Sept. 15, 1953 C. K. FERGUSON 2,652,130

GAS-OIL SEPARATOR

Filed June 26, 1950 2 Sheets-Sheet 1

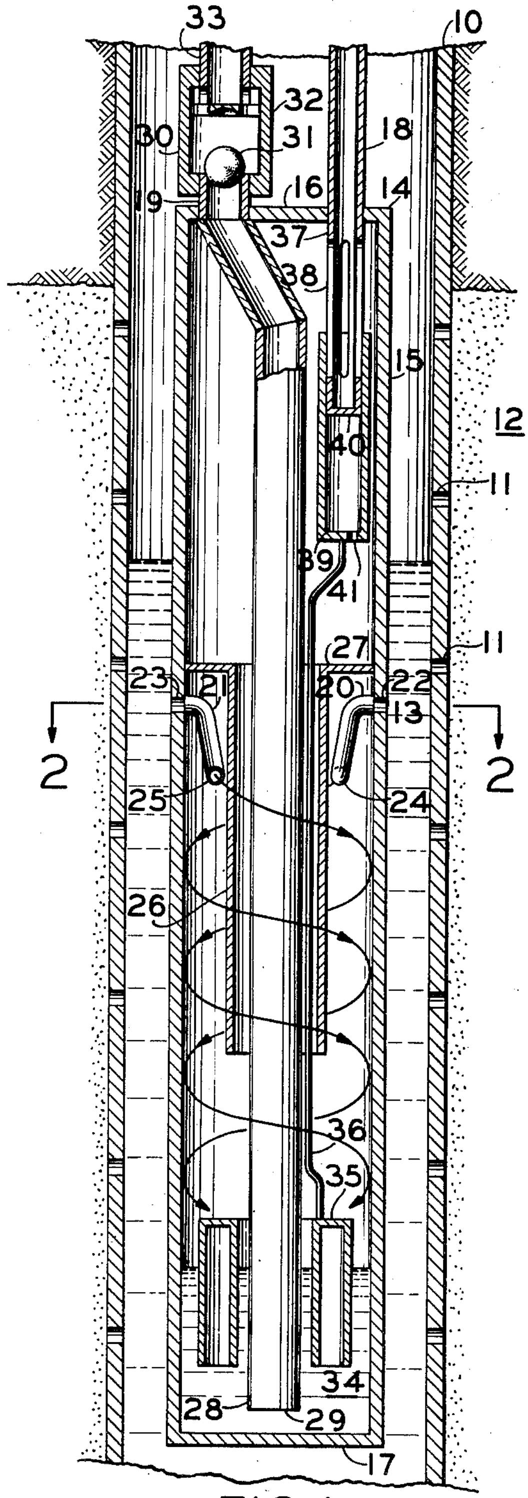

FIG. 1

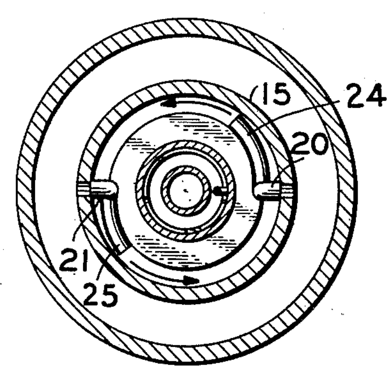

FIG. 2

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2 Sheets-Sheet 2

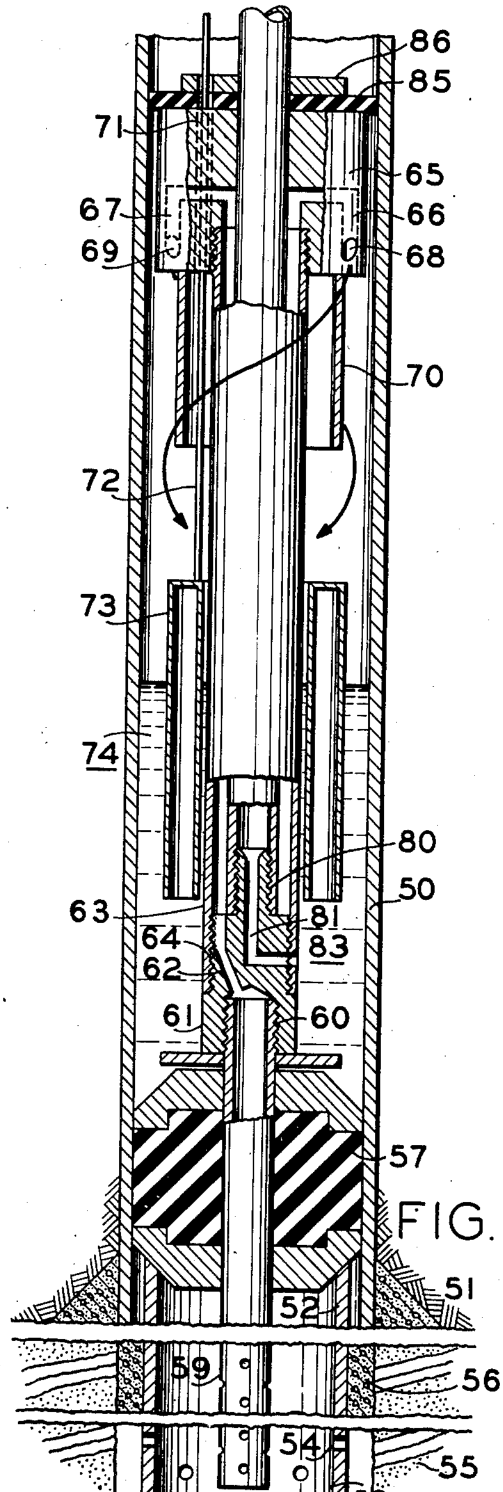

FIG. 3

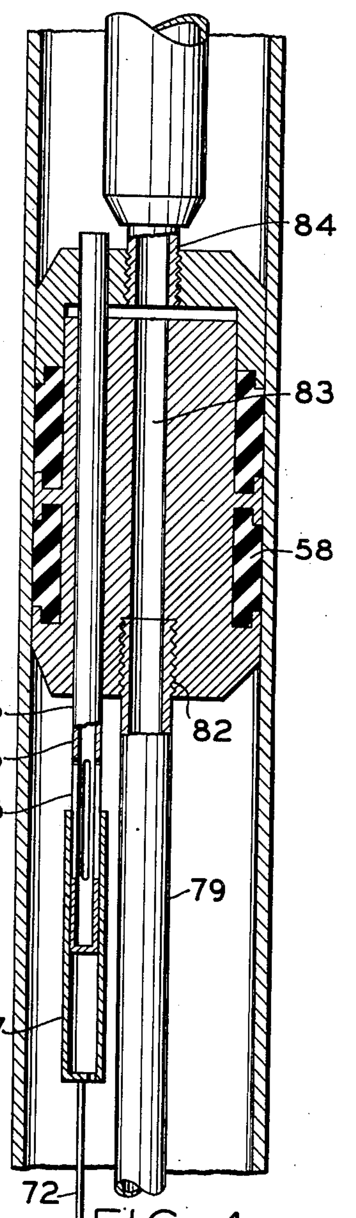

FIG. 4

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GAS-OIL SEPARATOR

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6 Claims. (Cl. 183—2.7)

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The present invention relates to deep well pumping apparatus, and, more particularly, to apparatus for the separation of gas and oil in a deep producing well.

In the production of oil from deep wells by means of pumping apparatus, the problem is frequently presented of separating gas from the gas-oil mixture produced into the well prior to the point at which the intake of the pump is located. The gas present in the gas-oil mixture is usually due to either of two causes. In one case, the gas may be present in the formation reservoir as "free" gas which enters the well bore hole along with the liquid. In the other case, due to the change in pressure as fluid flows from the reservoir into the well bore, the lighter components of the fluid may change from liquid phase to gas phase. It will be understood that this pressure drop is due to the pressure differential between the formation and well bore which is responsible for the flow of fluid into the well bore. However, irrespective of the source of the gas which enters the well bore, this gas generally appears as a mixture with the oil which is to be produced by the pumping apparatus.

The principal difficulty in operating a positive displacement pump, such as that used in the production of oil from deep wells, is that the mixture of incompressible liquid and compressible gas decreases the volumetric efficiency of the pump. This results from the pump performing as a partial compressor of gas in the mixture on both the intake and discharge strokes of the pump, and causes a loss in the amount of liquid displacement that may be obtained from each stroke. In extreme cases, the pump may even cease to pump liquid and become "gas locked," due to the complete displacement of liquid by the compressible gas. Additionally, the gas which enters the well bore with the production mixture has a tendency to accumulate within the body of the liquid mixture until sufficient gas has collected to overcome the viscosity of the liquid. At that time the accumulation of gas accelerates in its rise through the fluid, thereby producing a surging pressure condition which is frequently termed "heading." The principal difficulty which results from such a "heading" condition is that large variations in the bottom hole pressure adversely affect the efficient production of the well.

In the solution of this problem of removing gas from the gas-liquid mixture prior to the introduction of liquid to the pump mechanism, gas-oil separators, or anchors, have been proposed which depend entirely upon the gravimetric separation of the oil and gas phases by admitting the mixture to an enclosed chamber. Some devices of this type admit the gas-oil mixture to the chamber through pressure-reducing orifices which, due to linear acceleration and reduction of pressure, serve only to increase the amount of gas present in the chamber; however, the gas which may be separated in this manner cannot escape from the well bottom without again contacting a gas-oil mixture. As a result, the benefits of separation have been virtually defeated due to this mechanical intermixing of the separated gas with the production mixture. Additionally, dependence upon either gravity or mere linear acceleration by flowing through an orifice has not provided a separating action effective in removing all gas from the mixture.

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Broadly, the present invention contemplates a gas-liquid separator for a deep well pump which comprises a first chamber for receiving the gas-liquid mixture from the producing formation of the well, a second chamber communicating with the inlet of the pump, conduit means having nozzle means connected thereto for inter-connecting the chambers, the nozzle means being adapted to discharge the mixture downwardly and substantially tangentially into the second chamber, a liquid production conduit extending from the pump to the top of the well, separate means forming a gas discharge conduit from the upper end of the second chamber to the top of the well independently of the liquid production conduit, a valve for the gas discharge conduit and float means responsive to the liquid level in the second chamber to control the gas valve.

It is an object of the present invention to provide a more efficient gas-oil separator for removing gas from a gas-liquid mixture prior to the admission of liquid to a deep well pumping mechanism.

It is a further object of the present invention to provide a bottom-hole separator for centrifugal separation of gas from a gas-oil mixture produced by a well.

It is a still further object of the present invention to provide a separator for a production mixture of gas and oil, wherein gas is more completely separated from the mixture and prevented from re-contacting the production mixture after separation is effected.

Another object of the invention is to provide a gas-oil separator in which, following separation of liquid from a gas-oil mixture, the liquid head on the inlet to a deep well pump may be maintained substantially constant.

Another object of the present invention is to provide a gas-oil separator adapted to produce a relatively low and constant bottom-hole pressure in a deep well being produced by pump means.

Further objects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings which form an integral part of the present specification.

In the drawings:

Fig. 1 is a vertical sectional view of a gas-oil separator of the type contemplated by this invention in which the entire separator is located within the perforated portion of the well liner.

Fig. 2 is a cross-sectional view in the direction of the arrows 2—2 in Fig. 1.

Fig. 3 is a vertical sectional view of the lower portion of an alternative form of gas-oil separator in accordance with the present invention which is adapted to be positioned in a well casing.

Fig. 4 is a vertical sectional view of the upper portion of the gas-oil separator shown in Fig. 3 and is a continuation thereof.

Referring now to the drawings, and in particular to Fig. 1, there is shown in vertical section one form of the gas-oil separator, constructed in accordance with the present invention, which is adapted to be positioned in a well liner **10** which may be perforated by holes **11** adjacent a producing sand or formation **12**. The gas-oil mixture **13** which is to be separated into gas and oil, or liquid components, is produced from sand **12** into the well bore through holes **11** and admitted into a first chamber within the well defined by liner **10**. Liner **10** is connected to a conventional well casing (not shown) which is sealed off at the surface in a manner well known in the art to prevent escape of gas. The surface well seal with liner **10** and the well casing thereby defines the first chamber in this embodiment.

For the purpose of obtaining the desired separation of the lighter component, gas, from the mixture **13**, a second chamber means **14** which may comprise a cylindrical sidewall member **15**, sealed at the upper and lower ends by walls **16** and **17** respectively, is adapted to be supported adjacent the perforated portion of well liner **10** by a gas string, or conduit means, **18** and a liquid string, or conduit means, designated generally as **19**. It will be understood that the gas string **18** and liquid string **19** may be supported in any suitable manner (not shown) in order to so locate chamber means **14** at the desired depth in the well.

For the purpose of introducing gas-oil mixture **13** from the first chamber, a pair of conduit means **20** and **21** are connected to openings **22** and **23** in sidewall **15** of second chamber **14**. Openings **22** and **23** are preferably so located that the normal level of mixture **13** in the well is above these openings. However, since the top of the well casing is sealed off to provide the first chamber mentioned hereinabove, the mid-perforation pressure, that is, the average pressure along the perforated portion of the liner, provides the driving force for the gas-liquid mixture entering the second chamber. As best seen in Fig. 2, it will be noted that the fluid mixture inlet conduits **20** and **21** are provided with nozzle means **24** and **25**, respectively, which are so directed in respect to sidewall **15** of chamber **14** that the fluid mixture is discharged downwardly and tangentially against the side of cylinder wall **15** as shown by the helical flow lines. In this manner a centrifugal separation may be effected to separate the gas component from the oil in mixture **13**. While some separation is obtained by the reduction in pressure obtained by passage of the mixture through the nozzles, the separating action is principally due to centrifugal motion imparted to the mixture which causes the heavier and lighter components to be separated mechanically. For this reason, it is desirable that the mixture be directed downwardly aand outwardly so that the liquid will pass to the bottom along the cylindrical sidewall **15** while the gas escapes near the center of the chamber, independently of the oil. For this purpose a concentric baffle tubing **26**, having an outwardly turned flange **27**, is so positioned that the upper end of chamber **14** communicates with the lower end of the chamber only through tubing **26**. By this arrangement, gas separated from mixture **13**, which is directed downwardly by the separating action, may readily rise to the upper end of chamber **14**.

A liquid production conduit **28** is arranged to pass through the center of tubing **26** and has an opening **29** adjacent the lower end wall **17** of chamber **14**. The upper end of conduit **28** may be connected by any convenient means to liquid string **19**. String **19** is preferably connected to the lower end of a deep well pump (not shown) through a standing valve **30** comprising a ball **31** and a conventional cage means **32** and a conduit **33**. It will be understood that in accordance with conventional practice the outlet of the deep well pump is preferably connected to a production string (not shown) which communicates with the surface independently of the casing and liner **10**.

For the purpose of controlling the level of the oil, or liquid, **34** in the lower end of the chamber **14** so that opening **29** of conduit **28** is continually submerged but nozzle openings **24** and **25** are not so submerged, a level control means is provided by float **35** which is adapted to raise and lower a rod member **36** passing through the central opening of baffle tubing **26**. Rod **36** in turn is arranged to control a valve means, designated generally as **37**, provided for the gas conduit, or passage, means **18**. Valve means **37** in general comprises a plurality of elongated slots **38** cut in the portion of passage means **18** which extends into chamber **14** through the upper end wall **16** and a tubular sliding member **39** which is arranged to open and cover the slots **38** in accordance with the level of liquid **34** in chamber **14**. It will be noted that the lower end of conduit means **18** below slots **38** is preferably closed by an end wall **40**. In order to statically balance sliding member **39** when it is raised and lowered on conduit **18**, a vent **41** is provided in the lower end of sliding member **39**.

Referring now to the alternative arrangement of gas-oil separator, in accordance with the present invention, shown in Figs. 3 and 4, it will be noted that a well casing **50** which has previously been cemented in the well bore, as represented by cement **51**, is adapted to support a well liner **52** which has a lower portion **53** provided with perforations, such as openings **54**. Lower portion **53** is located adjacent a production sand **55** in order to introduce the gas-oil mixture produced from formation **55** into liner **52**. Liner **52** may be sealed in the well bore by conventional means, designated as cement **56**.

In order to provide a separating chamber into which the gas-oil mixture may be introduced, a packer designated generally as 57 of any conventional hook-wall type is arranged to seal off a portion of the lower end of casing 50 so that a lower, or first chamber, is defined within the well bore by liner 52 and packer 57. This first chamber communicates with an upper, or second, chamber defined within casing 50 by the casing wall, lower packer 57 and upper packer 58 which is similar to packer 57. Communication between the chambers is provided by a liquid conduit 59 usually designated a tail pipe, which extends from the upper chamber and down through packer 57 into the lower chamber to a position adjacent perforated portion 53 of the liner 52. The upper end of the fluid conduit tubing 59 is preferably provided with pipe threads 60 which engage similar threads on a distributing block 61. Block 61 has a passage, or conduit, means 62 inter-connected with an outer conduit line 63 which in turn is connected by pipe threads 64 to distributing block 61. Conduit 63 in turn is connected to a nozzle block 65 which is centrally positioned in the upper portion of the second chamber. The nozzle block is formed with passages 66 and 67 which have nozzle means 68 and 69 respectively for directing the fluid downwardly and tangentially against the side wall of casing 50. To prevent the upward passage of gas between block 61 and casing 50, a packing washer 85 may be positioned above the block, as shown, with a clamping washer 86 positioned to hold packing 85 against block 61. As a conduit for the separated gas, a concentric baffle tubing 70 is provided which extends downwardly from nozzle block 65 and communicates with the upper chamber through a gas passage means provided by axial bore 71 in nozzle block 65. Axial bore 71 also provides passage means for rod 72 which is actuated by float means 73. Float means 73 is responsive to the level of liquid 79 which has been separated from the gas-oil mixture. Rod 72 is adapted to control gas passage valve means, designated generally as 75, which is located in the upper chamber and which, as described in the previous embodiment, may include slots 76 and a sliding sleeve 77. Gas valve 75 is connected to a gas passage, or conduit, means 78 which extends through upper packer means 58 and terminates at a position above the upper end of packer 58 for a purpose to be described hereinafter.

For the purpose of introducing to the pump, oil from which gas has been separated, a liquid production conduit, or tubing, means is provided by a concentric tubing designated generally as 79. Conduit 79 may be connected to distributing block 61 by means of pipe threads 80 so that conduit 79 communicates with a passage 81 in block 61. In this way, fluid in the lower end of the upper chamber may be admitted to conduit 79. For convenience of assembling the conduit members when the gas-oil separator is installed in a well, tubing 79 may be terminated by pipe threads 82 which mate with similar threads in packer 58 and thereby communicate with passage 83 in the packer, which in turn is connected to the inlet of a deep well pump, designated generally as 84.

Referring now to the operation of the embodiment of the apparatus shown in Figs. 1 and 2, it will be apparent that the well production mixture 13 enters the first chamber defined by the liner 10 through the perforations 11 and normally stands to such a depth in the liner 10 that the inlet ports 22 and 23 of the inner chamber 14 are submerged in the well production fluid mixture 13. Then, by introducing mixture 13 through conduits 20 and 21 and expelling the fluid through nozzles 24 and 25, the mixture is given a downward and tangential motion to produce a centrifugal separating action on the mixture. By this action the heavier liquid component is permitted to accumulate in the lower portion of chamber 14 and from thence be introduced to the deep well inlet conduit 20 through opening 29. Following the separation of gas from the mixture, escape of such gas is provided through tubing 26 which communicates with the upper end of chamber 14 so the gas may be released through slots 38 in valve means 37 and into conduit 18. Due to the fact that the sleeve member 39 is adapted to open and close slots 38 in response to the liquid level in the lower end of chamber 14, a greater or lesser amount of gas is permitted to enter conduit means 18. The rate of gas flow through valve means 37 controls the pressure within chamber 14 and, as a consequence, the flow rate of gas-liquid mixture 13 through nozzles 24 and 25. In this way the level of liquid 34 may be effectively controlled depending upon the percentage of gas and liquid present in the separator chamber. By virtue of the separate passage provided by gas conduit 18 which communicates with the surface, the possibility of contact between gas initially separated in chamber 14 and the production liquid mixture is eliminated, thereby preventing the inter-mingling of gas with mixture 13. Likewise, by virtue of the control provided by valve 37 to govern the escape of gas through passage 18, an adequate volume of separated liquid 34 is present to insure the most efficient operation of the deep well pump which is interconnected to liquid conduit 28. Furthermore, float operated valve means 37 provides the necessary pressure regulation between the various passageways from the production sand to the pump and gas outlets of the separator. The alternative arrangement shown in Figs. 3 and 4 is very similar in operation and function to that shown in Figs. 1 and 2, with the exception that rather than the two chambers being concentric in relation to each other, the first and second chambers may be vertically displaced to take advantage of the full diameter of the casings and liners employed in the well. This is accomplished in the embodiment shown in Figs. 3 and 4 by virtue of side wall packing means 57 and 58 which define separate upper and lower chambers. In this arrangement, the gas-oil mixture is introduced to the second, or upper, separating chamber, through conduit 59 which communicates with passage 62 and the annular passage defined by outer tubing 63 and inner tubing 79. Tubing 63 is connected to passages 66 and 67 in nozzle block 65 so that the production fluid mixture is introduced to the upper chamber through nozzle means 68 and 69 in such a manner that a downward and tangential motion is imparted to the fluid to effect the desired centrifugal separation. The separated liquid is then collected in the lower end of this chamber and drawn into the deep well pump through passage 81 and tubing 79 which are interconnected to the inlet of pump 83. In this embodiment of the invention, the separated gas passes upwardly through tubing 70 and passageway 71 in nozzle block 65 and is permitted to accumulate in the upper portion of the cylinder, or chamber, defined by the side wall packers. The upward flow of the accumulated gas is through gas passage **78** which is controlled by means of float **73**, rod **72** and valve means **75**. However, in this embodiment, since the lower chamber is isolated from the second chamber by means of packers **57** and **58**, the annulus between casing **50** and the oil production tubing connected from the outlet of the pump to the earth's surface may be utilized as the gas escape passage without the necessity of extending a gas string from the top of the well. For this reason the gas conduit **78** may be terminated at a point immediately above upper packer **58**.

Among the modifications and changes in the devices and their modes of operation, as described hereinabove, which may be made without departing from the scope of this invention, is the location of the gas-oil separator within the well. It will be appreciated that the optimum location of the gas-oil separator will in general be dictated by the well pressure, rate of fluid flow from the producing formation into the well bore, and the percentage of gas in the production fluid, as well as the viscosity and density of the fluid. Since these factors and their effects upon the production of oil and gas from a deep well are so well known in the art, it will be understood that the only essential requirement for the operation of a gas-oil separator constructed in accordance with my invention is that the inlet conduit for the second chamber be so located that the fluid to be separated be forced through the nozzles which impart a centrifugal motion to such fluid. Hence, the location of the embodiment shown in Figs. 1 and 2 may be at any position within the well so long as the inlet ports **22** and **23** are submerged in the production fluid. Generally this will be below the fluid level in the well, but if surging or heading occurs, there may be times when that level may be momentarily lowered below the inlet ports **22** and **23**. With the form of the apparatus shown in Figs. 3 and 4, it will be apparent that the sidewall packing means **57** and **58** may be positioned in either the well casing or liner at any level above the well inlet.

It will be apparent from the foregoing detailed description of the two different embodiments of the present invention that a gas-oil separator has been provided which is capable of more efficiently removing gas from a gas-liquid mixture prior to the introduction of liquid to a deep well pumping mechanism. Likewise, by virtue of the centrifugal separation provided by a bottom hole separator constructed in accordance with the present invention, means have been provided for centrifugal separation of the gas-oil production mixture to separate the heavier component, oil, and the lighter component, gas. Additionally an apparatus has been provided for maintaining the separation of the gas removed by the gas-oil separator to prevent the re-contacting and intermingling of such gas with the production mixture. It will be further apparent that by the use of a gas-oil separator constructed in accordance with the present invention that a relatively low and constant bottom-hole pressure may be obtained to increase the efficiency of the deep-well pumping mechanism.

While further modifications and changes in the present invention will be apparent to those skilled in the art from the description of the foregoing embodiments, all such modifications and changes as fall within the scope of the appended claims are intended to be included thereby.

I claim:

1. A gas-liquid separator for the lower end of the casing of a well comprising means forming a first chamber having an inlet and adapted to receive and accumulate the gas-liquid mixture entering said well, means forming a second chamber adjacent said first chamber and vertically aligned therewith, conduit means connecting said chambers having nozzle means connected thereto adapted to discharge said mixture downwardly and tangentially into said second chamber, a liquid production conduit extending from said second chamber to the top of said well, means forming a gas passage from the upper end of said second chamber to the top of said well independently of said liquid production conduit, a valve for said gas passage means and float means in said second named chamber responsive to liquid level therein to control said valve.

2. A gas-oil separator for a producing well adapted to be positioned adjacent the lower end of a perforated well liner comprising cylinder means having a pair of end walls defining an axially extending chamber within said liner; production fluid inlet means comprising conduit means connecting said chamber to the perforated portion of said liner and nozzle means positioned in the upper end of said cylinder means to direct the stream of production fluid introduced therethrough downwardly and tangentially against the side wall of said cylinder means whereby the gas and oil components of said fluid may be separated; liquid conduit means having an opening adjacent the lower end of said cylinder means and extending through the upper end wall for conveying liquid to the top of said well, gas vent means extending through said upper end wall to establish a gas passage between the upper end of said cylinder and the top of the well independent of said liquid conduit means, valve means for controlling the opening and closing of said vent means, and float means adapted to rise and fall with the liquid level in the lower end of said cylinder means to control said valve means.

3. A gas-oil separator for a producing well having a well liner, comprising a cylinder means adapted to be positioned near the lower portion of the well liner, end walls for said cylinder means to form a chamber, production fluid inlet means for admitting said fluid to said chamber comprising conduit means and nozzle means connected thereto for directing the flow of said fluid downwardly and tangentially against the side wall of said cylinder means to effect a separation of the liquid and gas components of said production fluid, liquid conduit means having an opening adjacent the lower end wall of said chamber for conveying oil to the top of said well, means forming a gas passage from the top of said chamber to the top of said well to prevent association of the gas separated in said chamber from contacting said production fluid, valve means for said gas passage means, and float means responsive to the liquid level in said chamber for controlling said valve means.

4. A gas-oil separator adapted to be positioned adjacent the lower end of a perforated well liner comprising an upper and a lower packing means adapted to be axially spaced above the perforated section of said liner and engageable with the side walls of said liner to form a cylindrical chamber within said liner, production fluid conduit means

connected between said perforated section of said liner and a position intermediate said packing means, nozzle means connected to said conduit means for directing the flow of production fluid into said chamber downwardly and tangentially to said side wall to effect a separation of gas from said fluid, a liquid production conduit extending from the top of said well through said upper packing means to a position adjacent said lower packing means, conduit means forming a gas passage extending from the top portion of said chamber through said upper packing means to the top of said well, valve means for controlling the gas flow through said gas passage and float means responsive to the liquid level in said chamber to control said valve means.

5. A gas-oil separator adapted to be positioned adjacent the lower end of a well casing comprising upper and lower sidewall packing means axially spaced to form a cylindrical chamber within said casing, conduit means between the producing zone of said well and a point intermediate said packing means, nozzle means connected to said conduit means for directing the flow of production fluid from the producing zone downwardly and tangentially against the casing wall within said chamber to separate the gas and liquid components of said fluid, a liquid production conduit extending to the top of said well and communicating with the lower end of said chamber, conduit means forming a gas passage extending from the top portion of said chamber and through said packing means to the top of said well, said last-named conduit means having valve

means associated therewith for controlling the pressure within said chamber and liquid level responsive means for controlling said valve means in accordance with the liquid level in the lower end of said chamber.

6. A gas-oil separator for use in a well bore, comprising means having an inlet and forming a first oil-accumulating chamber adapted to communicate with an oil and gas producing formation, means forming a second chamber, a passageway connecting said chambers, the inlet of said passageway being below the level of the oil in said first chamber, the outlet of said passageway being directed tangentially and downwardly with respect to said second chamber, an oil outlet extending to the top of the well and communicating with the lower portion of said second chamber, a gas outet conduit for the upper portion of said second chamber and extending to the top of said well, and a float-controlled valve for said gas outlet.

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