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(54) **AUTONOMOUS INFLOW RESTRICTORS FOR USE IN A SUBTERRANEAN WELL**

(76) Inventors: **Rune Freyer**, Stavanger (NO); **Geirmund Saetre**, Stavanger (NO); **Gerry Kennedy**, Stavanger (NO); **William Mark Richards**, Frisco, TX (US)

Correspondence Address:
**SMITH IP SERVICES, P.C.**
**P.O. Box 997**
**Rockwall, TX 75087**

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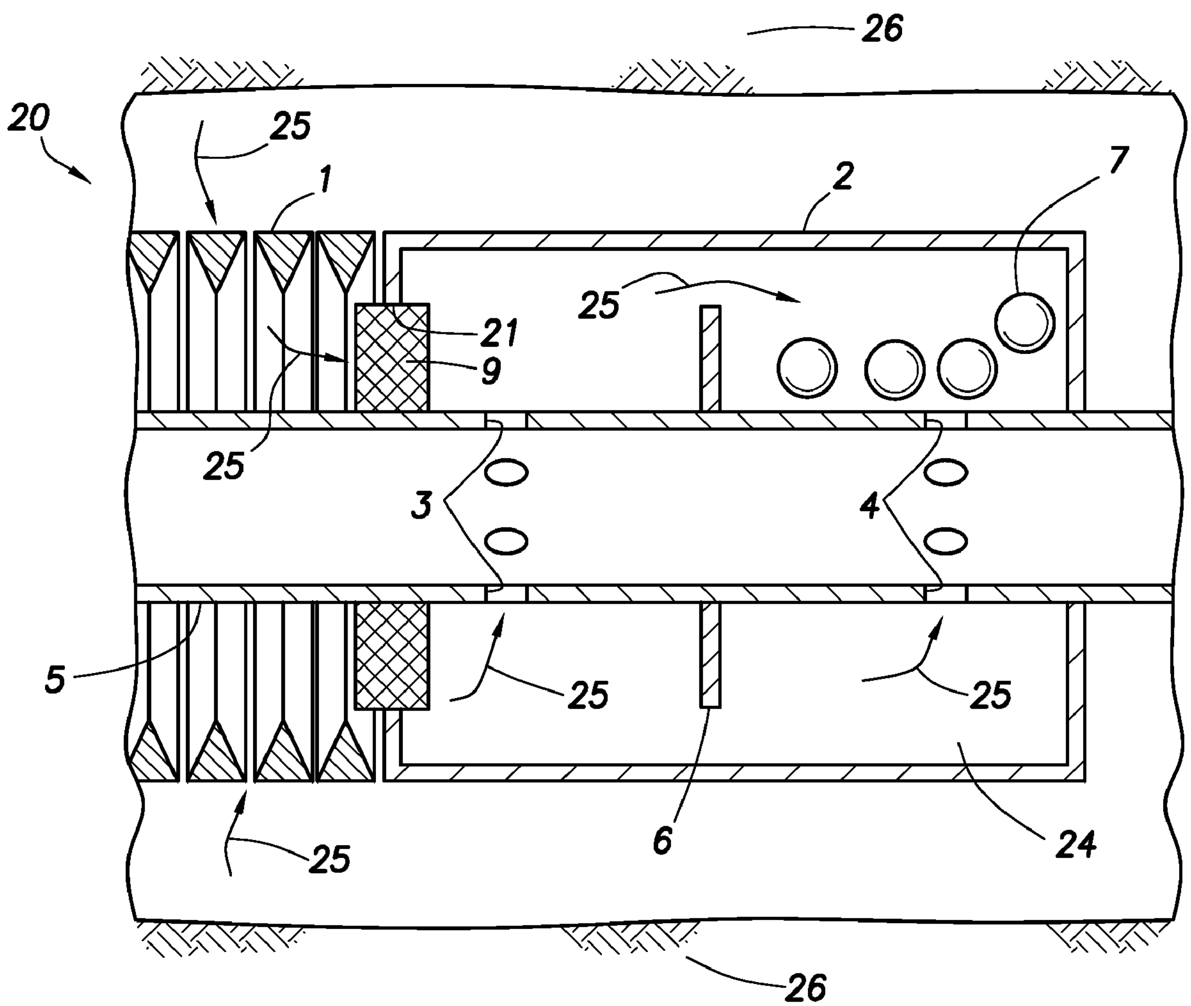
(57) **ABSTRACT**

Autonomous flow restrictors for use in a subterranean well. An apparatus is disclosed for use in a well wherein both oil and gas are produced. The apparatus includes multiple flow blocking members having a density less than that of the oil. The members are positioned within a chamber with the members increasingly restricting a flow of the gas out of the chamber through multiple outlets. Another apparatus is disclosed for restricting production of at least one undesired fluid which has a density different from a density of a desired fluid. The apparatus includes at least one flow restrictor and at least one bypass flow restrictor. The bypass restrictor may have a greater restriction to flow therethrough as compared to the other flow restrictor. The apparatus further includes multiple flow blocking members operative to increasingly restrict flow of the undesired fluid through the flow restrictor in response to an increased proportion of the undesired fluid.



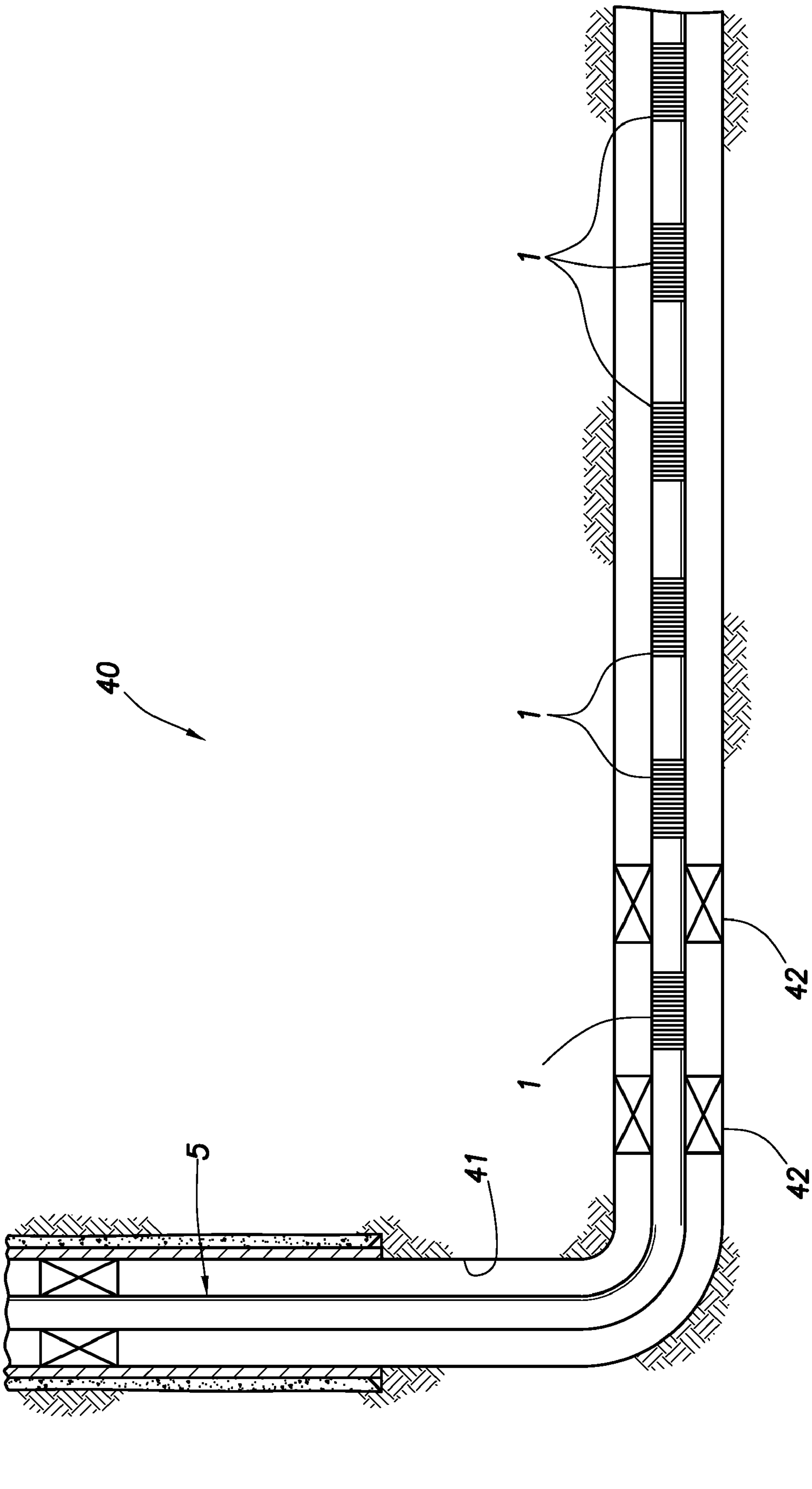



FIG. 1

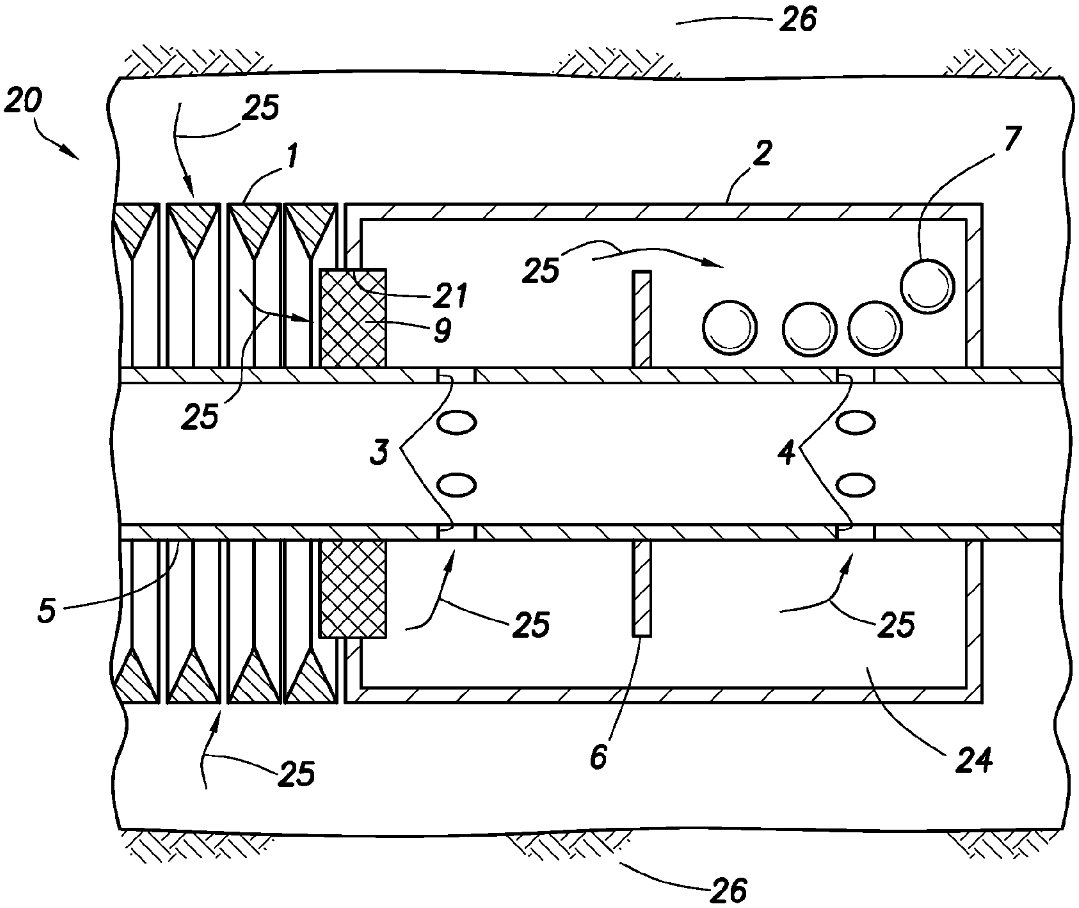

26
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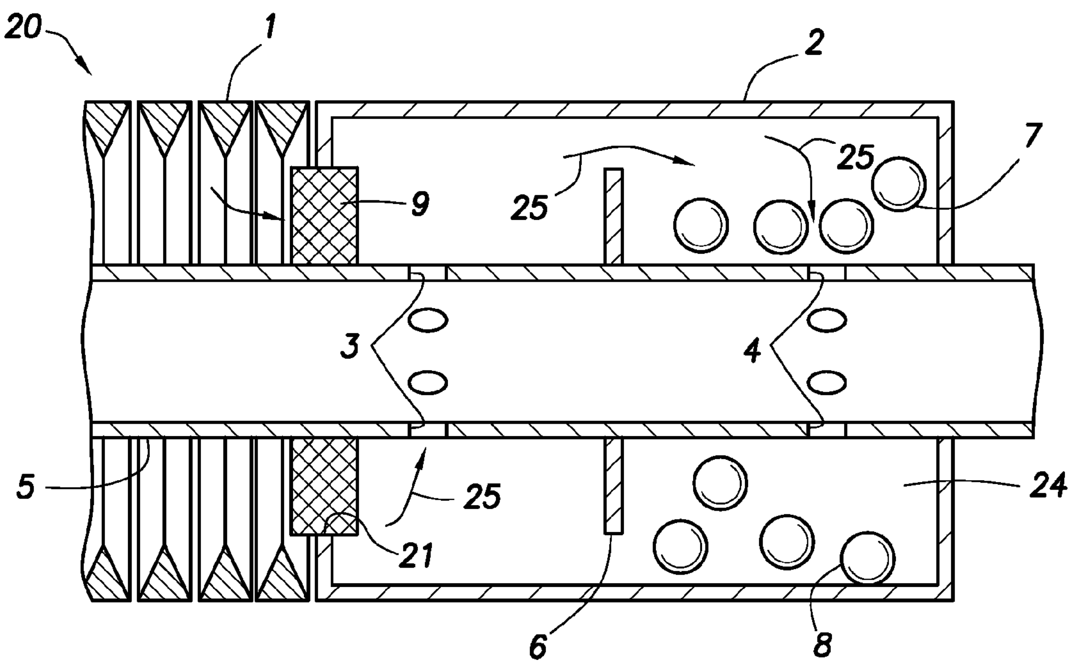
FIG.2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8

FIG.3

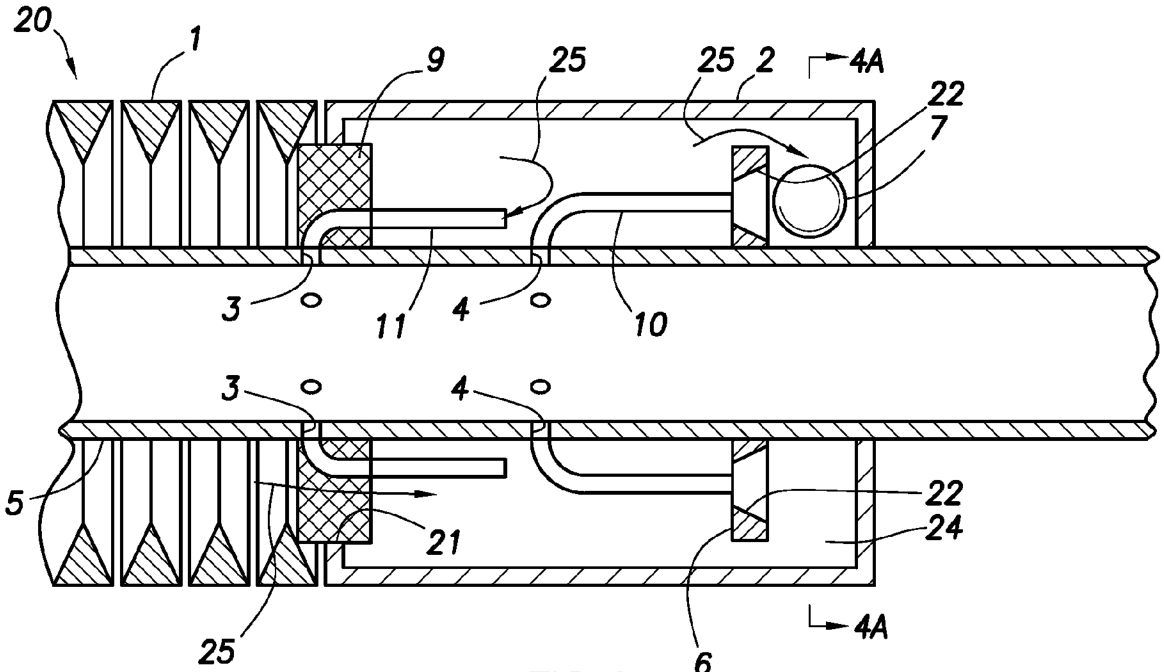


FIG.4

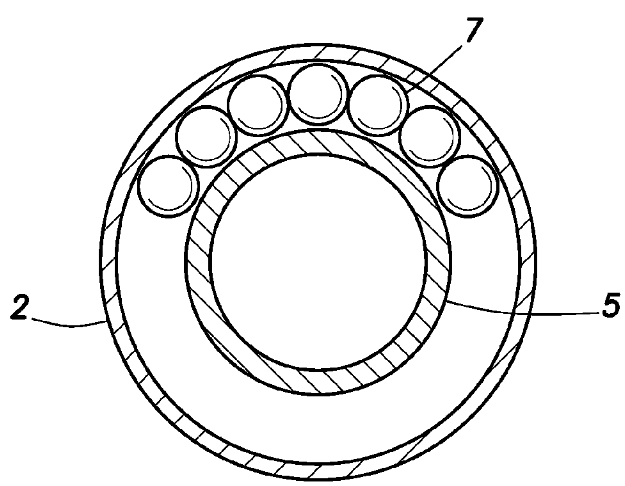


FIG.4A

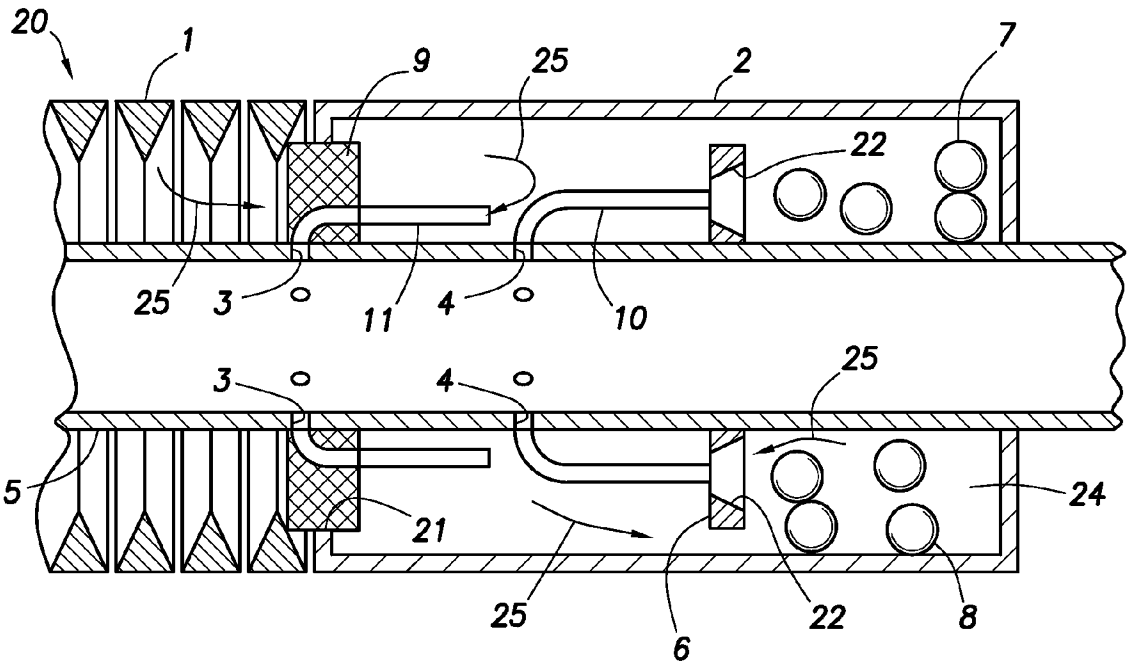
20
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FIG.5

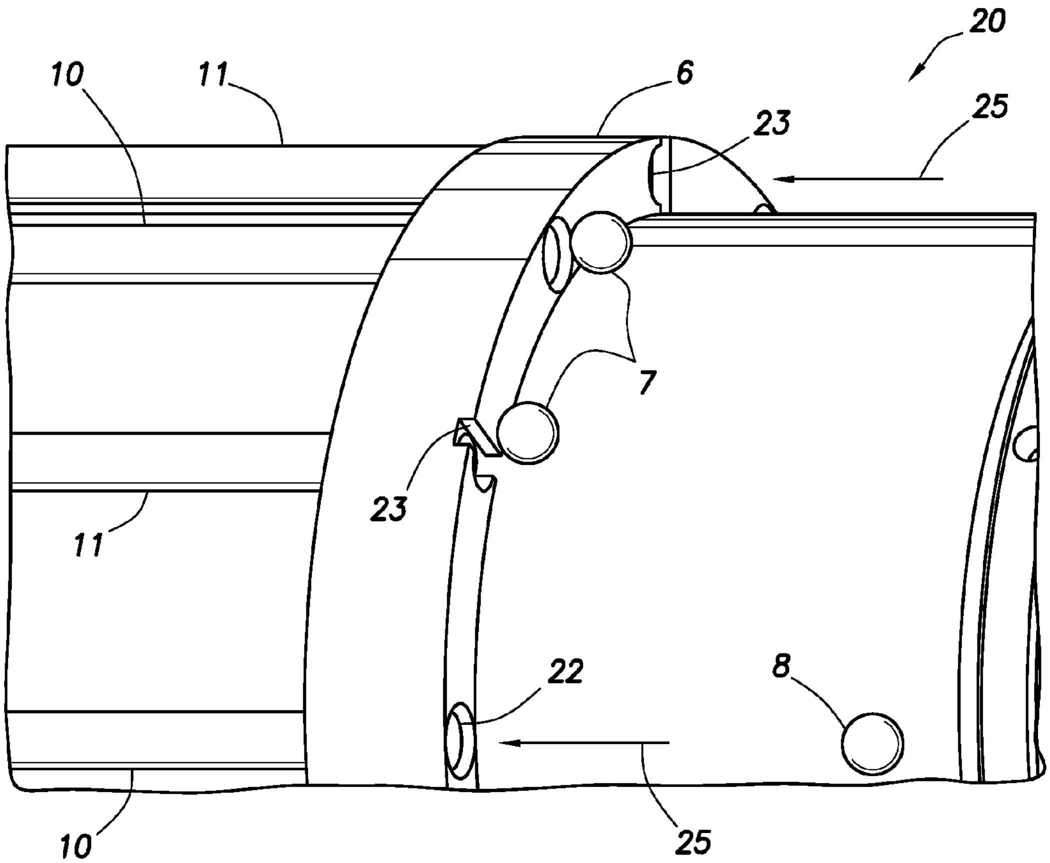
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FIG.8

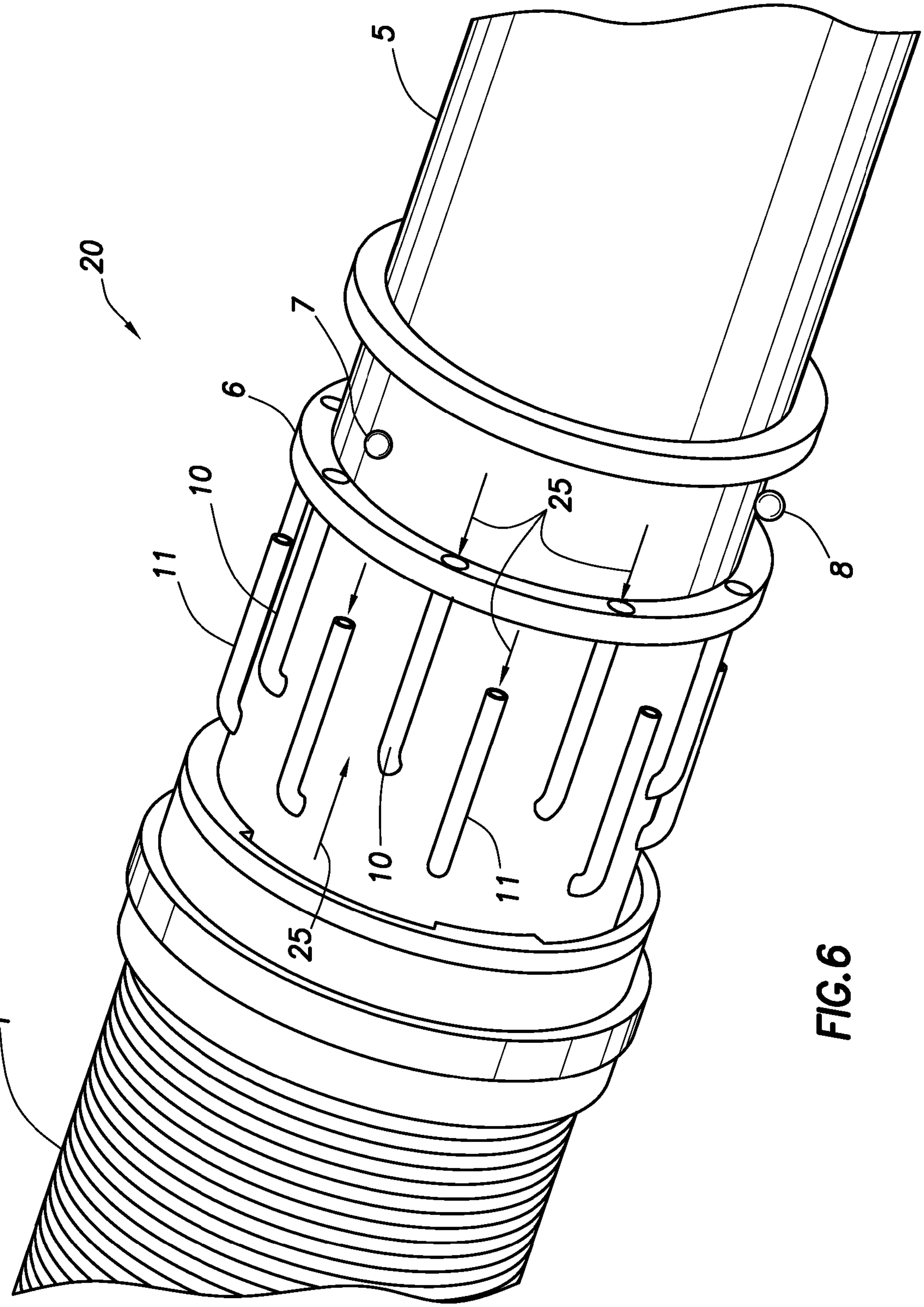



FIG.6

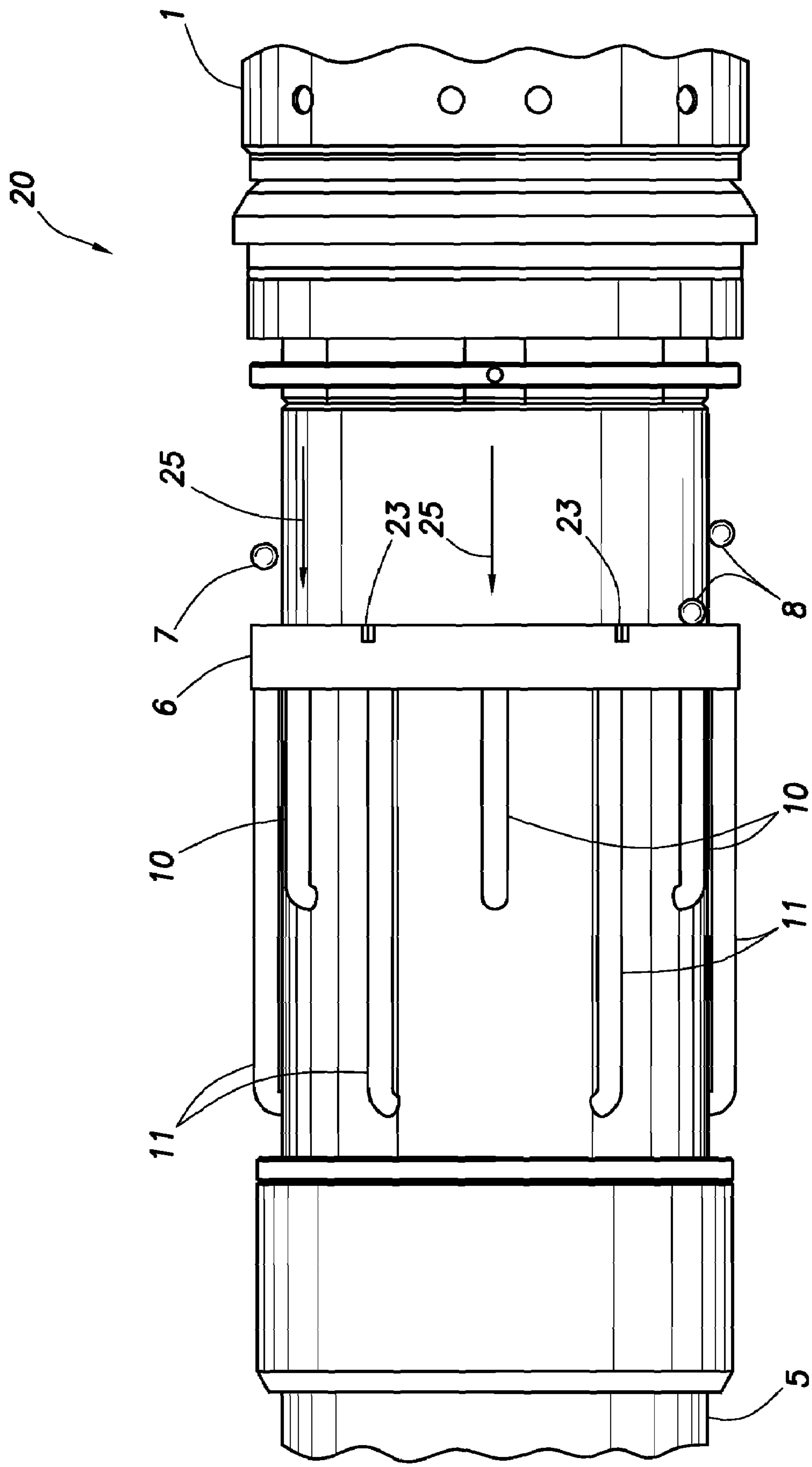
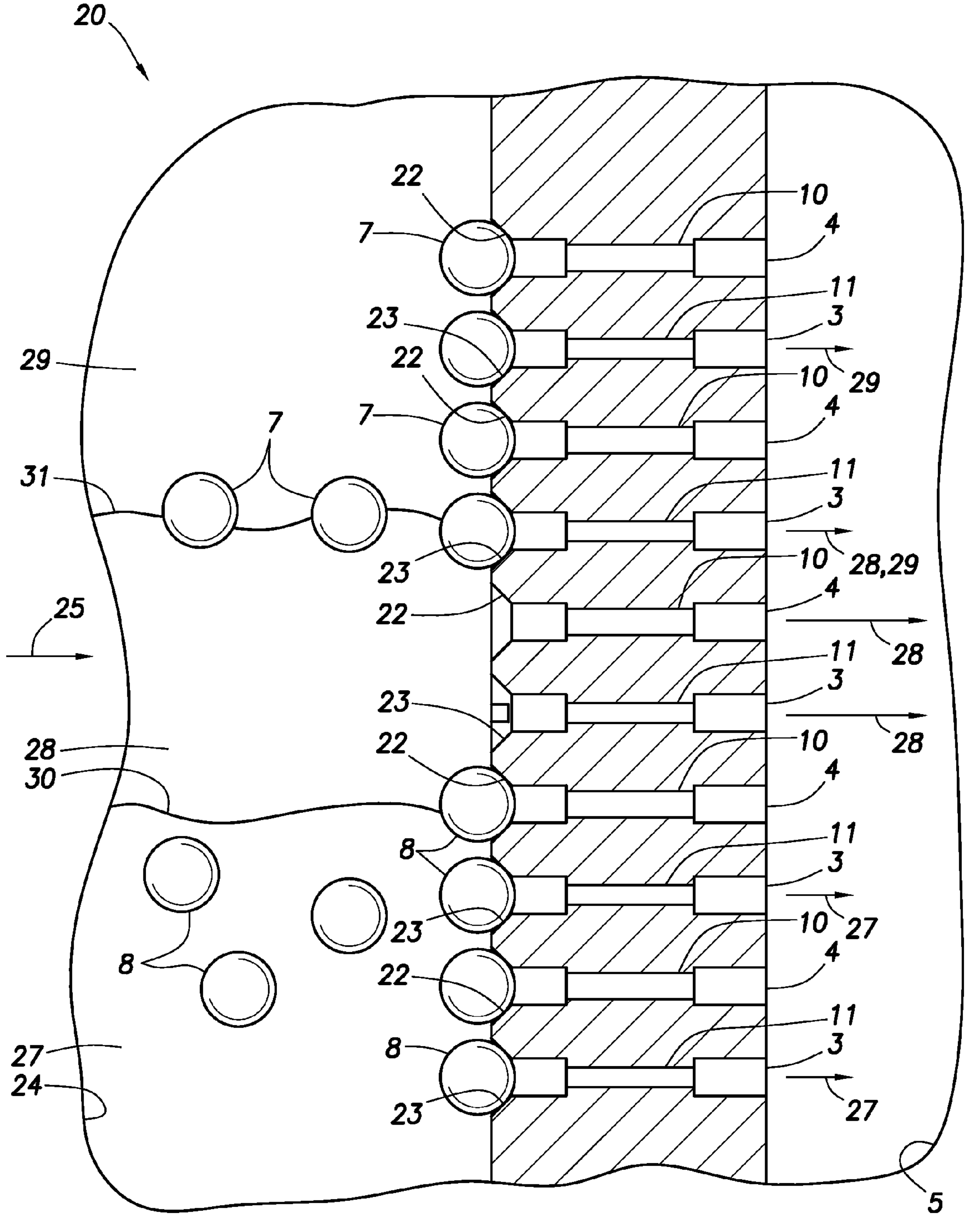



FIG. 7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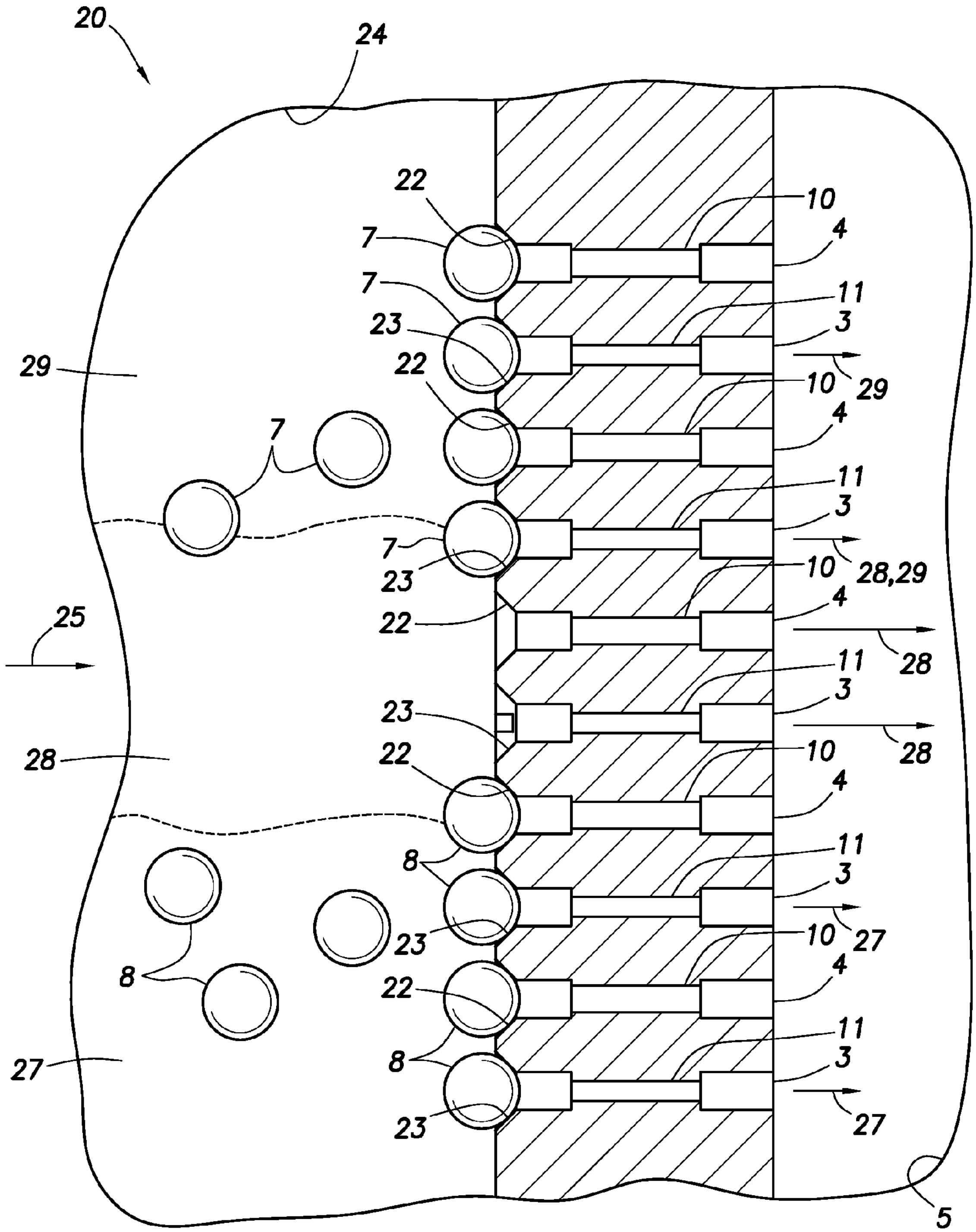
27
5

FIG.9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4
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23
27
5

FIG. 10

# AUTONOMOUS INFLOW RESTRICTORS FOR USE IN A SUBTERRANEAN WELL

## BACKGROUND

**[0001]** The present invention relates to equipment utilized and operations performed in conjunction with a subterranean well and, in embodiments described below, more particularly provides apparatus for automatically controlling inflow from a subterranean formation into a tubular string situated in the well.

**[0002]** When the proportion of formation water and/or gas produced from a well becomes excessive, production has to be stopped in many cases. Breakthrough of water or gas can vary along the well from one zone to another, and is dependent on the reservoir permeability, pressure communication in the reservoir, coning and other inhomogeneities in the reservoir. However, shut-in of a zone mainly producing water can result in increased production from other zones in the well which mainly produce oil.

**[0003]** In recent years this knowledge has lead to the development of systems comprising surface controlled valves and adjustable nozzles. Some of the disadvantages associated with such systems are technical complexity and the necessity of complicated downhole equipment, thereby resulting in poor reliability. Another disadvantage is that such systems typically constrict the flow area of tubing situated in the well.

**[0004]** Certain well installations benefit from having a flow restriction device in a well screen. For example, such flow restriction devices have been useful in preventing water coning, balancing production from long horizontal intervals, etc. These flow restriction devices are sometimes referred to as "inflow control devices."

**[0005]** In certain proposed inflow control devices, the devices are adapted to counter frictional effects caused by the flow of fluid through the tubing. However, these devices do not have the ability to regulate the pressure drop across the system based on water cut in the fluid. Before flowing into the tubing, the produced fluids have to flow through a fixed flow restriction, such as a capillary tube or nozzle, typically arranged around the tubing in the form of a helical thread. The fluid flows through grooves of the thread.

**[0006]** Another proposed inflow control device is used when gas is desired to be produced from a well without simultaneous production of water. The device is equipped with spherical, stacked controlled buoyancy elements, each of which has a density less than water. Upon ingress of water from the formation, the elements become buoyant and close one or more openings, so as to prevent water from flowing into the tubing.

**[0007]** Yet another proposed inflow control device includes a flow chamber secured to the tubing and provided with floating bodies, each having a density approximately equal to that of formation water. The chamber is formed with an inlet and surrounds nozzles providing fluid communication between the tubing and the formation. When the inflow includes a sufficient proportion of water, the floating bodies become buoyant and float from a position within the chamber distant from the nozzles to a position closing or covering the nozzles, thereby restricting the inflow into the tubing.

**[0008]** From the foregoing, it is apparent that improvements are needed in the art of automatic inflow control in wells. The improvements may be useful in other operations, as well.

## SUMMARY

**[0009]** In carrying out the principles of the present invention, an apparatus is provided which solves at least one problem in the art. An example is described below in which the flow of gas, or alternating water or gas, along with produced oil is restricted. Another example is provided in which features are included to prevent outlets in the apparatus from being plugged and the like.

**[0010]** According to one described embodiment, there is provided an apparatus for restricting the flow of undesired fluids from a subterranean formation into a tubular string situated in a hydrocarbon producing well. The apparatus includes a flow housing secured to the tubular string and adapted to surround outlets communicating the tubular string with the formation via the housing. The housing has an inlet for the fluid and is provided with flow blocking members which, when the fluid does not mainly include oil, are adapted to float from a position within the housing distant from the outlets to a position closing, covering or otherwise increasingly restricting flow through the outlets.

**[0011]** Preferably, the flow blocking members are in the form of balls. If the undesired fluid is gas, then preferably the members have a density less than oil, so as to increasingly shut off or choke the flow into the tubular string when an increased proportion of gas is produced.

**[0012]** If the undesired fluid is water, then preferably the members have a density approximately equal to the water. Alternatively, the members may have a density less than that of the water, or greater than that of oil or gas (whichever of these is desired to be produced and has the greatest density). As another alternative, some of the members may have a density approximately equal to that of the water, and some of the members may have a density less than that of the water.

**[0013]** The outlets are preferably provided with restrictors. Some of the restrictors may have greater flow restriction therethrough than others of the restrictors. Some of the restrictors may be used to bypass the effect of the flow blocking members, so that the flow blocking members have no effect on flow through these restrictors. Alternatively, the flow blocking members may engage and increasingly restrict flow through the restrictors, without entirely preventing flow through the restrictors.

**[0014]** When producing undesired gas along with desired oil, it is possible to restrict the flow of the gas by using a flow blocking member density lighter than the produced oil, preferably from about 600 $kg/m^3$ to about 800 $kg/m^3$. Similarly, in case of unwanted amounts of produced water or gas, the flow of water can be increasingly restricted by addition of flow blocking members having a density equal to the formation water density, normally approximately 1030 $kg/m^3$. Upon production of water, the members may become neutrally buoyant and able to increasingly restrict flow through the outlets due to drag caused by flow through the outlets.

**[0015]** By using tubular extensions for the outlets, a desired pressure drop can be maintained, while allowing for a larger diameter internal passage, as compared to a simple nozzle. Bypass outlets, or restrictors not being closed by the

members, allow for some flow of oil and gas or water into the tubular string, thereby not completely stopping the production even at a high level of gas or water cut.

**[0016]** To reduce the flow from various zones of the formation potentially producing an excessively large proportion of gas or water, more than one apparatus can be disposed at relatively short intervals along the tubular string. Since these apparatuses operate independently of each other and with immediate response, greater selectivity and better control is achieved.

**[0017]** Thus, an apparatus is provided for use in a well wherein fluid is produced which includes both oil and gas. The apparatus includes multiple flow blocking members, each of the members having a density less than that of the oil. The members are positioned within a chamber so that the members increasingly restrict a flow of the gas out of the chamber through multiple outlets.

**[0018]** Also provided is an apparatus for restricting production of at least one undesired fluid from a well, the undesired fluid having a density different from a density of a desired fluid. The apparatus includes at least one flow restrictor and at least one bypass flow restrictor. The bypass restrictor may have a greater restriction to flow therethrough as compared to the other flow restrictor.

**[0019]** The apparatus further includes multiple flow blocking members. The members are operative to increasingly restrict flow of the undesired fluid through the flow restrictor in response to an increased proportion of the undesired fluid.

**[0020]** These and other features, advantages, benefits and objects of the present invention will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of representative embodiments of the invention hereinbelow and the accompanying drawings, in which similar elements are indicated in the various figures using the same reference numbers.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0021]** FIG. **1** is a schematic partially cross-sectional view of a well system embodying principles of the present invention;

**[0022]** FIG. **2** is a schematic cross-sectional view of an apparatus embodying principles of the invention which may be used in the well system of FIG. **1**, the apparatus including a flow housing and flow blocking members in the form of balls having a density less than oil;

**[0023]** FIG. **3** is a schematic cross-sectional view of an alternate configuration of the apparatus, wherein balls having an increased density are included;

**[0024]** FIG. **4** is a schematic cross-sectional view of another alternate configuration of the apparatus, including tubular restrictor extensions of fluid outlets and bypass outlets, respectively;

**[0025]** FIG. **4**A is a cross-sectional view of the apparatus, taken along line **4**A-**4**A of FIG. **4**;

**[0026]** FIG. **5** is a schematic cross-sectional view of another alternate configuration of the apparatus, similar to the configuration of FIG. **3**, but including tubular restrictor extensions of the fluid outlets and bypass outlets, respectively;

**[0027]** FIG. **6** is a schematic cut-way view in perspective of another alternate configuration of the apparatus;

**[0028]** FIG. **7** is a schematic cut-way view of another alternate embodiment of the apparatus, wherein both the fluid restrictors and bypass restrictors are connected between outlets and a excluder;

**[0029]** FIG. **8** is a schematic fragmentary perspective view illustrating different inlet shapes of the fluid restrictors and bypass restrictors in the configuration of FIG. **7**;

**[0030]** FIG. **9** is a schematic cross-sectional view of the apparatus with separate stratified layers of gas, oil and water in a chamber of the apparatus; and

**[0031]** FIG. **10** is a schematic cross-sectional view of the apparatus with mixtures of different proportions of gas, oil and water in the chamber.

## DETAILED DESCRIPTION

**[0032]** It is to be understood that the various embodiments of the present invention described herein 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 invention. The embodiments are described merely as examples of useful applications of the principles of the invention, which is not limited to any specific details of these embodiments.

**[0033]** In the following description of the representative embodiments of the invention, directional terms, such as "above", "below", "upper", "lower", etc., are used for convenience in referring to the accompanying drawings.

**[0034]** The embodiments described below each include an apparatus which automatically controls the flow from a subterranean formation into a tubular string situated in a hydrocarbon producing well. Although the drawings illustrate a tubular string oriented in a horizontal direction, it is to be understood that the invention is applicable to tubular strings orientated in the vertical direction, as well as any other direction. The formation from which fluid is produced may be found either offshore or onshore.

**[0035]** Representatively illustrated in FIG. **1** is a well system **40** which embodies principles of the present invention. A tubular string **5** (such as a production tubing string) is installed in a wellbore **41** of a well. The tubular string **5** includes multiple well screens **1** positioned in an uncased generally horizontal portion of the wellbore **41**.

**[0036]** One or more of the well screens **1** may be positioned in an isolated portion of the wellbore **41**, for example, between packers **42** set in the wellbore. In addition, or alternatively, many of the well screens **1** could be positioned in a long, continuous portion of the wellbore **41**, without packers isolating the wellbore between the screens.

**[0037]** Gravel packs could be provided about any or all of the well screens **1**, if desired. A variety of additional well equipment (such as valves, sensors, pumps, control and actuation devices, etc.) could also be provided in the well system **40**.

**[0038]** It should be clearly understood that the well system **40** is merely representative of one well system in which the principles of the invention may be beneficially utilized. However, the invention is not limited in any manner to the details of the well system **40** described herein. For example, the screens **1** could instead be positioned in a cased and perforated portion of a wellbore, the screens could be positioned in a generally vertical portion of a wellbore, the screens could be used in an injection well, rather than in a production well, etc.

**[0039]** As described more fully below, the screens **1** are each part of an apparatus **20** which includes an inflow control device. However, it should be clearly understood that it is not necessary for the apparatus **20** to include a screen **1**, since an inflow control device can be used apart from a screen, if desired.

**[0040]** Each apparatus **20** is operative to variably restrict flow from an adjacent zone into the tubular string **5**. When the zone corresponding to a particular one of the apparatuses **20** produces a greater proportion of an undesired fluid (such as water, or sometimes gas), the apparatus will increasingly restrict flow from that zone. Thus, the other zones which are producing a greater proportion of desired fluid (such as oil) will contribute more to the production via the tubular string **5**. In particular, there will be a greater pressure drop from the formation to the tubular string **5**, resulting in a greater production of desired fluid, due to the increased restriction to flow from the zones which produce greater proportions of undesired fluid.

**[0041]** As representatively illustrated in FIG. **2**, the apparatus **20** includes a flow housing **2** secured to the tubular string **5**, e.g., with the housing secured to a pipe interconnected as a part of the tubular string. Outlets **4** provide fluid communication between an interior chamber **24** of the housing **2** and an interior of the tubular string **5**.

**[0042]** Oil to be produced from a formation is able to flow into the tubular string **5** at a rate partly determined by the number of outlets **4**, and the length and flow areas thereof. The outlets **4** may, for example, be in the form of nozzles or other types of flow restrictors.

**[0043]** An inlet **21** is formed at an end of the housing **2** for receiving fluid **25** from a subterranean formation **26**. To prevent plugging due to presence of particles and other debris in the formation fluid **25**, the inlet **21** may be provided with a suitable filter **9**.

**[0044]** A screen **1** of appropriate kind can be placed upstream of the inlet **21**. Alternatively, the housing **2** could be positioned upstream of the screen **1**, if desired. The screen **1** is not necessary in keeping with the principles of the invention.

**[0045]** One or more flow blocking members **7** in the form of balls are present within the housing **2** to restrict flow of undesired portions of the fluid **25** via the outlets **4**, for example, when the oil produced includes undesirable quantities of gas. In that situation, the density of each of the members **7** is preferably less than that of the oil, enabling each to either maintain a position within the housing **2** distant from the outlets **4** (when only a very small proportion of gas is present in the chamber **24**), or a position (not shown) shutting off or choking flow through the outlets (when a larger proportion of gas is present in the chamber).

**[0046]** Thus, when the fluid **25** is mainly oil, the members **7** will be positioned relatively distant from the outlets **4**, for example, at the top of the chamber **24**. However, when a sufficient proportion of gas also is present in the fluid **25**, the members **7** will restrict flow of the gas by shutting off or choking flow through certain ones of the outlets **4**.

**[0047]** It should be understood that, although the members **7** are depicted in the drawings and described herein as being in the form of balls, other shapes (such as cylindrical, prismatic, etc.) may be used in keeping with the principles of the invention. It also is not necessary for a particular member **7** to completely block flow through a respective outlet **4**, since the member could instead merely increasingly restrict flow through the outlet, if desired.

**[0048]** By selecting an average density preferably from about 600 $kg/m^3$ to about 800 $kg/m^3$, and by keeping in mind that the density of oil is typically somewhat less than 900 $kg/m^3$, the members **7** will be in a buoyant or "free-floating" state as long as the gas potentially included in the fluid does not lower the overall density of the fluid **25** below the selected member density. On the other hand, if the influx of gas should result in an overall density of the fluid approximately equal to the member density, then the members **7** will have "neutral buoyancy" and will be dragged to the outlets **4** due to the pressure drop over these. The respective outlet **4** can be blocked by means of a single member **7** or, alternatively, can be blocked by means of several members.

**[0049]** The density of the members **7** is preferably between the density of oil and the density of gas. If the oil and gas are separated in the chamber **24** (i.e., with the lower density gas above the higher density oil), then the members **7** will be positioned at the interface between the oil and gas.

**[0050]** As the interface descends in the chamber **24** (i.e., there is an increasing proportion of gas in the chamber), an increasing number of the outlets **4** will be blocked by the members **7**. As the interface ascends in the chamber **24** (i.e., there is an increasing proportion of oil in the chamber), a decreasing number of the outlets **4** will be blocked by the members **7**.

**[0051]** Thus, the apparatus **20** provides multiple benefits. As the proportion of gas increases, the restriction to flow of the fluid **25** through the housing **2** also increases. Furthermore, the members **7** block the outlets **4** which are more exposed to the gas in the chamber **24**, thereby providing a larger pressure drop across the apparatus, increasing the pressure drop across other zones in the well, allowing greater production from oil producing zones, and thereby allowing a greater production of oil from other zones to flow into the tubular string **5**.

**[0052]** There might be instances in which a complete closedown of production is undesirable, no matter how great the proportion of gas in the fluid **25**. Optional bypass outlets **3** can be used to provide communication between the interior of the housing **2** and the interior of the tubular string **5**, thereby allowing for some production, even though the members **7** may have shut off or choked flow through the remaining outlets **4** (such as, in case of large gas quantities in the fluid **25**).

**[0053]** The bypass outlets **3** may, for example, be in the form of nozzles or other types of flow restrictors. Preferably, the outlets **3** have greater restriction to flow therethrough as compared to the outlets **4**, for example, so that if the fluid **25** contains a large proportion of gas, only very limited flow through the outlets **3** will be permitted.

**[0054]** The members **7** are retained distant from the bypass outlets **3** by means of an excluder **6** in the form of a spacer ring secured to the tubular string **5** and having a height to prevent passage of the members **7** to the bypass outlets. Other types of excluders (such as screens, traps, etc.) may be used in keeping with the principles of the invention.

**[0055]** To prevent an excessive quantity of gas from being produced from multiple zones, the fluid **25** from different zones can be individually restricted by disposing more than one apparatus **20** along the tubular string **5**. One or more apparatus **20** can be used to control the flow of fluid from each corresponding zone. As a result, the well will produce an increased proportion of oil, due to the fact that the zones producing excessive amounts of gas are shut off or increasingly choked by the corresponding apparatus **20**.

**[0056]** An alternate configuration of the apparatus **20** is representatively illustrated in FIG. **3**. One significant difference between the configurations of FIGS. **2** and **3** is that the configuration of FIG. **2** includes the presence of additional members **8** in the chamber **24**, each of the members having a density approximately equal to that of water, or at least greater density than that of oil.

**[0057]** The members **8** in the configuration of FIG. **3** preferably have a density of about 1030 kg/m$^3$. The members **7** in the configuration of FIG. **3** preferably have a density of about 600 kg/m$^3$ to about 800 kg/m$^3$. The density of the members **8** is preferably approximately the density of water, although the density of the members **8** may be between the density of water and the density of oil, if desired. The density of the members **7** is preferably between the density of oil and the density of gas.

**[0058]** The addition of such heavier members **8** provides the capability of increasingly restricting flow of the fluid **25**, not only when excessive gas is produced along with oil, but also when excessive water is produced. Unlike the lower density members **7**, the heavier members **8** are preferably not buoyant as long as the well is producing a sufficient proportion of oil. Instead, in this situation, the members **8** would preferably be positioned in a bottom portion of the chamber **24**.

**[0059]** "Neutral buoyancy" of the members **8** only occurs when a sufficient proportion of water is produced to cause a sufficiently increased proportion of water in the produced fluid **25**. When the density of the fluid **25** increases by a sufficient amount, the heavier members **8** become neutrally buoyant and are carried by the water phase and engage the outlets **4**, due to the pressure drop across the outlets, thereby restricting flow of the fluid into the tubular string **5**.

**[0060]** There might be some concerns as to plugging, etc. of fluid outlets **4** and bypass outlets **3** if they have very small internal diameters. To prevent such problems, FIGS. **4-8** depict other configurations of the apparatus **20**. These embodiments are generally similar to the one discussed above and differ therefrom at least in part by having tubular flow restrictors **10**, **11** providing flow passages between the interior of the housing **2** and the fluid outlets **4** and bypass outlets **3**, respectively.

**[0061]** The restrictors **10**, **11** allow for larger internal passage dimensions than otherwise possible for the outlets **4**, **3** while still maintaining desired pressure drops between the interior of the housing **2** and the interior of the tubular string **5**. The housing **2** can include members **7** having a density between that of oil and gas or, alternatively, members **8**, **7** having a density between that of oil and water (or approximately equal to water), and less than that of oil, respectively, as described above.

**[0062]** Both the flow restrictors **10** and bypass restrictors **11** are preferably formed with a portion extending parallel to the tubular string **5**, as depicted in FIGS. **4-6**. Ends of the flow restrictors **10** opposite the outlets **4** are secured to the excluder **6** in an appropriate manner.

**[0063]** The members **7** are retained distant from the bypass restrictors **11** by the excluder **6**. In addition, the excluder **6** is provided with seats **22** for engagement with the members **7**. When a member **7** engages one of the seats **22**, flow from the chamber **24** into the corresponding restrictor **10** is prevented, or at least is increasingly restricted.

**[0064]** As depicted in the configuration of FIG. **7**, the bypass restrictors **11** are longer than the flow restrictors **10**. In this manner, flow through the bypass restrictors **11** is more restrictive compared to flow through the flow restrictors **10**, so that less fluid is produced when the members **7**, **8** prevent or increasingly restrict flow through the flow restrictors.

**[0065]** Other methods may be used to provide increased restriction to flow through the bypass restrictors **11**. For example, the flow area of each bypass restrictor **11** may be less than the flow area of each flow restrictor **10**, the total flow area of the bypass restrictors may be less than the total flow area of the flow restrictors (e.g., by providing fewer bypass restrictors than flow restrictors), the bypass restrictors may be provided with circuitous or tortuous flow paths, etc. Thus, any manner of increasingly restricting flow through the bypass restrictors **11** relative to flow through the flow restrictors **10** may be used in keeping with the principles of the invention.

**[0066]** To reduce the height of the housing **2**, the bypass restrictors **11** may also be connected to the excluder **6**, as depicted in FIGS. **7** and **8**. In this configuration, the inlets **23** to the bypass restrictors **11** have a shape preventing the members **7**, **8** from completely blocking the bypass inlets. However, when one of the members **7**, **8** does engage one of the inlets **23**, flow into the corresponding bypass restrictor **11** is preferably increasingly restricted.

**[0067]** Note that, in the configuration of FIGS. **7** and **8**, the fluid **25** enters the inlets of the restrictors **10**, **11** in the same direction as the fluid flows into the chamber **24**. In this manner, the fluid **25** applies both dynamic and static pressure to the inlets of the flow restrictors **10**, **11**. In contrast, in the configuration of FIG. **6**, the fluid **25** changes direction to enter the inlets of the restrictors **10**, **11**, and so the fluid applies substantially only static pressure on the inlets of the restrictors.

**[0068]** It may now be fully appreciated that the apparatus **20** in its various configurations described above is capable of achieving a variety of desirable benefits in different situations. For example, when it is desired to limit the production of water from a gas well (i.e., it is desired to produce gas, but not water), the configurations of FIGS. **1-7** may be used (although the members **8** in FIGS. **3** and **5-8** may not be used), with the members **7** each having a density approximately equal to, or less than, that of water. In this manner, the members **7** will either have neutral buoyancy in the water, or will float on top of the water, when the water enters the housing **2**, and the members will thus be carried by the water to the outlets **4** or the seats **22** to thereby increasingly restrict or prevent flow of the water into the tubular string **5**.

**[0069]** As another example, when it is desired to limit the production of gas from an oil well (i.e., it is desired to produce oil, but not gas), the configurations of FIGS. **2-8** may again be used (although the members **8** in FIGS. **3** and **5-8** may not be used), with the members **7** each having a density less than that of oil. In this manner, the members **7** will float on top of the oil, or remain at the top of the housing **2** and away from the outlets **4** or the seats **22** as depicted in FIG. **4A**, until a sufficient proportion of gas is produced to allow the members to descend in the housing and close off (or at least increasingly restrict) flow through the outlets. This will restrict or prevent flow of the gas into the tubular string **5**.

[0070] Note that the case of restricting production of gas from an oil well is quite different from the case of restricting production of water from a gas well. When restricting the production of gas from an oil well, the members **7** are preferably not neutrally buoyant in the liquid phase (the oil), otherwise the members would be carried with the flow of the liquid to the outlets **4** or seats **22**. When restricting the production of water from a gas well, the members **7** may be neutrally buoyant in the liquid phase (the water), since it is desired for the members to be carried with the flow of the liquid to the outlets **4** or seats **22** to restrict the flow of the liquid into the tubular string **5**.

[0071] As yet another example, when it is desired to limit the production of gas and water from an oil well (i.e., it is desired to produce oil, but not gas or water), the configurations of FIGS. **3** and **5-8** may be used, with the members **7** each having a density less than that of oil, and the members **8** each having a density greater than that of oil. The members **7** will preferably have densities between the densities of oil and gas, and the members **8** will preferably have densities between the densities of oil and water, or approximately equal to the density of water.

[0072] In this manner, the members **7** will float on top of the oil, or remain at the top of the housing **2** and away from the outlets **4** or the seats **22** as depicted in FIG. **4**A, until a sufficient proportion of gas is produced to allow the members to descend in the housing and close off (or at least increasingly restrict) flow through the outlets. This will restrict or prevent flow of the gas into the tubular string **5**.

[0073] The members **8** will remain at the bottom of the housing **2** and away from the outlets **4** or the seats **22**, until a sufficient proportion of water is produced to allow the members to ascend in the housing and close off (or at least increasingly restrict) flow through the outlets. This will restrict or prevent flow of the water into the tubular string **5**.

[0074] Features of the apparatus **20** are schematically illustrated in FIG. **9**. The outlets **3**, **4** are depicted in FIG. **9** as being vertically distributed and providing for communication between the chamber **24** (on the left of the illustration) and the interior of the tubular string **5** (on the right of the illustration).

[0075] Of course, in the apparatus **20** as shown in the previous FIGS. **2-8**, the outlets **3**, **4** are not linearly distributed as they are depicted in FIG. **9**, but it will be appreciated that, due to the outlets being formed radially about the tubular string **5**, some of the outlets are vertically higher, and some of the outlets are vertically lower, relative to others of the outlets. Thus, FIG. **9** schematically represents this vertical distribution of the outlets **3**, **4**, as well as the vertical distribution of the seats and inlets **22**, **23** of the restrictors **10**, **11**.

[0076] In this example, the fluid **25** is stratified in the chamber **24** into a layer of water **27**, a layer of oil **28** and a layer of gas **29**. Some of the members **7** are blocking (or at least increasingly restricting) flow of the gas **29** through the outlets **3**, **4** into the tubular string **5**, and some of the members **8** are blocking (or at least increasingly restricting) flow of the water **27** through the outlets into the tubular string.

[0077] Thus, as the fluid **25** contains a greater proportion of gas **29** and/or water **27**, flow through the apparatus **20** is increasingly restricted. An increased proportion of oil **28** in the fluid **25**, however, results in a reduced restriction to flow through the apparatus **20**, since fewer of the outlets will be blocked by the members **7**, **8**.

[0078] As an interface **30** between the water **27** and oil **28** ascends in the chamber **24**, more of the members **8** block (or at least increasingly restrict) flow of the water through the restrictors **10**, **11**. As the interface **30** descends in the chamber **24**, the members **8** can disengage from the seats and inlets **22**, **23**, to thereby allow more of the oil **28** to flow through the restrictors **10**, **11** and via the outlets **3**, **4** to the interior of the tubular string **5**.

[0079] As an interface **31** between the gas **29** and the oil **28** descends in the chamber **24**, more of the members **7** block (or at least increasingly restrict) flow of the gas through the restrictors **10**, **11**. As the interface **31** ascends in the chamber **24**, the members **7** can disengage from the seats and inlets **22**, **23**, to thereby allow more of the oil **28** to flow through the restrictors **10**, **11** and via the outlets **3**, **4** to the interior of the tubular string **5**.

[0080] Note that the members **7** preferably remain at the interface **31** between the gas **29** and the oil **28**, since the members **7** are preferably less dense than the oil, but are not buoyant in the gas. The members **8**, however, may remain at the interface **30** between the oil **28** and the water **27** (for example, if the members **8** are less dense than the water, but more dense than the oil), or the members **8** may be neutrally buoyant in the water (for example, if the members have approximately the same density as the water).

[0081] The restrictors **10** are depicted in FIG. **9** as having larger internal passages as compared to the restrictors **11**. In this manner, flow through the restrictors **11** is more restricted as compared to flow through the restrictors **10**. When one of the members **7**, **8** engages an inlet **23** of one of the restrictors **11**, flow through the restrictor is increasingly restricted, but is not completely prevented.

[0082] Thus, in the example of FIG. **9**, some of the gas **29** is permitted to flow through the upper restrictors **11** which are engaged by the members **7**, and some of the water **27** is permitted to flow through the lower restrictors which are engaged by the members **8**, but these flows are very restricted. This increased restriction to flow is due to the engagement between the members **7**, **8** and the respective inlets **23**, and to the increased restriction to flow through the restrictors **11**.

[0083] As depicted in FIG. **9**, engagement between the members **7**, **8** and the seats **22** completely prevents flow through the corresponding restrictors **10**. However, such engagement could permit an increased restriction to flow, without completely preventing flow, if desired.

[0084] Note that it is not necessary for the fluid **25** to be stratified into separate fluid layers as illustrated in FIG. **9**. Instead, the fluid **25** could include mixtures of oil, water and/or gas in varying proportions.

[0085] In FIG. **10** the apparatus **20** is schematically illustrated in a configuration similar to that depicted in FIG. **9**. However, in the configuration of FIG. **10**, the upper portion of the chamber **24** has an increased proportion of gas **29** therein, the lower portion of the chamber has an increased proportion of water **27** therein, and a middle portion of the chamber has an increased proportion of oil **28** therein.

[0086] Unlike the configuration of FIG. **9**, the water **27**, oil **28** and gas **29** are not stratified, but are instead mixed in varying proportions. A less dense mixture of the fluid **25** (e.g., having a relatively greater proportion of gas **29**) ascends to the top of the chamber **24**, a more dense mixture of the fluid (e.g., having a relatively greater proportion of water **27**) descends to the bottom of the chamber, and the most desirable mixture of the fluid (e.g., having a relatively greater proportion of oil **28** than the other mixtures) is between the other mixtures.

**[0087]** Thus, when the fluid **25** contains undesirable fluids (for example, water or sometimes gas), restriction to flow through the apparatus **20** increases. A greater proportion of undesirable fluids in the produced fluid **25** results in a greater restriction to flow through the apparatus **20**. Thus, production from a zone producing undesirable fluids is reduced (due to the increased restriction to flow through its corresponding apparatus **20**), while production from other zones producing more desirable fluids is increased.

**[0088]** Note that, in the configuration of FIG. **10**, the members **7** may be neutrally buoyant in the portion of the fluid **25** having the greater proportion of gas **29** therein. Thus, the members **7** do not necessarily remain at any particular interface between fluids.

**[0089]** All of the members **7** do not necessarily have the same density, and all of the members **8** do not necessarily have the same density. Instead, the members **7** could have a range of different densities, and the members **8** could have a range of densities, so that the members are neutrally buoyant in different densities of the fluid **25**. In this manner, a greater number of the members **8** would be available to block or restrict flow of the fluid **25** having a greater proportion of water, and a greater number of the members **7** would be available to block or restrict flow of the fluid having a greater proportion of gas.

**[0090]** The configurations of the apparatus **20** including both of the members **7**, **8** as illustrated in FIGS. **3** and **5-10** have the members positioned within a single internal chamber **24** of the housing **2**. However, the members **7**, **8** could instead be positioned in respective separate chambers, if desired. In addition, instead of the members **7**, **8** closing off or restricting flow through the same outlets **4**, restrictors **10**, seats **22**, etc., separate outlets, restrictors and/or seats could be provided for the respective members, if desired.

**[0091]** Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the invention, 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 invention. 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**. An apparatus for use in a subterranean well wherein fluid is produced which includes both oil and gas, the apparatus comprising:

multiple first flow blocking members, each of the first members having a density less than that of the oil, and the first members being positioned within a chamber so that the first members increasingly restrict a flow of the gas out of the chamber through multiple first outlets.

**2**. The apparatus of claim **1**, wherein passages between the chamber and the first outlets are vertically distributed.

**3**. The apparatus of claim **2**, wherein at least one of the passages is provided with an inlet which permits at least limited flow of the gas through the corresponding passage when one of the first members is engaged with the inlet.

**4**. The apparatus of claim **2**, wherein a first portion of the passages has greater flow restriction than a second portion of the passages.

**5**. The apparatus of claim **4**, wherein the first members do not increasingly restrict flow through the first portion of the passages in response to an increased proportion of gas in the chamber.

**6**. The apparatus of claim **4**, wherein the first members increasingly restrict, but do not prevent, flow through the first portion of the passages in response to an increased proportion of gas in the chamber.

**7**. The apparatus of claim **1**, wherein the first members increasingly restrict flow of the gas through an increased number of the first outlets in response to an increased proportion of the gas in the chamber.

**8**. The apparatus of claim **1**, wherein the produced fluid also includes water, and wherein the apparatus further comprises multiple second flow blocking members, each of the second members having a density greater than that of the oil, so that the second members increasingly restrict a flow of the water outward through multiple second outlets.

**9**. The apparatus of claim **8**, wherein the second members are positioned in the same chamber as the first members.

**10**. The apparatus of claim **8**, wherein the first and second members are not positioned in the same chamber.

**11**. The apparatus of claim **8**, wherein passages for flow to the second outlets are vertically distributed.

**12**. The apparatus of claim **11**, wherein at least one of the passages is provided with an inlet which permits at least limited flow of the water through the corresponding passage when one of the second members is engaged with the inlet.

**13**. The apparatus of claim **11**, wherein a first portion of the passages has greater flow restriction than a second portion of the passages.

**14**. The apparatus of claim **13**, wherein the second members do not increasingly restrict flow through the first portion of the passages in response to an increased proportion of water.

**15**. The apparatus of claim **13**, wherein the second members increasingly restrict, but do not prevent, flow through the first portion of the passages in response to an increased proportion of water.

**16**. The apparatus of claim **8**, wherein the second members increasingly restrict flow of the water through an increased number of the second outlets in response to an increased proportion of the water.

**17**. An apparatus for restricting production of at least a first undesired fluid from a subterranean well, the first fluid having a first density different from a second density of a second desired fluid, the apparatus comprising:

at least one first flow restrictor having a first flow restriction;

at least one second flow restrictor having a second flow restriction; and

multiple first flow blocking members, the first members being operative to increasingly restrict flow of the first fluid through the first restrictor in response to an increased proportion of the first fluid.

**18**. The apparatus of claim **17**, wherein the apparatus includes multiple first flow restrictors, and wherein passages of the first restrictors are vertically distributed.

**19**. The apparatus of claim **17**, wherein the second flow restriction is greater than the first flow restriction.

**20**. The apparatus of claim **17**, wherein the first members increasingly restrict, but do not prevent, flow of the first fluid through the second restrictors.

**21**. The apparatus of claim **17**, wherein the second restrictors have inlets which prevent complete flow blocking engagement between the first members and the inlets.

**22**. The apparatus of claim **17**, wherein the first members have a density less than the second density of the second fluid.

**23**. The apparatus of claim **17**, wherein the first members have a density less than the first density of the first fluid.

**24**. The apparatus of claim **17**, wherein the first members have a density approximately equal to the first density of the first fluid.

**25**. The apparatus of claim **17**, wherein a third undesired fluid has a third density different from the first and second densities, and wherein the apparatus further comprises multiple second flow blocking members, the second members being operative to increasingly restrict flow of the third fluid through the first restrictor in response to an increased proportion of the third fluid.

**26**. The apparatus of claim **25**, wherein the apparatus includes multiple first flow restrictors, and wherein passages of the first restrictors are vertically distributed.

**27**. The apparatus of claim **25**, wherein the second flow restriction is greater than the first flow restriction.

**28**. The apparatus of claim **25**, wherein the second members increasingly restrict, but do not prevent, flow of the third fluid through the second restrictors.

**29**. The apparatus of claim **25**, wherein the second restrictors have inlets which prevent complete flow blocking engagement between the second members and the inlets.

**30**. The apparatus of claim **25**, wherein the second members have a density less than the third density of the third fluid.

**31**. The apparatus of claim **25**, wherein the second members have a density greater than the second density of the second fluid.

**32**. The apparatus of claim **25**, wherein the second members have a density approximately equal to the third density of the third fluid.

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