these situations, the injected fluid would be flowed through the system 25 from the inlet 38 to the outlet 40, and thence into the formation. The pressure pulses would be transmitted from the outlet 40 into the formation as the fluid composition 36 is flowed through the system 25 and into the formation. As with production operations, pressure pulses transmitted into the formation are useful in injection operations, because they enhance mobility of the injected fluids through the formation.

[0078] Other uses for the pressure pulses generated by the system 25 are possible, in keeping with the principles of this disclosure. In another example described more fully below, pressure pulses are used in a gravel packing operation to reduce voids and enhance consolidation of gravel in a gravel pack.

[0079] It will be appreciated that the system 25 obtains the benefits described above when fluid flows from the inlet 38 to the outlet 40 of the system. However, in some circumstances it may be desirable to generate pressure pulses both when fluid is flowed from the tubular string 22 into the formation 20 (e.g., in stimulation/injection operations), and when fluid is flowed from the formation into the tubular string (e.g., in production operations).

[0080] If it is desired to generate the pressure pulses both when fluid flows into the formation 20 and when fluid flows from the formation, multiple systems 25 can be used in parallel, with one or more of the systems being configured so that fluid flows from the inlet 38 to the outlet 40 when flowing the fluid into the formation, and with one or more of the other

systems being configured so that fluid flows from the inlet to the outlet when flowing the fluid from the formation. Check valves or fluidic diodes could be used to prevent or highly restrict fluid from flowing to the inlet 38 from the outlet 40 in each of the systems 25.

[0081] Referring additionally now to FIGS. 4A & B, another configuration of the variable flow resistance system 25 is representatively illustrated. The system 25 of FIGS. 4A & B is much less complex as compared to the system of FIG. 3, at least in part because it does not include the flow path selection devices 50, 52.

[0082] The vortex chamber 84 of FIGS. 4A & B is also somewhat different, in that two inlets 94, 96 to the chamber are supplied with flow of the fluid composition 36 via two flow passages 98, 100 which direct the fluid composition to flow in opposite directions about the outlet 40 (or at least in directions so that the flows from the inlets 94, 96 counteract each other). As depicted in FIGS. 4A & B, fluid which enters the chamber 84 via the inlet 94 is directed to flow in a clockwise direction (as viewed in FIGS. 4A & B) about the outlet 40, and fluid which enters the chamber via the inlet 96 is directed to flow in a counter-clockwise direction about the outlet.

[0083] In FIG. 4A, the system 25 is depicted in a situation in which an increased velocity of the fluid composition 36 results in a majority of the fluid composition flowing into the chamber 84 via the inlet 94. The fluid composition 36, thus spirals about the outlet 40 in the chamber 84, and a resistance to flow through the system 25 increases.

[0084] Relatively little of the fluid composition 36 flows into the chamber 84 via the inlet 96 in FIG. 4A, because the flow passage 100 is connected to branch passages 102a-c which branch from the flow passage 98 at eddy chambers 104a-c. At relatively high velocities, the fluid composition 36 tends to flow past the eddy chambers 104a-c, without a substantial amount of the fluid composition flowing through the eddy chambers and branch passages 102a-c to the flow passage 100.

[0085] This effect can be enhanced by increasing a width of the flow passage 98 at each eddy chamber 104a-c (e.g., as depicted in FIG. 4A, $w1 < w2 < w3 < w4$). The volume of the eddy chambers 104a-c can also decrease in the downstream direction along the passage 98.

[0086] In FIG. 4B, a velocity of the fluid composition 36 has decreased (due to the increased flow restriction in FIG. 4A), and as a result, proportionately more of the fluid composition flows from the passage 98 into the branch passages 102a-c and via the passage 100 to the inlet 96. Since the flows into the chamber 84 from the two inlets 94, 96 are opposed to each other, they counteract each other, resulting in a disruption of the vortex 90 in the chamber.

[0087] As depicted in FIG. 4B, the fluid composition 36 flows less spirally about the outlet 40, and more directly to the outlet, thereby reducing the resistance to flow through the system 25. As a result, the velocity of the fluid composition 36 will increase, and the system 25 will return to the situation depicted in FIG. 4A.

[0088] It will be appreciated that the resistance to flow through the system 25 of FIGS. 4A & B will alternately increase and decrease as the fluid composition 36 flows through the system. A backpressure at the inlet 38 will alternately increase and decrease, resulting in pressure pulses being transmitted to elements upstream of the inlet.

[0089] Flow through the outlet 40 will also alternately increase and decrease, resulting in pressure pulses being transmitted to elements downstream of the outlet. A vortex 90 can be alternately created and dissipated in the chamber 84 as a result of the changing proportions of flow of the fluid composition 36 through the inlets 94, 96.

[0090] As with the system 25 of FIG. 3 described above, the system of FIGS. 4A & B can be configured so that the alternating increases and decreases in flow restriction through the system will occur when a characteristic of the fluid composition is within a predetermined range. For example, the alternating increases and decreases in flow restriction could occur when a viscosity, velocity, density and/or other characteristic of the fluid composition is within a desired range. As another example, the alternating increases and decreases in flow restriction could occur when a ratio of desired fluid to undesired fluid in the fluid composition is within a desired range.

[0091] In an oil production operation, it may be desired to transmit pressure pulses into the formation 20 when a large enough proportion of oil is being produced, in order to enhance the mobility of the oil through the formation. From another perspective, the system 25 could be configured so that the alternating increases and decreases in flow restriction occur when the viscosity of the fluid composition 36 is above a certain level (and so that the pressure pulses are not propagated into the formation 20 when an undesirably high proportion of water or gas is produced).

[0092] In an injection operation, it may be desired to transmit pressure pulses into the formation 20 when a large proportion of the injected fluid composition 36 is steam, rather than water. From another perspective, the system 25 could be configured so that the alternating increases and decreases in flow restriction occur when the density of the fluid composition 36 is below a certain level (and so that the pressure pulses are not propagated into the formation 20 when the fluid composition includes a relatively high proportion of water).

[0093] Thus, for a particular application, the vortex chamber(s), the various flow passages and other components of the system 25 are preferably designed so that the alternating increases and decreases in flow restriction through the system occur when the characteristics (e.g., density, viscosity, velocity, etc.) of the fluid composition 36 are as anticipated or desired. Some prototyping and testing will be required to establish how the various components of the system 25 should be designed to accomplish the particular objectives of a particular application, but undue experimentation will not be necessary if the principles of this disclosure are carefully considered by a person of ordinary skill in the art.

[0094] Referring additionally now to FIGS. 5A & B, another configuration of the variable flow resistance system 25 is representatively illustrated. The system 25 of FIGS. 5A & B is similar in many respects to the system of FIGS. 4A & B, but differs at least in that the branch passages 102a-c and eddy chambers 104a-c are not necessarily used in the FIGS. 5A & B configuration. Instead, the flow passage 100 itself branches off of the flow passage 98.

[0095] Another difference is that circular flow inducing structures 106 are used in the chamber 84 in the configuration of FIGS. 5A & B. The structures 106 operate to maintain circular flow of the fluid composition 36 about the outlet 40, or at least to impede inward flow of the fluid composition toward the outlet, when the fluid composition does flow cir-

cularly about the outlet. Openings 108 in the structures 106 permit the fluid composition 36 to eventually flow inward to the outlet 40.

[0096] The structures 106 are an example of how the configuration of the system 25 can be altered to produce the pressure pulses when they are desired (e.g., when the fluid composition 36 has a predetermined viscosity, velocity, density, ratio of desired to undesired fluid therein, etc.). The manner in which the flow passage 100 is branched off of the flow passage 98 is yet another example of how the configuration of the system 25 can be altered to produce the pressure pulses when they are desired.

[0097] In FIG. 5A, the system 25 is depicted in a situation in which an increased velocity of the fluid composition 36 results in a majority of the fluid composition flowing into the chamber 84 via the inlet 94. The fluid composition 36, thus, spirals about the outlet 40 in the chamber 84, and a resistance to flow through the system 25 increases.

[0098] Relatively little of the fluid composition 36 flows into the chamber 84 via the inlet 96 in FIG. 5A, because the flow passage 100 is branched from the flow passage 98 in a manner such that most of the fluid composition remains in the flow passage 98. At relatively high velocities, the fluid composition 36 tends to flow past the flow passage 100.

[0099] In FIG. 5B, a velocity of the fluid composition 36 has decreased (due to the increased flow restriction in FIG. 5A), and as a result, proportionately more of the fluid composition flows from the passage 98 and via the passage 100 to the inlet 96. Since the flows into the chamber 84 from the two inlets 94, 96 are oppositely directed (or at least the flow of the fluid composition through the inlet 96 opposes the flow through the inlet 94), they counteract each other, resulting in a disruption of the vortex 90 in the chamber.

[0100] As depicted in FIG. 5B, the fluid composition 36 flows less spirally about the outlet 40, and more directly to the outlet, thereby reducing the resistance to flow through the system 25. As a result, the velocity of the fluid composition 36 will increase, and the system 25 will return to the situation depicted in FIG. 5A.

[0101] It will be appreciated that the resistance to flow through the system 25 of FIGS. 5A & B will alternately increase and decrease as the fluid composition 36 flows through the system. A backpressure at the inlet 38 will alternately increase and decrease, resulting in pressure pulses being transmitted to elements upstream of the inlet.

[0102] Flow through the outlet 40 will also alternately increase and decrease, resulting in pressure pulses being transmitted to elements downstream of the outlet. A vortex 90 can be alternately created and dissipated in the chamber 84 as a result of the changing proportions of flow of the fluid composition 36 through the inlets 94, 96.

[0103] Referring additionally now to FIG. 6, another configuration of the well system 10 is representatively illustrated. In this configuration, a gravel packing operation is being performed, in which the fluid composition 36 comprises a gravel slurry which is flowed out of the tubular string 22 and into the annulus 28 to thereby form a gravel pack 110 about one or more of the well screens 24.

[0104] In this gravel packing operation, the fluid portion of the gravel slurry (the fluid composition 36) flows inwardly through the well screen 24 and via the system 25 into the interior of the tubular string 22. Configured as described above, the system 25 preferably propagates pressure pulses into the gravel pack 110 as the gravel slurry is flowed into the

annulus 28, thereby helping to eliminate voids in the gravel pack, helping to consolidate the gravel pack about the well screen 24, etc.

[0105] When production of fluids from the formation 20 is desired, the system 25 can propagate pressure pulses into the formation as fluid flows from the formation into the wellbore 12, and thence through the screen 24 and system 25 into the interior of the tubular string 22. Thus, the system 25 can beneficially propagate pressure pulses into the formation 20 during different well operations, although this is not necessary in keeping with the principles of this disclosure.

[0106] Alternatively, or in addition, another variable flow resistance system 25 may be incorporated into the tubular string 22 as part of a component 112 of the gravel packing equipment (such as a crossover or a slurry exit joint). The system 25 can, thus, alternately increase and decrease flow of the fluid composition 36 into the annulus 28, thereby propagating pressure pulses into the gravel pack 110, in response to flow of the fluid composition through the system.

[0107] A sensor 114 (such as a fiber optic acoustic sensor of the type described in U.S. Pat. No. 6,913,079, or another type of sensor) may be used to detect when the system 25 propagates the pressure pulses into the gravel pack 110, into the formation 20, etc. This may be useful in the well system 10 configuration of FIG. 6 in order to determine which of multiple gravel packs 110 is being properly placed, where along a long gravel pack appropriate flow is being obtained, etc. In the well system 10 configuration of FIG. 1, the sensor 114 may be used to determine where the fluids 30 are entering the tubular string 22 at an appropriate rate, etc.

[0108] Referring additionally now to FIG. 7, another configuration of the variable flow resistance system 25 is representatively illustrated. The configuration of FIG. 7 is similar in most respects to the configuration of FIGS. 5A & B, but differs at least in that a control passage 116 is used in the configuration of FIG. 7 to deflect more of the fluid composition 36 toward the flow passage 100 when the fluid composition is spiraling about the chamber 84.

[0109] When a majority of the fluid composition 36 flows through the inlet 94 into the chamber 84, a momentum of the fluid composition spiraling about the outlet 40 can cause a relatively small portion of the fluid composition to enter the control passage 116. This portion of the fluid composition 36 will impinge upon the significantly larger portion of the fluid composition flowing through the passage 98, and will tend to divert more of the fluid composition to flow into the passage 100.

[0110] If the fluid composition 36 spirals more about the outlet 40, more of the fluid composition will enter the control passage 116, resulting in more of the fluid composition being diverted to the passage 100. If the fluid composition 36 does not spiral significantly about the outlet 40, little or no portion of the fluid composition will enter the control passage 116.

[0111] Thus, the control passage 116 can be used to adjust the velocity of the fluid composition 36 at which flow rates through the passages 98, 100 become more equal and resistance to flow through the system 25 is reduced. From another perspective, the control passage 116 can be used to adjust the velocity of the fluid composition 36 at which flow through the system 25 alternately increases and decreases to thereby propagate pressure pulses, and/or the control passage can be used to adjust the frequency of the pressure pulses.

[0112] Referring additionally now to FIGS. 8A-C, another configuration of the variable flow resistance system 25 is

representatively illustrated. This configuration is similar in many respects to the system 25 of FIGS. 5A & B, in that the fluid composition 36 enters the chamber 84 via the passage 98, and a greater proportion of the fluid composition also enters the chamber via the passage 100 as the velocity of the fluid composition decreases, as the viscosity of the fluid composition increases, as the density of the fluid composition decreases and/or as a ratio of desired to undesired fluid in the fluid composition increases.

[0113] In the configuration of FIGS. 8A-C, the passages 98, 100 are formed on a generally cylindrical mandrel 118 which is received in a generally tubular housing 120, as depicted in FIG. 8A. The mandrel 118 may be, for example, shrink fit, press fit or otherwise secured tightly and/or sealingly within the housing 120.

[0114] As seen in FIG. 8B, the chamber 84 is formed axially between an end of the mandrel and an inner end of the housing 120. The outlet 40 extends through an end of the housing 120.

[0115] Each of the passages 98, 100 is in fluid communication with the chamber 84. However, flow of the fluid composition 36 which enters the chamber 84 via the inlet 94 will flow circularly within the chamber, and flow of the fluid composition which enters the chamber via the inlet 96 will flow more directly toward the outlet 40, as depicted in FIG. 8C.

[0116] In another example, the inlet 96 could be configured to direct the flow of the fluid composition 36 in a direction which opposes that of the fluid composition which enters the chamber via the inlet 94 (as indicated by fluid composition 36a in FIG. 8C), so that the flows counteract each other as described above for the configuration of FIGS. 5A & B. The chamber 84 may also be provided with the structures 106, openings 108 and control passage 116 as described above, if desired.

[0117] It may now be fully appreciated that the above disclosure provides several advancements to the art of propagating pressure pulses in a well. The variable flow resistance system 25 can generate pressure pulses due to alternating increases and decreases in flow resistance through the system, alternating creation and dissipation of a vortex in the vortex chamber 84, etc., and can be configured to do so when a characteristic of a fluid composition 36 flowed through the system is within a predetermined range.

[0118] The above disclosure provides to the art a method of propagating pressure pulses in a subterranean well. The method can comprise flowing a fluid composition 36 through at least one variable flow resistance system 25 which includes a vortex chamber 84 having at least one inlet 86, 88, 94, 96 and an outlet 40. A vortex 90 is created when the fluid composition 36 flows spirally about the outlet 40. A resistance to flow of the fluid composition 36 through the vortex chamber 84 alternately increases and decreases.

[0119] The vortex 90 may be alternately created and dissipated in response to flowing the fluid composition 36 through the variable flow resistance system 25.

[0120] The pressure pulses can be propagated upstream and/or downstream from the variable flow resistance system 25 when the flow resistance alternately increases and decreases. The pressure pulses may be propagated from the variable flow resistance system 25 into a subterranean formation 20 when the flow resistance alternately increases and decreases.

[0121] The pressure pulses may be propagated through a gravel pack 110 when the flow resistance alternately increases and decreases.

[0122] The step of flowing the fluid composition 36 can further include flowing the fluid composition 36 from a subterranean formation 20 into a wellbore 12. The step of flowing the fluid composition 36 can further include flowing the fluid composition 36 from the wellbore 12 into a tubular string 22 via the variable flow resistance system 25.

[0123] The flow resistance may alternately increase and decrease when a characteristic of the fluid composition 36 is within a predetermined range. The characteristic can comprise a viscosity, velocity, density and/or ratio of desired to undesired fluid in the fluid composition 36. The flow resistance may alternately increase and decrease only when the characteristic of the fluid composition 36 is within the predetermined range.

[0124] The step of flowing the fluid composition 36 through the variable flow resistance system 25 can include flowing multiple fluid compositions 36 through respective multiple variable flow resistance systems 25. The method can include the step of detecting which of the variable flow resistance systems 25 have flow resistances which alternately increase and decrease in response to flow of the respective fluid composition 36.

[0125] Also described above is a subterranean well system 10 which can include at least one variable flow resistance system 25 which propagates pressure pulses into a subterranean formation 20 in response to flow of a fluid composition 36 from the formation 20.

[0126] The well system 10 may also include a tubular string 22 positioned in a wellbore 12 intersecting the subterranean formation 20. The variable flow resistance system 25 can propagate the pressure pulses into the formation 20 in response to flow of the fluid composition 36 from the formation 20 and into the tubular string 22.

[0127] The variable flow resistance system 25 may include a vortex chamber 84 having at least one inlet 86, 88, 94, 96 and an outlet 40. A vortex 90 may be created when the fluid composition 36 flows spirally about the outlet 40.

[0128] The vortex 90 may be alternately created and dissipated in response to flow of the fluid composition 36 through the variable flow resistance system 25.

[0129] The above disclosure also describes a variable flow resistance system 25 for use in a subterranean well, with the variable flow resistance system 25 comprising a vortex chamber 84 having an outlet 40, and at least first and second inlets 94, 96. The first inlet 94 may direct a fluid composition 36 to flow in a first direction, and the second inlet 96 may direct the fluid composition 36 to flow in a second direction, so that any of the fluid composition flowing in the first direction opposes any of the fluid composition flowing in the second direction.

[0130] A resistance to flow of the fluid composition 36 through the vortex chamber 84 may decrease as flow through the first and second inlets 94, 96 becomes more equal. Flow through the first and second inlets 94, 96 may become more equal as a viscosity of the fluid composition 36 increases, as a velocity of the fluid composition 36 decreases, as a density of the fluid composition 36 decreases, and/or as a ratio of desired fluid to undesired fluid in the fluid composition 36 increases.

[0131] A resistance to flow of the fluid composition 36 through the vortex chamber 84 may increase as flow through the first and second inlets 94, 96 becomes less equal.

[0132] The fluid composition 36 may flow to the first inlet 94 via a first flow passage 98 which is oriented generally tangential to the vortex chamber 84. The fluid composition 36 may flow to the second inlet 96 via a second flow passage 100 which is oriented generally tangential to the vortex chamber 84, and the second passage 100 may receive the fluid composition 36 from a branch of the first flow passage 98.

[0133] Also described above is a method of propagating pressure pulses in a subterranean well, which method can include the steps of flowing a fluid composition 36 through at least one variable flow resistance system 25 which includes a vortex chamber 84 having at least one inlet 86, 88, 94, 96 and an outlet 40, a vortex 90 being created when the fluid composition 36 flows spirally about the outlet 40; and the vortex 90 being alternately created and dissipated in response to the step of flowing the fluid composition 36 through the variable flow resistance system 25.

[0134] A resistance to flow of the fluid composition 36 through the vortex chamber 84 may alternately increase and decrease when the vortex 90 is alternately created and dissipated.

[0135] The pressure pulses may be propagated upstream and/or downstream from the variable flow resistance system 25 when the vortex 90 is alternately created and dissipated.

[0136] The pressure pulses may be propagated from the variable flow resistance system 25 into a subterranean formation 20 when the vortex 90 is alternately created and dissipated.

[0137] The pressure pulses may be propagated through a gravel pack 110 when the vortex 90 is alternately created and dissipated.

[0138] The vortex 90 may be alternately created and dissipated when a characteristic of the fluid composition 36 is within a predetermined range. The characteristic may comprise a viscosity, velocity, density and/or a ratio of desired to undesired fluid in the fluid composition 36.

[0139] The vortex 90 may be alternately created and dissipated only when the characteristic of the fluid composition 36 is within the predetermined range.

[0140] The at least one inlet can comprise first and second inlets 94, 96. The variable flow resistance system 25 can further include a control passage 110 which receives a portion of the fluid composition 36 from the vortex chamber 84, thereby influencing more of the fluid composition 36 to flow into the chamber 84 via the second inlet 96, when the fluid composition 36 spirals about the outlet 40 in the chamber 84 due to flow of the fluid composition 36 into the chamber 84 via the first inlet 94.

[0141] It is to be understood that the various examples described above may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of the present disclosure. The embodiments illustrated in the drawings are depicted and described merely as examples of useful applications of the principles of the disclosure, which are not limited to any specific details of these embodiments.

[0142] Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to these specific embodiments, and such changes are within the scope of the principles of the present disclosure. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration

and example only, the spirit and scope of the present invention being limited solely by the appended claims and their equivalents.

What is claimed is:

1. A method of propagating pressure pulses in a subterranean well, the method comprising:

flowing a fluid composition through at least one variable flow resistance system which includes a vortex chamber having at least one inlet and an outlet, a vortex being created when the fluid composition flows spirally about the outlet; and

a resistance to flow of the fluid composition through the vortex chamber alternately increasing and decreasing.

2. The method of claim 1, wherein the vortex is alternately created and dissipated in response to the step of flowing the fluid composition through the variable flow resistance system.

3. The method of claim 1, wherein the pressure pulses are propagated upstream from the variable flow resistance system when the flow resistance alternately increases and decreases.

4. The method of claim 1, wherein the pressure pulses are propagated downstream from the variable flow resistance system when the flow resistance alternately increases and decreases.

5. The method of claim 1, wherein the pressure pulses are propagated from the variable flow resistance system into a subterranean formation when the flow resistance alternately increases and decreases.

6. The method of claim 1, wherein the pressure pulses are propagated through a gravel pack when the flow resistance alternately increases and decreases.

7. The method of claim 1, wherein the step of flowing the fluid composition further comprises flowing the fluid composition from a subterranean formation into a wellbore.

8. The method of claim 7, wherein the step of flowing the fluid composition further comprises flowing the fluid composition from the wellbore into a tubular string via the variable flow resistance system.

9. The method of claim 1, wherein the flow resistance alternately increases and decreases when a characteristic of the fluid composition is within a predetermined range.

10. The method of claim 9, wherein the characteristic comprises a viscosity of the fluid composition.

11. The method of claim 9, wherein the characteristic comprises a velocity of the fluid composition.

12. The method of claim 9, wherein the characteristic comprises a density of the fluid composition.

13. The method of claim 9, wherein the flow resistance alternately increases and decreases only when the characteristic of the fluid composition is within the predetermined range.

14. The method of claim 1, wherein the flow resistance alternately increases and decreases when a ratio of desired to undesired fluid in the fluid composition is within a predetermined range.

15. The method of claim 1, wherein the step of flowing the fluid composition through the variable flow resistance system further comprises flowing multiple fluid compositions through respective multiple variable flow resistance systems, and further comprising the step of detecting which of the variable flow resistance systems have flow resistances which alternately increase and decrease in response to flow of the respective fluid composition.

16. A subterranean well system, comprising:

at least one variable flow resistance system which propagates pressure pulses into a subterranean formation in response to flow of a fluid composition from the formation.

17. The well system of claim 16, further comprising a tubular string positioned in a wellbore intersecting the subterranean formation, and wherein the variable flow resistance system propagates the pressure pulses into the formation in response to flow of the fluid composition from the formation and into the tubular string.

18. The well system of claim 16, wherein the variable flow resistance system includes a vortex chamber having at least one inlet and an outlet, and wherein a vortex is created when the fluid composition flows spirally about the outlet.

19. The well system of claim 18, wherein the vortex is alternately created and dissipated in response to flow of the fluid composition through the variable flow resistance system.

20. The well system of claim 18, wherein a resistance to flow of the fluid composition through the vortex chamber alternately increases and decreases.

21. The well system of claim 20, wherein the pressure pulses are propagated upstream from the inlet when the flow resistance alternately increases and decreases.

22. The well system of claim 20, wherein the pressure pulses are propagated downstream from the inlet when the flow resistance alternately increases and decreases.

23. The well system of claim 20, wherein the flow resistance alternately increases and decreases when a characteristic of the fluid composition is within a predetermined range.

24. The well system of claim 23, wherein the characteristic comprises a viscosity of the fluid composition.

25. The well system of claim 23, wherein the characteristic comprises a velocity of the fluid composition.

26. The well system of claim 23, wherein the characteristic comprises a density of the fluid composition.

27. The well system of claim 20, wherein the flow resistance alternately increases and decreases only when the characteristic of the fluid composition is within the predetermined range.

28. The well system of claim 20, wherein the flow resistance alternately increases and decreases when a ratio of desired to undesired fluid in the fluid composition is within a predetermined range.

29. The well system of claim 16, wherein the at least one variable flow resistance system comprises multiple variable flow resistance systems through which multiple fluid compositions are flowed, and further comprising at least one sensor that detects which of the variable flow resistance systems have a flow resistance which alternately increases and decreases in response to flow of the respective fluid composition.

30. A method of propagating pressure pulses in a subterranean well, the method comprising:

flowing a fluid composition through at least one variable flow resistance system which includes a vortex chamber having at least one inlet and an outlet, a vortex being created when the fluid composition flows spirally about the outlet; and

the vortex being alternately created and dissipated in response to the step of flowing the fluid composition through the variable flow resistance system.

31. The method of claim 30, wherein a resistance to flow of the fluid composition through the vortex chamber alternately increases and decreases when the vortex is alternately created and dissipated.

32. The method of claim 30, wherein the pressure pulses are propagated upstream from the variable flow resistance system when the vortex is alternately created and dissipated.

33. The method of claim 30, wherein the pressure pulses are propagated downstream from the variable flow resistance system when the vortex is alternately created and dissipated.

34. The method of claim 30, wherein the pressure pulses are propagated from the variable flow resistance system into a subterranean formation when the vortex is alternately created and dissipated.

35. The method of claim 30, wherein the pressure pulses are propagated through a gravel pack when the vortex is alternately created and dissipated.

36. The method of claim 30, wherein the step of flowing the fluid composition further comprises flowing the fluid composition from a subterranean formation into a wellbore.

37. The method of claim 36, wherein the step of flowing the fluid composition further comprises flowing the fluid composition from the wellbore into a tubular string via the variable flow resistance system.

38. The method of claim 30, wherein the vortex is alternately created and dissipated when a characteristic of the fluid composition is within a predetermined range.

39. The method of claim 38, wherein the characteristic comprises a viscosity of the fluid composition.

40. The method of claim 38, wherein the characteristic comprises a velocity of the fluid composition.

41. The method of claim 38, wherein the characteristic comprises a density of the fluid composition.

42. The method of claim 38, wherein the vortex is alternately created and dissipated only when the characteristic of the fluid composition is within the predetermined range.

43. The method of claim 30, wherein the vortex is alternately created and dissipated when a ratio of desired to undesired fluid in the fluid composition is within a predetermined range.

44. The method of claim 30, wherein the step of flowing the fluid composition through the variable flow resistance system further comprises flowing multiple fluid compositions through respective multiple variable flow resistance systems, and further comprising the step of detecting which of the variable flow resistance systems have vortices which are alternately created and dissipated in response to flow of the respective fluid composition.

45. The method of claim 30, wherein the at least one inlet comprises first and second inlets, and wherein the variable flow resistance system further comprises a control passage which receives a portion of the fluid composition from the vortex chamber, thereby influencing more of the fluid composition to flow into the chamber via the second inlet, when the fluid composition spirals about the outlet in the chamber due to flow of the fluid composition into the chamber via the first inlet.

* * * * *

[54] **FLAP-EQUIPPED POWER FLUID
AMPLIFIER**

[75] Inventors: Karl Axel Zetterström,
Trollhattan; Tage Lennart
Wetterstad, Ljungby; Per-Olov
Abrahamsson, Opalgatan, all of
Sweden

[73] Assignee: Volvo Flygmotor AB, Trollhattan,
Sweden

[22] Filed: May 21, 1971

[21] Appl. No.: 145,781

[30] Foreign Application Priority Data

Dec. 3, 1970 Sweden 16401/70

[52] U.S. Cl. 137/829, 235/201 ME

[51] Int. Cl. F15c 3/00

[58] Field of Search 137/81.5

[56] References Cited

UNITED STATES PATENTS

3,053,276	9/1962	Woodward.....	137/81.5
3,605,780	9/1971	Kranz.....	137/81.5
3,276,463	10/1966	Bowles.....	137/81.5
3,568,700	3/1971	Verhelst et al.	137/81.5

3,621,859	11/1971	Scott.....	137/81.5
3,623,496	11/1971	Kawabata	137/81.5
3,638,671	2/1972	Harvey et al.	137/81.5
3,640,133	2/1972	Adams.....	137/81.5
3,640,256	2/1972	Mangion.....	137/81.5 X

Primary Examiner—Samuel Scott
Attorney—Sommers & Young

[57] **ABSTRACT**

A fluid amplifier having a fluid flow inlet, a pair of fluid flow outlets, a control fluid flow inlet and a pivotable triangular flap member located in the branching point of the fluid flow outlets, said member being located downstream of the control fluid inlet and adapted to open either of said fluid flow outlets. The flap member is free from direct actuation by the control fluid but is actuated by the fluid flow guided into either outlet and is pivotably journaled about an axis located within the triangular contour, whereby the flap member is automatically switched over to a position with the selected active outlet opened and the other passive outlet completely closed.

3 Claims, 14 Drawing Figures

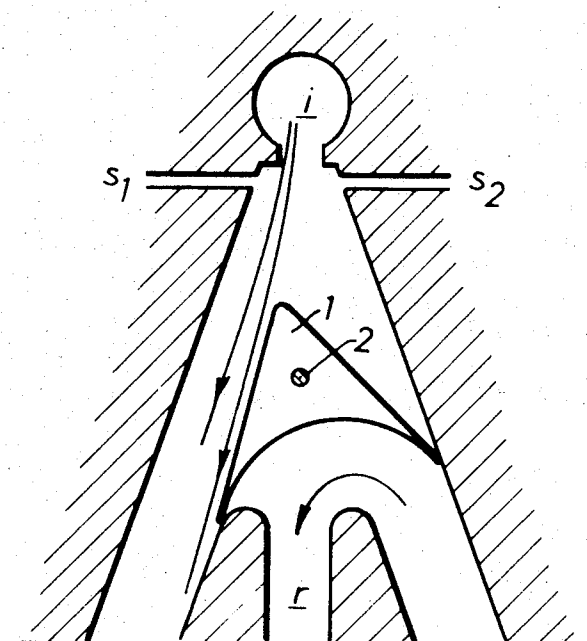


FIG. 1a

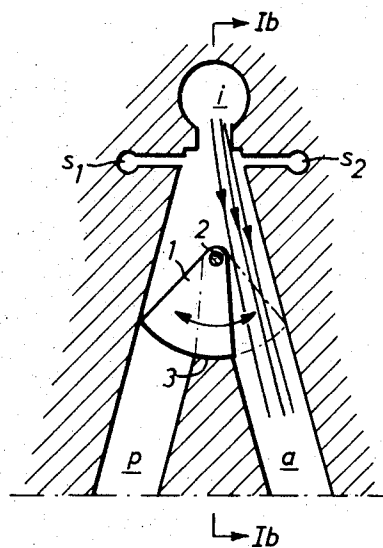


FIG. 1b

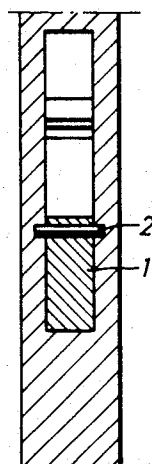


FIG. 2

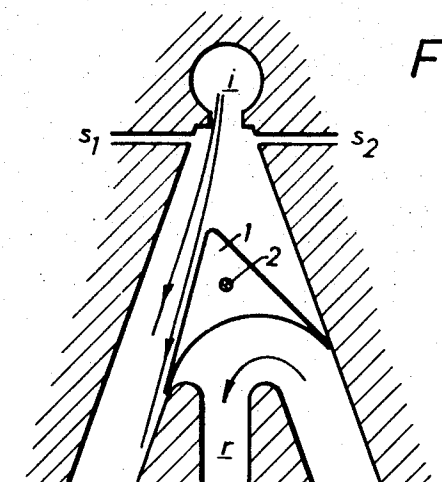


FIG. 3a

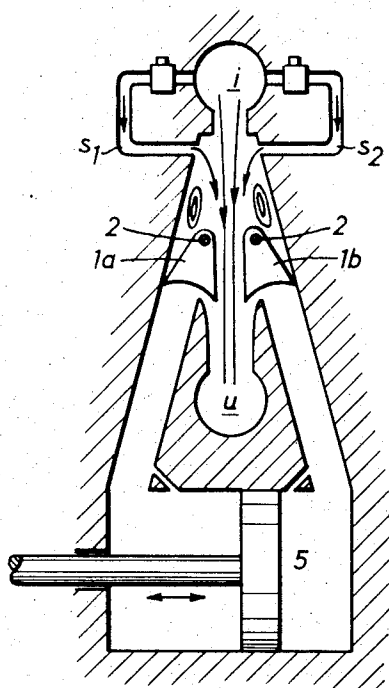


FIG. 3b

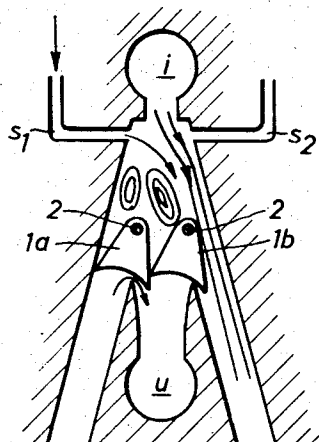
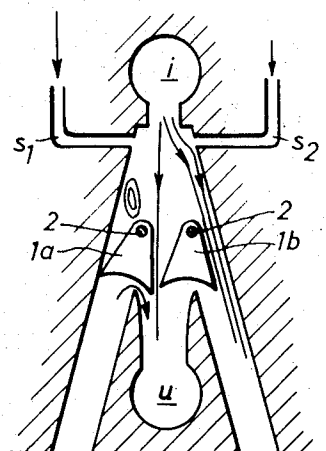


FIG. 3c

FIG. 4a

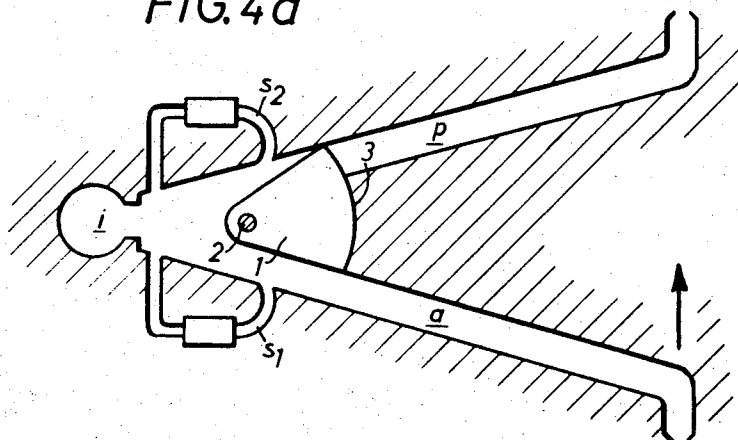


FIG. 4b

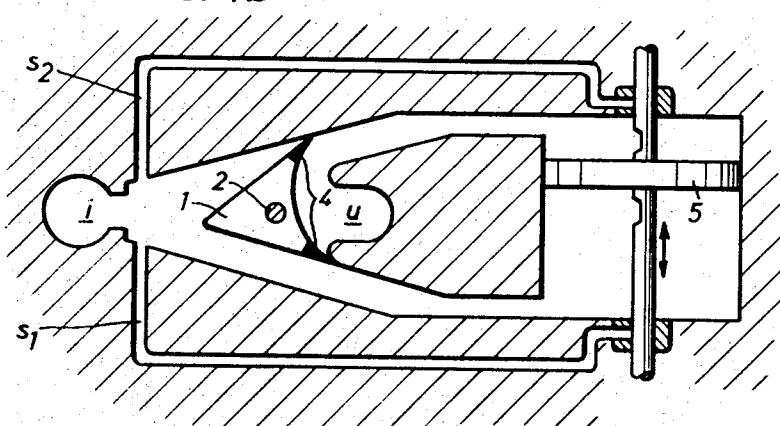
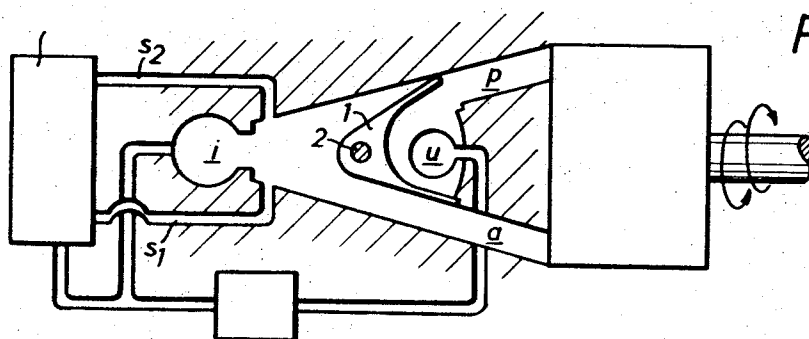
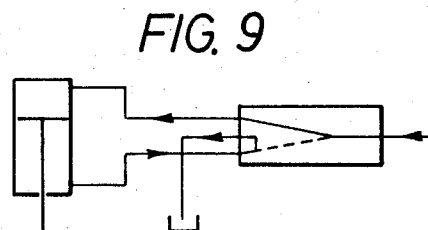
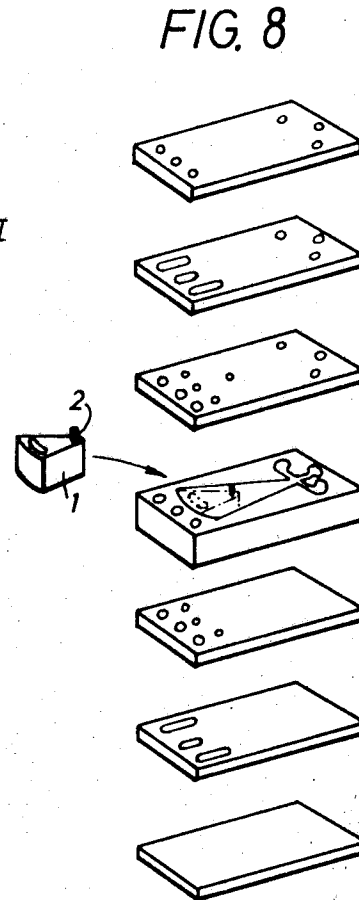
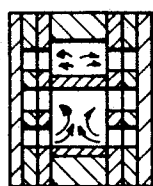
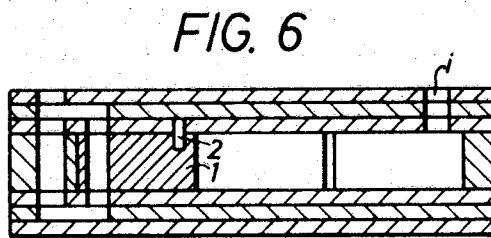
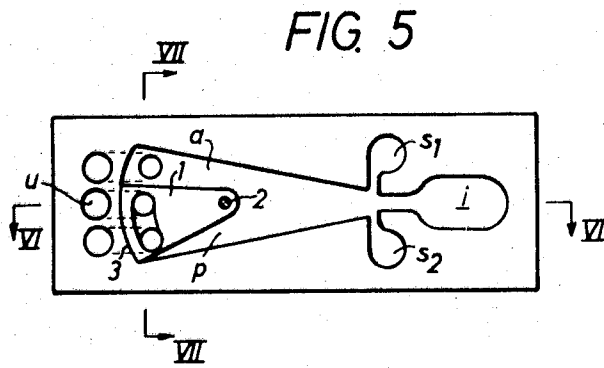


FIG. 4c





FLAP-EQUIPPED POWER FLUID AMPLIFIER

The present invention relates to a fluid amplifier having a fluid flow inlet, a pair of fluid flow outlets, at least one control fluid inlet and at least one flap member located in the branching point of the fluid flow outlets, said member being pivotable and having a triangular contour in plan view and adapted to open either of said fluid flow outlets.

The fluid amplifiers originally developed, i.e., those that are proportional or mono-, bi-, or tri-directional fluid amplifiers etc. have turned out to be very load sensitive. The controlled fluid flow cannot be brought to develop any substantial output since disturbances in operation will occur. Thus, when the jet in the active outlet flows against a pressure substantially greater than the pressure in the passive outlet, the jet will move progressively or suddenly over to the passive outlet. For this reason, such a common fluid amplifier without movable part has not been able to provide any substantial output and has thus not been usable as an output stage in a fluid amplifier system.

To eliminating such major drawback of said fluid amplifiers, attempts have been made to arrange valve means such as flaps in such fluid amplifiers. An example of this is the disclosure of the U.S. Pat. specification No. 3,053,276. The structure according to said patent specification involves a certain improvement of the fluid amplifier and removes to a certain extent the drawback of instability as mentioned, but it has also turned out to have serious disadvantages. The structure stated in said U.S. Pat. specification No. is such that the control fluid flow directly acts upon the valve flap arranged at the outlets of the fluid amplifier, and therefore a significant control fluid pressure must be sacrificed to provide a switch-over. Also, the structure according to said U.S. Pat. specification cannot bear any greater load since, the greater the pressure of the active outlet, the more the flap will be pressed against the adjacent wall, and this finally will make it completely impossible to move the flap.

The present invention now aims at the elimination of the above-stated drawbacks and disadvantages and to provide a fluid amplifier of the kind stated, in which effects of hitherto inconceivable magnitude can be obtained without any detrimental effects at all concerning the reliability of the switch-over function.

The feature substantially distinguishing the present invention is that the flap member is free from direct actuation by the control fluid but is instead actuated by the introduction of the fluid flow into either of the outlets so that the flap member then automatically will be switched over to a position with the selected active outlet opened and the other passive outlet completely closed, said flap member being pivotably journaled about an axis located within the triangular contour.

As will be evident from the following, in the invention the flap member according to the stated US patent specification has, in effect, been turned around and been provided with a contrary shape and thereby the particularly advantageous effect has been obtained that the main jet can be caused to move the flap member instead of the control fluid flow as in the last-mentioned art structure.

The invention also has a plurality of other important advantages. Firstly, it of course provides complete reliability with complete elimination of progressive or sud-

den unintended adjustments of the flap member. Furthermore, the adjustment of the flap member can be controlled with small control fluid pulses so that the fluid amplifier has a high rate of amplification. The direction of the flow also can be changed very quickly, and the fluid amplifier can bear very high loads and gives small pressure losses. Therefore, the fluid amplifier according to the present invention also is very well suited for connection with a fluid amplifier system, contrary to a mechanical valve. Finally, the device of course can be used for gaseous fluids as well as liquids.

By way of example, the invention will be further described below with reference to the accompanying drawings, in which FIG. 1a and 1b is a plan view in section and a longitudinal side elevational section of a principally basic embodiment of the invention;

FIGS. 2, 3a-3c and FIGS. 4a-4c are various possible applications of said basic inventive principle;

FIGS. 5-9 illustrate a further embodiment of the present invention, wherein FIG. 5 is a sectional plan view, FIG. 6 a longitudinal side elevational section, FIG. 7 an end sectional view, FIG. 8 an exploded perspective view and FIG. 9 a flow diagram of said further embodiment.

In FIGS. 1a and 1b thus is illustrated a common bidirectional fluid amplifier having a fluid flow inlet *i* and two fluid flow outlets, one denominated *a* for active and the other *p* for passive. The fluid flow entering from the inlet thus passes out through the outlet *a* in the condition illustrated in FIG. 1a. Furthermore there are illustrated two control fluid inlets *s*₁ and *s*₂, respectively, from which a controlling fluid pulse can be directed towards the fluid flow jet in the fluid amplifier and cause the same to be switched over from one of the outlets to the other, the outlets then of course interchanging their denominations *a* and *p*.

According to the present invention, in the branching point between the two fluid flow outlets, is arranged a flap member 1, which has triangular shape in plan view and in the present particular embodiment has the shape of a sector of a circle, such as is illustrated in FIG. 1a. Said flap member 1 is pivotally journaled about a pivot 2, which is located adjacent the peak of the circle sector or the center of the circular arc surface. Said circular arc surface of the flap member is located downstream of the pivot 2 and is spaced with smallest possible clearance from the end surface 3 of the partition wall between the two fluid flow outlets at their branching. Said end surface suitably has a contour shape following as close as possible the circular arcuate surface of the flap member. Said flap member 1 is freely pivotably journaled on the pivot 2.

The operation of the flap member 1 is as follows: in the condition illustrated in FIG. 1a, the flap member gives a free passage to the fluid flow jet going from the inlet to the active outlet. When a control fluid pulse is applied to the fluid amplifier through the control fluid inlet *s*₂ and the fluid flow jet thus is switched over against the opposite outlet, the main jet automatically will act upon the flap member owing to the location thereof downstream of the pivot 2. Experimentally it has been determined that this switching over of the flap member by means of the main flow will occur clearly and distinctly such that the other fluid flow outlet in the amplifier will be the active one while the previous active outlet now becomes the passive. In said passive outlet then resides a low pressure, while in the other

above-described embodiments. To eliminate this sensitivity, a further improved embodiment can be utilized such as illustrated in FIGS. 5-9 of the drawings.

Similar to the preceding embodiments, in the branching between the fluid flow outlets is mounted a flap member 1, but at its base side opposite to the pivot 2, which base side suitably is circularly arcuate, there is provided a connecting conduit 6, extending substantially parallel to said base side. At each end, said conduit 6 opens in a port or aperture at right angles to the plane of the flap member 1. Similarly, the two outlets *a* and *p* are connected to outlet conduits opening at right angles to the plane of the flap member. Between said outlet conduits a return conduit *u* to the power fluid source is also provided.

Because of the connecting conduit 6 in the flap member, a by-pass of a fluid flow returning through the respective outlet to said return conduit is permitted as is the case also in several of the preceding embodiments. In the present embodiment however, there is obtained a complete balancing of the forces acting upon the flap member 1, and therefore the same become very insensitive to loads. Another advantage is that, when making the fluid amplifier in a sandwich structure such as illustrated in FIG. 8, it is possible to have the connecting conduit 6 open to both sides of the triangular flap member, the conduits leading from either side of said flap member then being connected to each other to provide a common connection exteriorly of the fluid amplifier to only one side thereof.

We claim:

1. A fluid amplifier having in combination:

a fluid flow inlet;

a pair of fluid flow outlets;

at least one control fluid inlet;

at least one pivotable flap member which is of generally triangular contour in plain view and located downstream of the control fluid inlet so as to be non-responsive directly to fluid entering said control fluid inlet, said member being pivotably journaled about an axis located within its triangular contour and selectively operable between two distinctively different positions in each of which said fluid flow inlet communicates for fluid flow with a respective one only of said fluid flow outlets, said flap being actuated from a first to a second of its two positions only in response to the momentary diversion of the direct flow path between said fluid flow inlet and the then-active fluid flow outlet in response to an input to said control fluid inlet which momentary diversion causes said fluid to impinge upon said flap and quickly actuates said flap to its second position,

and a partition wall between said fluid flow outlets defining therein a return conduit,

said triangular flap member having a downstream base side formed with a concave configuration towards the center of gravity of said flap member for allowing the by-pass of a return fluid flow through the passive outlet back through the return conduit.

2. A fluid amplifier according to claim 1, characterized in that two flap members are arranged side-by-side substantially in register with each edge of the return conduit in the partition wall.

3. A fluid amplifier having in combination:

a fluid flow inlet;

a pair of fluid flow outlets;

at least one control fluid inlet;

at least one pivotable flap member which is of generally triangular contour in plain view and located downstream of the control fluid inlet so as to be non-responsive directly to fluid entering said control fluid inlet, said member being pivotably journaled about an axis located within its triangular contour and selectively operable between two distinctively different positions in each of which said fluid flow inlet communicates for fluid flow with a respective one only of said fluid flow outlets, said flap being actuated from a first to a second of its two positions only in response to the momentary diversion of the direct flow path between said fluid flow inlet and the then-active fluid flow outlet in response to an input to said control fluid inlet which momentary diversion causes said fluid to impinge upon said flap and quickly actuates said flap to its second position,

said flap member having the shape of a sector of a circle with the partition wall between the fluid flow outlets closely following said sector periphery,

said flap member adjacent its circularly arcuate base side opposite the pivot axis being provided with a connecting conduit extending substantially parallel to said base side and at each end opening to at least one port at right angles to the plane of the flap member and adapted to be connected with, at one hand, a respective one of said outlets and, on the other hand, with a return conduit arranged between said pair of outlets and adapted to allow a by pass of a fluid flow returning through said respective outlet to said return conduit,

said pair of outlets as well as said return conduit being arranged to open into the fluid amplifier chamber at right angles to the plane of the flap member in register with the ports belonging to the connecting conduit.

* * * * *