



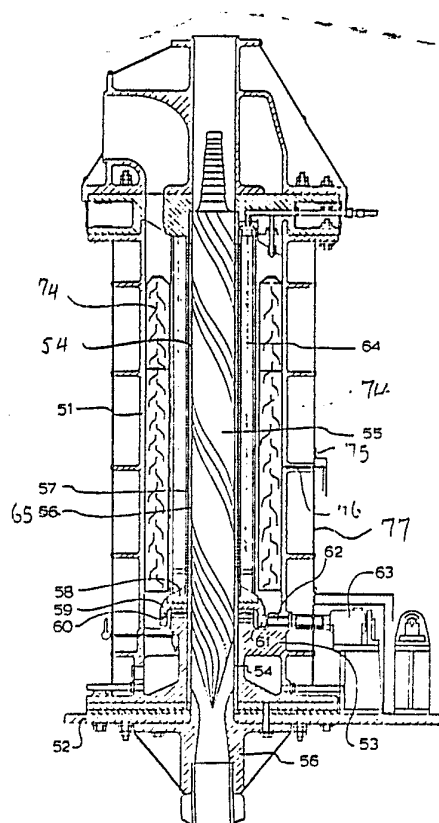
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: AN OIL/GAS SEPARATOR

## (57) Abstract

A separator for separating gas from oil in a mixture thereof such as at an oil well head comprises one or a plurality of separator devices (13) each basically comprising a foraminous wall constituted by a sleeve (22, 56) surrounding a closely fitting solid core (23) having a plurality of helical channels defining flattened flow paths bounded on a major face by the foraminous sleeve (22; 56) so that gas can escape to a gas gallery (20) whilst the oil tends to pass along the helical channels to an oil collector (16). A secondary outer foraminous sleeve (57) may be provided to vary the effective resistance offered by the foraminous wall by relative displacement with respect to the first mentioned sleeve (56) causing variation in the overlap of the apertures in the two sleeves.



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An Oil/Gas Separator

The present invention relates generally to the separation of gas from oil in a mixture thereof, and particularly to a method and apparatus for effecting separation of gas from oil at high pressure such as exists, for example, at the well head of an oil well.

It is known that the gaseous content of the oil coming from an oil well limits the availability and usefulness of the oil in the well, and it is conventional practice to burn off or "flare" surplus gas from an oil well. This represents a waste of potentially useful energy. The gas present in the oil, however, represents a considerable disadvantage from the point of view of oil handling since it causes irregular flow and pressure fluctuations which disrupt the smooth working of the oil handling equipment. The commodity of primary interest in an oil well is, of course, the oil to be derived from it, and the feature of the oil well which has paramount importance is therefore the continuity of the oil flow. The present invention seeks to provide apparatus for separating gas from oil in a mixture thereof at high pressure in which continuity of oil flow can be ensured despite irregular flow of the mixture and pressure fluctuations such as are experienced at the well head, and in which there is also an ability to control the pressure drop to requirements.

The present invention also seeks to provide apparatus for separating gas from oil, which uses the energy in the outflowing mixture from the well head to drive the separation process.

According to one aspect of the present invention a sep-



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arator device for separating gas from oil in a mixture thereof at high pressure, such as at the well head of an oil well, includes a guide duct for guiding the flow of the mixture at high pressure along a flow path a part of  
5 the surface area of which is defined by a gas-permeable surface, the flow path being so shaped that expansion of the gas content of the mixture drives it through the said gas-permeable surface where it is collected in a gas collection duct, the said guide duct directing the oil  
10 fraction to an oil delivery duct.

In the separator device of the present invention use is therefore made of the pressure in the gas to drive it through the gas-permeable wall, and in one embodiment  
15 this is encouraged by increasing, as much as possible, the potential contact area between the gas and the gas-permeable wall by directing the mixture through a flow path having a very flattened flow cross section. The separating effect is also encouraged by the venturi  
20 effect if the flattened portion of the guide duct has, in practice, a smaller cross sectional area than the duct guiding the gas/oil mixture to the separator device and the oil delivery and gas collection ducts which individually direct the separated fractions away from  
25 the separator device.

The separating effect of the device of the present invention is enhanced if there are provided a plurality of such guide ducts defined by a generally cylindrical  
30 gas-permeable sleeve housing a close fitting central core in which there is formed a plurality of shallow, generally axially extending channels. These shallow channels define the portion of flattened flow section and an increase in the separating effect can be achieved

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if, instead of extending purely axially, the shallow channels in the central core extend helically therealong since this causes a degree of swirl in the gas and oil mixture as it passes through the device encouraging the gas to collect at the radially outer part of the separator whilst the oil tends to remain at a radially inner position with respect to the gas.

It is believed that during its direct flow through a duct such as the duct leading to the separator, the gas tends to collect in a central position within the duct, surrounded by the flowing oil which nevertheless also contains gas bubbles and is therefore in a frothy or foaming state. The action of the separator of the present invention is thus to cause the gas to react differently from the oil to the forces they both experience, subsequently allowing the gas to pass through the gas-permeable wall whilst the oil is held within the separator spaced from the gas-permeable wall. A proportion of the oil will, however, pass through the gas-permeable wall particularly if this is formed, as in the preferred embodiment, of a foraminous sleeve around a central core, and this entrained oil can be separated out under the action of gravity at the relatively lower pressures involved by positioning the separator with its flow axis extending substantially vertically.

In another aspect the present invention comprises a separator device for separating gas from oil in a mixture thereof at high pressure, such as at the well head of an oil well, comprising means for causing the mixture to follow a generally helical flow path defined in part by a gas-permeable wall across which a pressure differential is maintained such that the gas in the

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mixture is urged to traverse the wall to a gas collection gallery or duct, whilst the oil is directed by guide means to an oil delivery duct. This helical flow or "swirl" of the mixture conveniently  
5 takes place within the above mentioned generally cylindrical sleeve which constitutes the gas-permeable wall and which defines the radially outer surface of the generally helical flow path of the mixture. The gas-permeable wall is in a preferred  
10 embodiment of the invention, provided with helical rows of perforations aligned with internal channels in such a way that the perforations only extend over a part of the axial extent of the channels leaving a solid wall portion for oil  
15 retention. These wall portions are preferably axially spaced. It is preferred that the elongate core has a plurality of helical channels, which may be defined by upstanding helically extending ridges on the core or may be formed as helical  
20 grooves in the core. If the core is provided with ridges, these preferably fit tightly against the inner surface of the gas-permeable wall so that each individual helical channel defines an entirely separate helical flow path for the mixture.

25

Oil entrained with the gas passing through the said gas-permeable wall can be collected at the lower end of the separator device if this is arranged in an upright orientation with the flow  
30 path for the mixture extending upwardly there-through providing the flow cross section in the gas gallery is sufficiently large in relation to the flow cross section within the above mentioned helical flow path to cause a substantial



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reduction in the velocity of the gas so that oil particles entrained therewith are not carried along with the gas but fall to the lower end of the gas gallery where an oil collection chamber is located.

5

The gas-permeable wall may have any convenient structure, and may be made of a porous material having pores of any convenient size. However, in order to avoid the possibility of clogging it is preferred that the gas-permeable wall is a foraminous wall having an array of perforations through which oil particles can also pass if entrained with the gas since, with the above described arrangement of the gas galleries, a small amount of oil entrained with the gas can be separated subsequently, and this is preferable to the alternative, which would be required in the case of an oil impermeable wall, of requiring periodic cleaning either by backwash or dismantling.

20 In a preferred embodiment of the invention the resistance to gas flow across the said gas-permeable surface is adjustable between predetermined minimum and maximum values. This may be achieved in an arrangement in which the gas-permeable wall is a foraminous wall or sleeve by providing means for varying the effective aperture size of the apertures in the foraminous wall or sleeve. Preferably the aperture size is varied by the provision of a secondary foraminous wall or sleeve closely adjacent the first and displaceable with respect thereto so that at least some of the apertures in the secondary wall or sleeve can be moved into or out of register with the apertures in the said wall or sleeve.

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If the secondary foraminous sleeve is coaxial with the said foraminous sleeve adjustment can effectively be obtained by relative axial displacement, although preferably the secondary foraminous sleeve is turn-  
5 able about its axis by means of a motor via a suitable drive transmission of the mixture through a selected number of the separator devices in dependence on the gas pressure, whereby to maintain the oil flow rate within certain values.

10

Preferably there is further provided an excess pressure safety valve which opens if the pressure of the mixture in the apparatus exceeds a critical threshold value. In a preferred embodiment the plurality of separator  
15 devices are positioned as an annular array with their axes upright around a central oil collection chamber interconnected with the individual oil collection means which collect oil from the gas galleries. This oil collection chamber is preferably also connected  
20 to the inlet of one or more of the separator devices whereby to recycle the oil collecting therein through that separator device or those separator devices to be passed to the said oil delivery duct. The pressure to drive the oil from the said oil collection chamber  
25 to be recycled through one or more of the separator devices is conveniently derived from separated gas drawn from the gas collection duct leading from another of the separator devices in the array.

30 The apparatus of the present invention may further include a safety valve positioned in the drill string at such a level that it will be between the sea bed and the surface when the final breakthrough into the

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- oilfield occurs. This safety valve is preferably in the form of a single gas separator device as defined above in a series in the drill string at a submarine position as mentioned above, the gas gallery of the separator device having one or a plurality of unidirectional pressure relief valves which are set to open upon the attainment in the gallery of a pressure above a certain threshold value.
- 5
- 10 The gas-permeable wall constituting part of the flow path of the mixture may have a predetermined fixed effective area, and therefore a fixed resistance to the flow of gas therethrough although since the ratio of gas and oil in the mixture varies considerably and large gas
- 15 "bubbles" frequently arrive at the well head with the oil, thereby causing rapid and strong fluctuations in the pressure it may be advantageous to be able to vary the effective area of the gas-permeable wall. This may be achieved, for example, by varying the proportion of the
- 20 wall area occupied by the gas apertures.

One of the known measures taken to counteract the detrimental effects of such variation in the pressure is to provide an extremely strong valve at the well head to

25 serve as a blow off prevention valve (this is housed in an assembly known as the BOP stack) which valve is closed rapidly when the approach of gas bubbles in the oil likely to cause sudden and damaging fluctuations in the pressure is detected by sensors in the drill string and at

30 the well head. In accordance with the principles of the present invention, however, the separator may be constructed in such a way that the resistance to gas flow can be varied to accommodate variations in the gas and oil pressures experienced at the well head.

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According therefore to this aspect of the present invention a separator device for separating gas from oil in a mixture thereof at high pressure, such as the well head of an oil well, and having a flow path for the mixture a  
5 substantial part of the surface area of which is defined by a gas-permeable surface, is provided with means by which the resistance to gas flow across the surface is adjustable between predetermined minimum and maximum  
10 values. Such adjustment of the resistance to flow of the gas-permeable surface may be achieved in a number of ways. For example, if, as discussed hereinabove the gas-permeable surface is constituted by a foraminous wall or sleeve surrounding a central core and defining the flow path for the mixture, there may be provided means for  
15 varying the effective aperture size of the apertures in the foraminous wall or sleeve.

The aperture size or the number of apertures which are open may for example be varied by the provision of a second-  
20 ary foraminous wall or sleeve closely adjacent the first and displaceable with respect thereto so that at least some of the apertures in the secondary wall or sleeve can be moved into or out of register with the apertures in the said wall or sleeve. A secondary filtering system may  
25 also be provided for separating residual oil entrained with the gas passing through the foraminous wall. Such filtering systems may incorporate a plurality of passages and oil traps allowing the gas to expand on its passage therethrough whilst collecting oil for delivery to an  
30 appropriate oil duct.

In the preferred embodiment of the invention the gas flow passage is constituted by a core with helical grooves therein closely surrounded by a foraminous sleeve, and the secondary sleeve is closely fitted around the said  
35 foraminous sleeve and rotatable about



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a common axis to bring the apertures thereof into or out of register with the apertures in the said foraminous sleeve. Rotation of the secondary sleeve may be effected automatically, via a suitable drive and transmission in dependence on signals received from sensors in the drill string and/or at the well head operable to detect the approach of gas bubbles or regions of strongly varying pressure so that the effective gas passage area in the foraminous sleeve can be substantially increased to accommodate the extra gas flow occurring when such bubbles arrive at the well head.

Various embodiments of the present invention will now be more particularly described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of apparatus incorporating a plurality of separator devices of the present invention;

Figure 2 is an axial view of a first embodiment of the separator apparatus illustrated in Figure 1;

Figure 3 is a cross sectional view taken on the line III-III of Figure 2;

Figure 4 is an axial section of a drill string safety valve incorporated in the separator apparatus of the present invention;

Figure 5 is an axial sectional view through a separator device formed as a second embodiment of the present invention;



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Figure 6 is a diagram illustrating a suitable arrangement of apertures in the separator device of Figure 5 to provide a variable flow resistance;

5 Figure 7 illustrates a further separator sleeve structure;

Figure 8 is a cross sectional view of a part of the sleeve of Figure 7.

10 Referring now to the drawings, in Figure 1 the apparatus as generally indicated comprises a base support framework 11 having a support platform 12 above which projects an array of six separator devices, each generally indicated 13, and below which is located an input flow coupling 14,  
15 for the mixture of oil and gas to be separated, and a gas flow control valve arrangement generally indicated 15.

Each gas/oil separator device 13 has two outlets 16,17 at its upper end, the outlets 16 comprising oil delivery ducts,  
20 and the outlets 17 comprising gas collection ducts which lead to a common gas header 18 from which extends a gas delivery duct 19.

The internal construction of the gas/oil separator devices 13 can be seen in Figures 2 and 3. Each separator column 13 comprises an outer cylindrical casing 20 flanged at each end for connection to the support surface 12 and a header assembly 21 at the lower and upper ends respectively. Within the cylindrical casing 20 and coaxial there-  
30 with is a cylindrical foraminous sleeve 22 housing a core 23 having six helically extending upstanding ridges 24 which define between them six shallow helical channels 27 (see Figure 3). The diameter of the core 23 is such that the radially outer surfaces of the ridges 24 are a close  
35. fit within the inner surface of the foraminous sleeve 22

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so that the helical channels 27 within the sleeve 22 are separate from one another throughout the whole length of the core 23 which extends axially the full length of the outer casing 20 from the lower to the upper flange thereof.

5

The perforations in the foraminous sleeve 22 may be regularly spaced over the whole of the length of the sleeve or may follow a spacing pattern determined in a manner such as best to accommodate variations in pressure along the length of the flow path defined by the separator. Each perforation is conveniently circular and in the region of  $\frac{1}{8}$ " diameter. The relative diameters of the outer casing 20 and the foraminous sleeve 22 are such that the flow cross section within the annular space between them is substantially greater than the flow cross section within the helical ducts defined between the foraminous sleeve 22 and the core 23. As shown the helical ducts have only one turn within the length of the core 23; in practice this may differ, however, and ducts having a plurality of turns may be employed. The number of turns may be varied in dependence on the conditions experienced at the well-head in order to obtain the best effect, and this can be achieved by interchanging the cores for others having a different pitch, or by constructing a variable pitch core.

The gas/oil mixture supplied to the lower end of each separator 13 is directed thereto by a respective mixture duct 25 extending from a control valve assembly, generally indicated 26 which receives gas and oil via a branching duct 28 from an input coupling 29.

As can be seen from Figure 3 only four of the separators 13 receive the mixture directly from the control valve assembly 26, these separators being identified

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by the subscript letters a,b,d and e. The two other separators 13, identified by the subscript letters c and f are connected to receive recirculated oil as will be described below.

5

To the upper flange of each outer cylindrical casing 20 of each separator 13 is connected a respective branch of gas header assembly 21 comprising a plurality of gas collection ducts 19 leading to a common gas delivery duct 19<sub>a</sub> which, as can be seen in Figure 1, extends centrally from the upper end of the apparatus.

Each foraminous sleeve 22 within the separator 13 has an imperforate section 30 at the upper end thereof which continues as an oil delivery duct 31 leading to the oil delivery headers 16 of Figure 1. These latter may, of course, be joined to a common oil delivery pipe at a point downstream from the separating apparatus.

20

Located centrally within the array of six separators is a recirculating oil tank 32 having inlets 33 connected by connection ducts 34 (see Figure 3) to the lower ends of the cylindrical outer casings 20 of each of the four separators 13<sub>a</sub>, 13<sub>b</sub>, 13<sub>d</sub>, 13<sub>e</sub>. Two outlets 35 from the lower end of the recirculation tank 32 lead, via ducts 36 to the main mixture inlet ports of the separators 13<sub>c</sub>, 13<sub>f</sub>. At the upper end of the oil recirculation tank 32 is a gas inlet supplied by a duct 38 via a control valve 39 from the gas gallery constituted by the annular space between the outer casing 20 and the foraminous sleeve 22 of one or more of the separators 13<sub>a</sub>, 13<sub>b</sub>, 13<sub>d</sub>, 13<sub>e</sub>.

30



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The apparatus described above operates as follows. The mixture of oil and gas in the condition at which it arrives at the well head of an oil well is supplied to the inlet coupling 28 from where it flows through the ducts 27 to the control valve assembly 26. This control valve assembly is operated in dependence on the current pressure and flow rate in the incoming material to open communication to one or more of the supply ducts 25 leading to the separators 13a, 13b, 13d, 13e. When the pressure and flow rate are high all the valves in the assembly 26 will be open so that all four separator columns will be in operation. At lower pressures one or more of the columns is shut off to compensate the apparatus for such variation so that the working pressures within the apparatus are maintained, as far as possible, within predetermined values.

As the mixture of gas and oil enters the separator column 13 from the supply duct 25 it experiences a progressive reduction in its available flow path and is guided into the helical channels 27. It will be noted from Figure 2 that the core 23 is tapered for the initial part of the mixture flow path within the separator so that the change in flow cross section is progressive over an initial section. With the dimensions illustrated the individual channels 27 have a flow cross section which is largely determined by the cylindrical inner surface of the foraminous wall of the outer sleeve 22 and the curved surface of the core 23. Only a very small proportion, less than 20%, of the overall surface area of the flow section is constituted by the radial walls of the ridges 24. Because of this, and because of the swirling action

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introduced by the helical flow path of the mixture the gas tends to collect at the radially outer part of the channels 27 whilst the oil flows up the radially inner part in contact with the surface of the core 23. The gas, which is under considerable pressure, passes through the apertures in the foraminous sleeve wall 22 into the gas galleries defined by the annular space 37 between the outer casing 20 and the sleeve 22 where it experiences a substantial drop in the pressure due to the very much greater cross sectional area of this passage in relation to the flow section of the helical channels 27. The gas then flows through the header 21 and delivery duct 29 to the gas collector duct 19. The oil continues up the central passage within the separator 13 into the oil delivery duct 31 from where it passes to the oil delivery headers 16.

Inevitably a proportion of the oil will pass through the sleeve 22 entrained with the gas as it expands. Because of this increased flow cross section the velocity of the gas falls substantially and suddenly, and oil particles entrained therewith can thus no longer be sustained by the gas flow and fall under the action of gravity to an oil collection sump defined by an imperforate lower section of the sleeve 22, between this sleeve and the outer casing 20. Such separated oil passes through the recirculation ducts 34 into the oil recirculation chamber 32 where, due to the gas pressure arriving via the inlet 37 and duct 38 it is driven to the inlet ports of the recirculation columns 13c, 13f via the ducts 36. These columns necessarily work at a lower pressure than the other four columns in the array due to the fact that the driving

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gas is derived from an upstream position with respect to the first four separator columns and consequently the gas pressure is lower than the pressure at the inlet 28 to the apparatus as a whole.

5

The operation of these recirculation separators may be intermittent if the amount of entrained oil collecting in the sumps in the four main separators is insufficient to maintain continuous flow. For this purpose the control valve 39 in the duct 38 is provided. Although this is shown as a manually operated hand wheel gate valve, it will be appreciated that such valve may be operated automatically or remotely, and that by closing off the driving gas oil can collect in the sumps at the lower end of the separators 13, and can drain under the action of gravity into the recirculation tank 32 until sufficient has been collected to re-open the recirculation separators 13c and/or 13f.

20

In this way the operation of the apparatus can be controlled to accommodate a wide range of fluctuations in the inlet pressure and flow rates.

25 A further control on the apparatus can be obtained by interchanging the cores 23 for cores of different pitch. It is envisaged that cores having pitches of 2ft, 4ft, 6ft, and 8ft would be provided, these to be used independently of one another in the assembled apparatus  
30 to increase or reduce the number of turns of the helix in the length of the separator to accommodate fluctuations in pressure and flow rate as the well varies.

In Figure 4 there is shown a submarine safety valve

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which is positioned in series in the drill string to be at a submarine level when the final breakthrough into the oilfield occurs. As can be seen in Figure 4 the safety valve, which is generally indicated 40, 5 comprises an outer casing 41 which tapers from an upper end 42 to a lower or inlet end 43.

Within the tapering outer casing 41 is a generally cylindrical inner sleeve comprising a parallel sided 10 cylindrical gas-permeable membrane 44 which may be of similar construction to the foraminous sleeve 22 in the gas/oil separator devices 13 illustrated in Figures 2 and 3. In the same way the cylindrical sleeve 44 houses the core 45 having a plurality of 15 helically extending upstanding ridges defining between them shallow helical channels 47.

Arranged around the wider end of the casing 41 are six unidirectional pressure relief valves 48 which 20 communicate with the gas gallery in the chamber 49 between the outer surface of the foraminous sleeve 44 and the casing 41. Each unidirectional valve 48 is set to the predetermined pressure in excess of the normal working pressure within the drill string so that 25 if excess pressures occur, particularly on breaking through the final section of rock into the oilfield, the drill rig itself will be relieved of the surge since this will be released through the valves 48. At normal pressures the valves 48 will remain closed 30 and the safety device will act simply as a section of the hollow drill string allowing the slurry, mud and gas to pass through it without any change.

Sensors 50 may be provided in the region between the safety valve 40 and the surface to detect the release



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of gas bubbles through the valves 48 so that a surge in pressure giving rise to such pressure relief action can be detected before it reaches the rig and appropriate action can be taken.

5

Referring now to Figures 5 and 6 the alternative separator device shown therein comprises a generally cylindrical support casing 51 mounted on a platform base 52 which also supports a base structure 53.

10

The base 53 supports a cylindrical sleeve 54 surrounding a central core 55 having a plurality of helical grooves formed therein. The core 55 is tapered at its lower end and enters the mouth of a venturi block 56 secured to the platform 52 and constituting an entrance coupling to the separator for connection to the upper end of a delivery pipe from a blow off prevention valve (BOF stack, not shown) at the well head. The internal flow passage within the venturi block 56 is shaped with a smoothly curved constriction such that the flow path from the BOP stack is divided at the entrance end of the central core 55 having the helical grooves without creating turbulence.

25 The sleeve 54 surrounds the core 55 and over the majority of its length has a plurality of apertures 65. Around the sleeve 54 is a secondary sleeve 57 which also has a plurality of apertures the spacing of which is different from that of the apertures in the sleeve 54. The outer sleeve 57 is a sliding fit over the inner sleeve 54 and is supported on an annular support 58 carried by a support member 59 having a ring of gear teeth 60 which mesh with pinions 61 driven by a shaft 62 from a motor 63. The motor 63 may be a stepping motor.

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Surrounding the outer sleeve 57 is a cylindrical chamber 64 which houses a secondary oil separation filter of any suitable type; in the illustrated embodiments it comprises a tubular spiral filter bank of high tensile nickel-titanium tubes arranged in six peripherally adjacent part-cylindrical banks. Surrounding this filter is a further bank of separator cartridges in the form of an array of platelets in a honeycombed structure. The spiral tubular filter banks 64 and the outer honeycomb structure 74 are both arranged to trap the oil entrained with gas passing through the apertures in the sleeves 54,57. As can be seen more clearly in Figure 6 the apertures in the sleeve 54, identified with the reference numeral 65 are spaced by a distance  $d$  from one another in a regular array both in the peripheral and the axial direction. The apertures in the sleeve 57, on the other hand, although being spaced regularly by the separation  $d$  in the axial direction, have an irregular spacing in the peripheral direction, some being spaced by the distance  $d$  some by  $d/2$  and some by  $d/3$ . The pattern illustrated in Figure 2 can be considered to repeat around the periphery of the sleeve 57. In this simple embodiment, therefore, the sleeve 57 can be positioned in a first position in which all the apertures 65 in the inner sleeve 54 have a corresponding aperture 66 in register therewith. By displacing the sleeve 57 to the left of Figure 6 with respect to the sleeve 56, however, the aperture 66 can be displaced out of register with the aperture 65 to bring an aperture 67 in register with one of the four apertures 65 of the sleeve 56. Thus, in this situation, only one quarter of the apertures 65 are open, the remainder being closed by the adjacent sleeve 57. Further movement of the sleeve 57 until the apertures 68 are in register with two of the apertures 65 allows one half of the apertures 65 to be open whilst the remainder are closed. By suitably arranging the pattern of apertures in the sleeve 57 four positions in which

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one, two, three or four apertures 65 from each set of four thereof can be selectively opened by bringing an appropriate aperture from the sleeve 57 into register therewith thereby allowing for a four-fold  
5 variation in resistance which can be accommodated by the separator to be obtained. In normal circumstances the sleeve 57 will be set with two or one of each set of four apertures open, and would be turned to open  
10 an increase in pressure when gas bubbles arrive at the well head.

Referring now to Figures 7 and 8 there is shown a perforated sleeve suitable for replacing the per-  
15 forated sleeve 56 in the embodiment of Figure 5 or, indeed, in the embodiment of Figure 2. This sleeve, only part of which is illustrated in Figure 7, is generally indicated with the reference numeral 71. It has a helical row of apertures 72 having delimit-  
20 ed axial extent, that is transverse the length of the helically extended row. Two further rows 73, 74 are intercalated therewith to form a triple start helix. The wall portion of the sleeve 71 between adjacent rows of apertures 72, 73 or 73,74 is im-  
25 perforate.

Figure 8 illustrates the cross sectional shape of a channel 75 formed within a core 76 closely fitting within the sleeve 71 in the same way as the core 55  
30 fits within the sleeve 56 in the embodiment of Figure 5.

The spiral groove 75 has a triangular cross section defined by a substantially radial wall 77 and an



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inclined wall 78 lying at approximately  $45^{\circ}$  to the diametral plane of the core to which the generatrix of the wall 77 is parallel. In Figure 8 can be seen two of the apertures in the rows 72, indicated 5 72a, 72b, and these, as illustrated in Figure 7, are elliptical with the major axis perpendicular to the length of the sleeve 71. As can be seen in Figure 8 the row of apertures 72 is aligned with that portion of the groove 76 adjacent the apex of the triangle 10 remote from the side 77. Thus, as the oil and gas mixture flows around the helical path defined by the channel the forces to which the gas and oil are subject cause the gas to occupy the space parallel to the side 78 whilst the oil occupies the space 15 defined by the apex of the triangle opposite the side 78. The gas thus communicates with the apertures 72a, 72b whilst the oil is retained in the channel by the imperforate section of the sleeve so that it is conveyed to the end of the helical 20 channel from where it goes to the oil collecting passages.

Referring back to Figure 5, the cleaning of the gas foil separator device shown can be programmed to take place regularly, after a certain flow has passed, this being detected by ultrasonic sensors 75, 76, located on the outer casing wall 77 and on the main cylindrical support casing 51.



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CLAIMS

1. A separator device for separating gas from oil in a mixture thereof at high pressure, such as at the well head of an oil well, including a guide duct for guiding the flow of the mixture at high pressure along a flow path a part of the surface area of which is defined by a gas-permeable surface the flow path being so shaped that expansion of the gas content of the mixture drives it through the said gas-permeable surface where it is collected in a gas collection duct, the said guide duct directing the oil fraction to an oil delivery duct.
2. A separator device as claimed in Claim 1, in which the major part of the surface area of the said flow path is constituted by two facing surfaces of the guide duct, which surfaces constitute at least 80% of the surface area of the guide duct.
3. A separator device as claimed in Claim 1 or Claim 2, in which there are formed a plurality of guide ducts defined by a generally cylindrical gas-permeable sleeve housing a close fitting central core having a plurality of shallow generally axially extending channels therein.
4. A separator device as claimed in Claim 3, in which the said shallow generally axially extending channels in the central core extend helically therealong whereby to cause the gas and oil mixture to swirl as it travels through the device.
5. A separator device for separating gas from oil in a mixture thereof at high pressure, such as at the

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well head of an oil well, comprising means for causing the mixture to follow a generally helical flow path defined in part by a gas-permeable wall across which a pressure differential is maintained such that the gas in the mixture is urged to traverse the wall to a gas collection gallery whilst the oil is directed by guide means to an oil delivery duct.

6. A separator device as claimed in any preceding claim, in which there are provided means for collecting oil entrained with the gas passing through the said gas-permeable wall.

7. A separator device as claimed in Claim 5 or Claim 6, in which the gas-permeable wall is a generally cylindrical sleeve within which the generally helical flow path of the mixture is defined.

8. A separator device as claimed in any of Claims 5 to 7, in which the flow path for the mixture is further defined by an elongate core within the said cylindrical sleeve and having at least one helical channel therein for causing the mixture to follow the said generally helical flow path.

9. A separator device as claimed in Claim 8, in which the said elongate core has a plurality of such helical channels defined by upstanding helically extending ridges on the core the ridges fitting tightly against the inner surface of the gas-permeable wall.

10. A separator device as claimed in any preceding Claim, in which the gas-permeable wall is foraminous.

11. A separator device as claimed in any preceding



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Claim, in which the resistance to gas flow across the said gas-permeable surface is adjustable between predetermined minimum and maximum values.

12. A separator device as claimed in Claim 2 or Claim 7, or any claims dependent thereon, in which there are provided means for varying the effective aperture size of the apertures in the foraminous wall or sleeve.

13. A separator device as claimed in Claim 12, in which the aperture size is varied by the provision of a secondary foraminous wall or sleeve closely adjacent the first and displaceable with respect thereto so that at least some of the apertures in the secondary wall or sleeve can be moved into or out of register with the apertures in the said wall or sleeve.

14. A separator device as claimed in Claim 13, in which the secondary foraminous sleeve is coaxial with the said foraminous sleeve and is turnable about its axis by means of a motor via a suitable drive transmission.

15. Apparatus for separating gas from oil in a mixture thereof at high pressure, such as at the well head of an oil well, comprising a plurality of separator devices as claimed in any preceding Claim and a flow control valve assembly for directing the flow of the mixture through a selected number of the separator devices in dependence on the gas pressure, whereby to maintain the oil flow rate within certain values.

16. Apparatus as claimed in Claim 15, in which



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there is further provided an excess pressure safety valve which opens if the pressure of the mixture in the apparatus exceeds a critical threshold value.

17. Apparatus as claimed in Claim 15 or Claim 16, in which there is further provided an oil collection chamber for collecting oil carried through the said gas-permeable wall entrained with the gas, this chamber being located in a central position surrounded by the said plurality of gas separator devices in an array thereof.

18. Apparatus as claimed in Claim 17, in which the said oil collection chamber is also connected to the inlet of one or more of the separator devices whereby to recycle the oil collecting therein through the separator device or devices for delivery to the said oil delivery duct.

19. Apparatus as claimed in Claim 17 or Claim 18, in which the pressure to drive the oil from the said oil collection chamber to be recycled through one or more of the separator devices is derived from separated gas drawn from the gas collection duct leading from another of the separator devices in the array.

20. Apparatus as claimed in any of Claims 15 to 19, further including a safety valve positioned in the drill string at a level such that it will be between the sea bed and the surface when the final breakthrough into the oilfield occurs, this safety valve comprising a separator device as claimed in any of Claims 1 to 14, in series in the drill string, the gas gallery of the separator device having one or a plurality of unidirectional pressure relief valves set to open at the

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attainment of a pressure in the gallery above a certain threshold value.

21. A separator device as claimed in Claim 1, in which the said flow path is substantially helical and bounded at the radially outer side by a substantially cylindrical wall having a plurality of apertures in a helical array the axial dimension of which array is less than the axial dimension of the said flow path.

22. A separator device as claimed in Claim 21, in which the said flow path is triangular in cross section.

23. A separator device as claimed in Claim 22, in which the said triangular cross section of the flow path includes a side inclined at an acute angle to the said cylindrical bounding wall and the array of apertures is located adjacent the acute angle.



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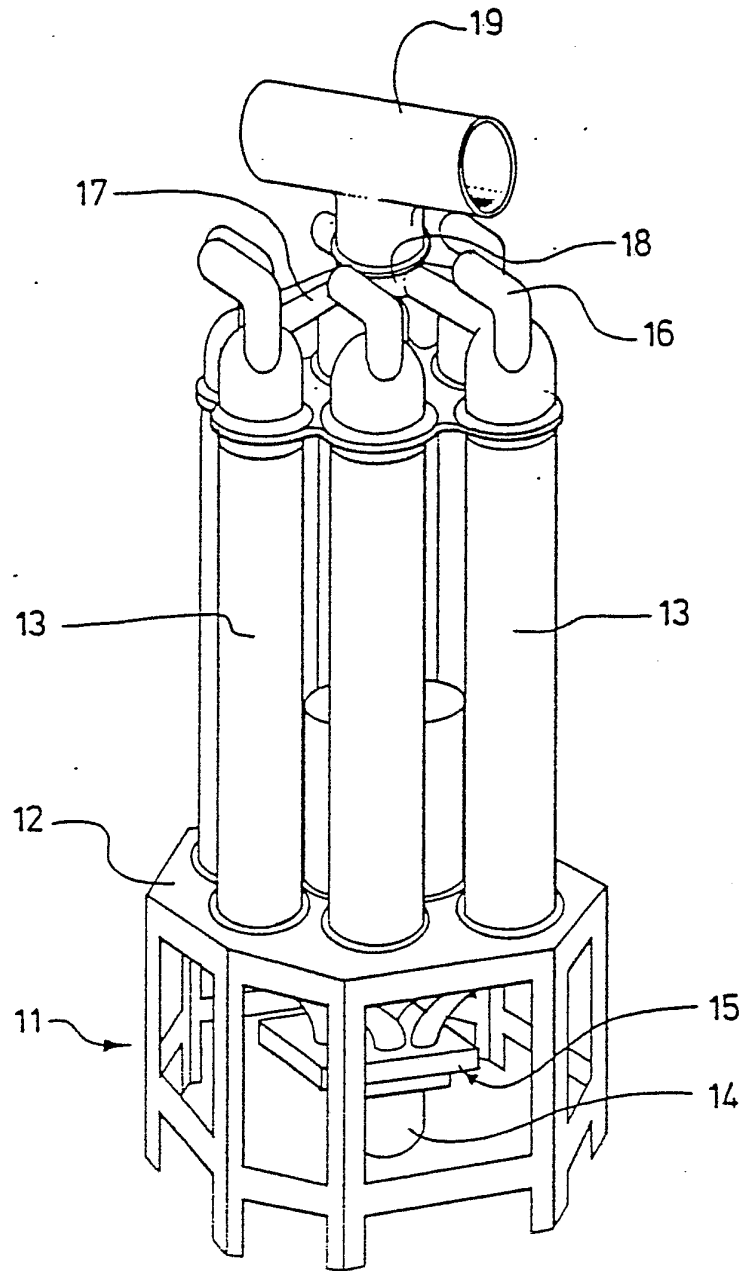


FIG. 1

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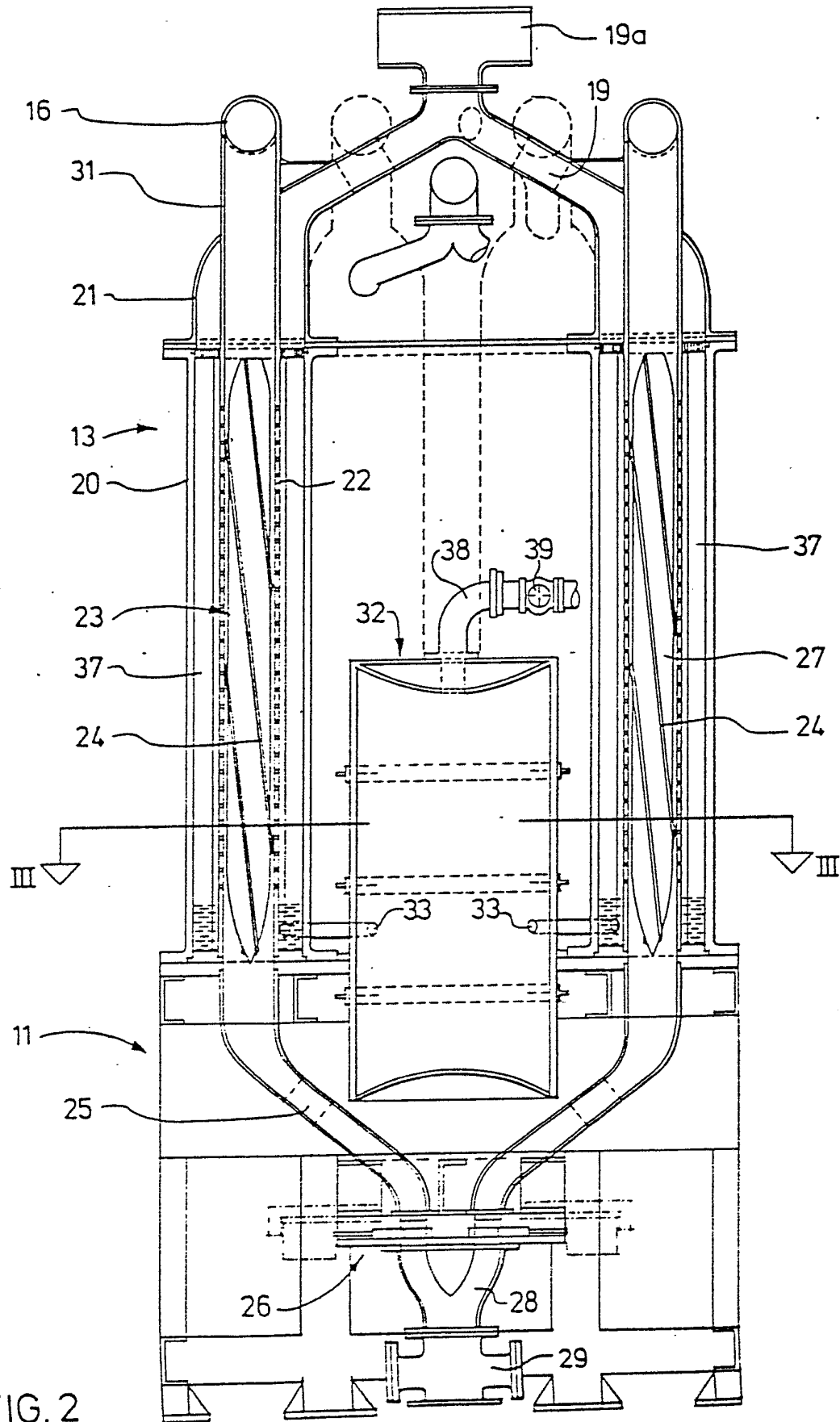


FIG. 2



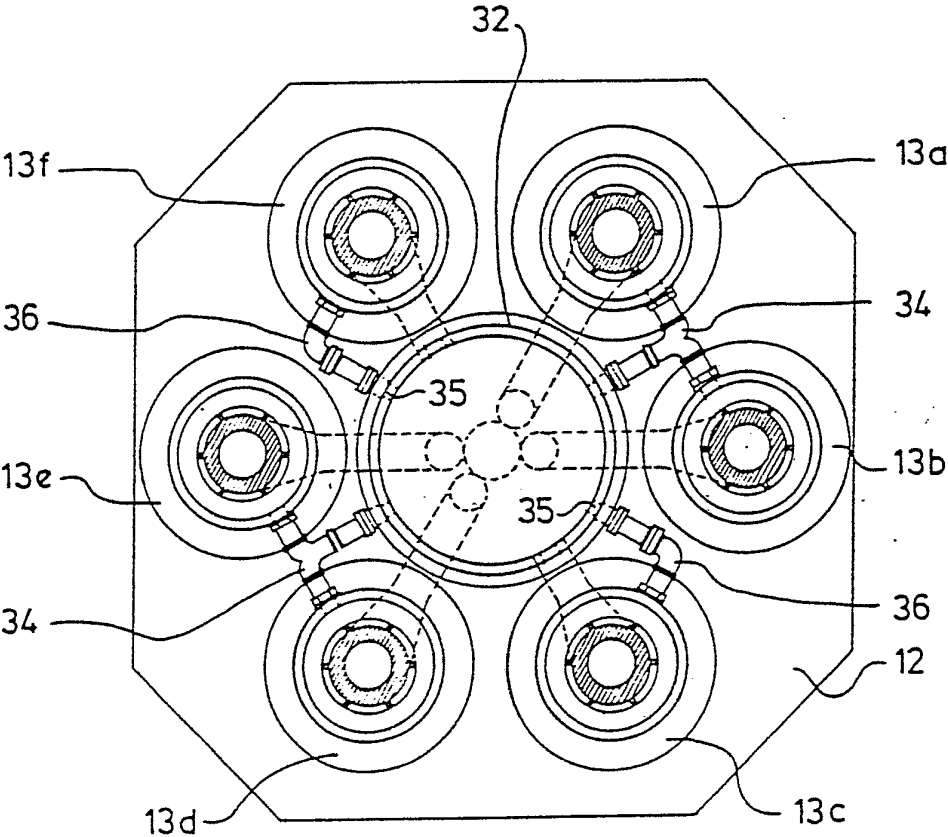


FIG. 3

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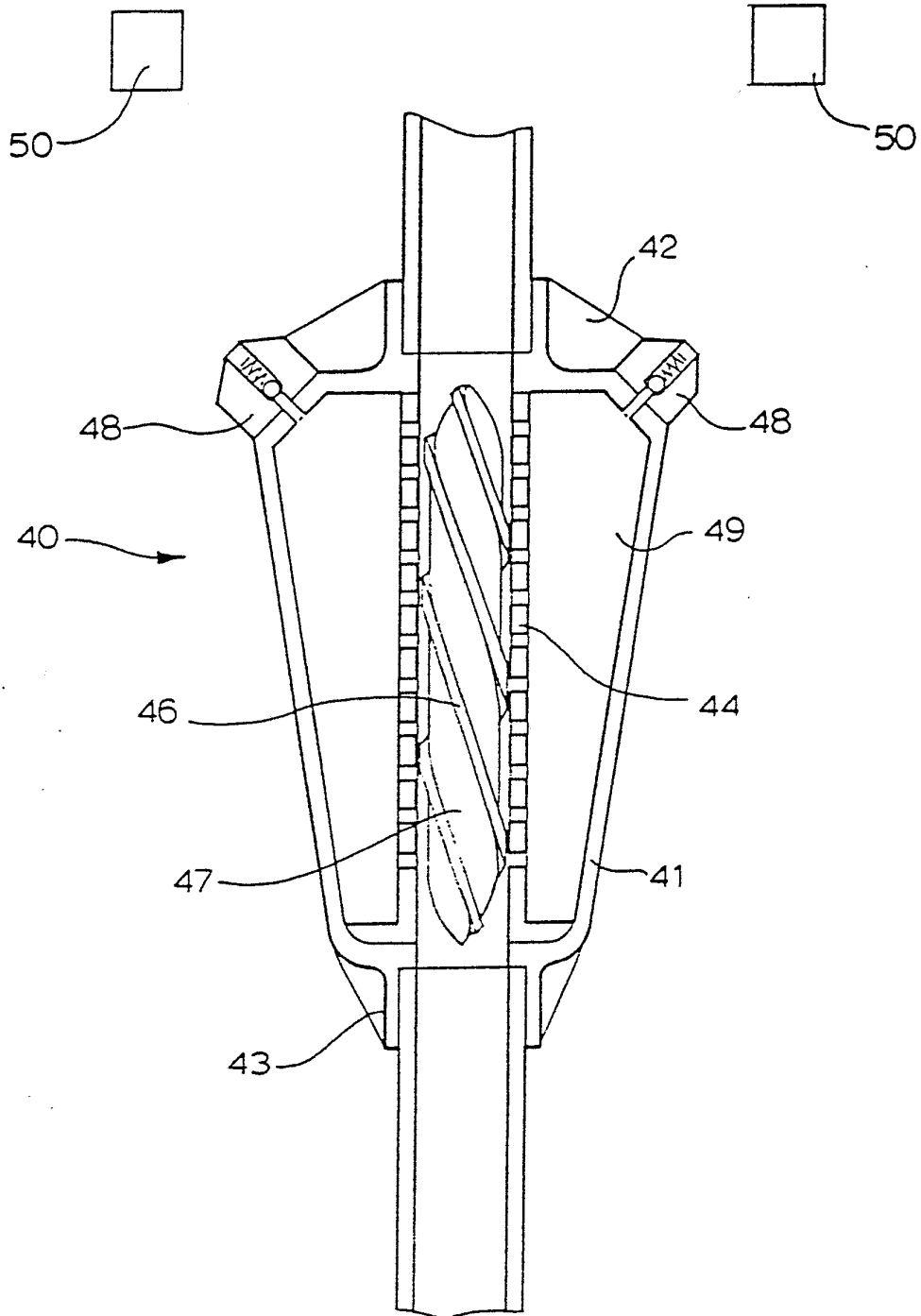


FIG. 4

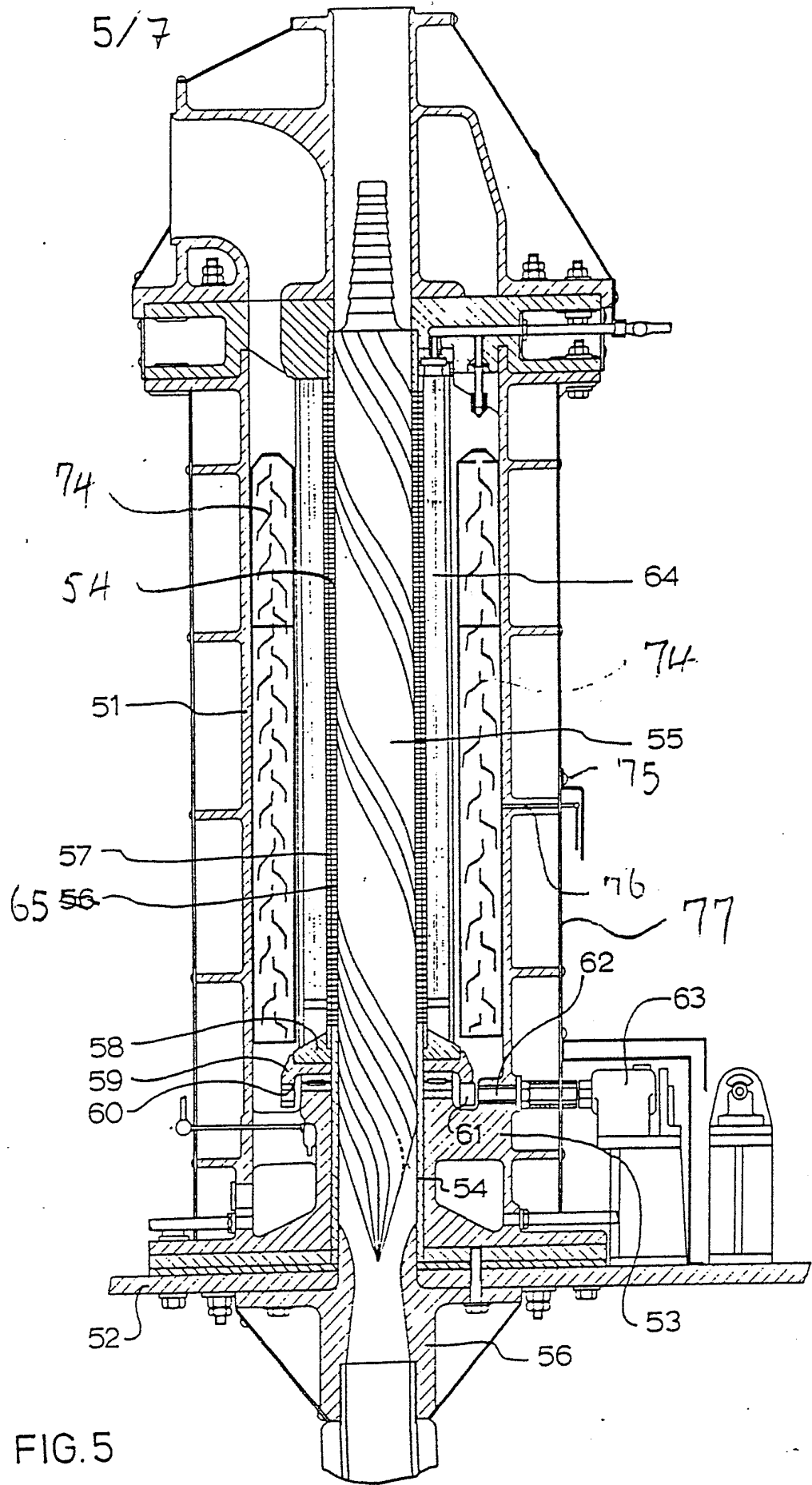


FIG. 5

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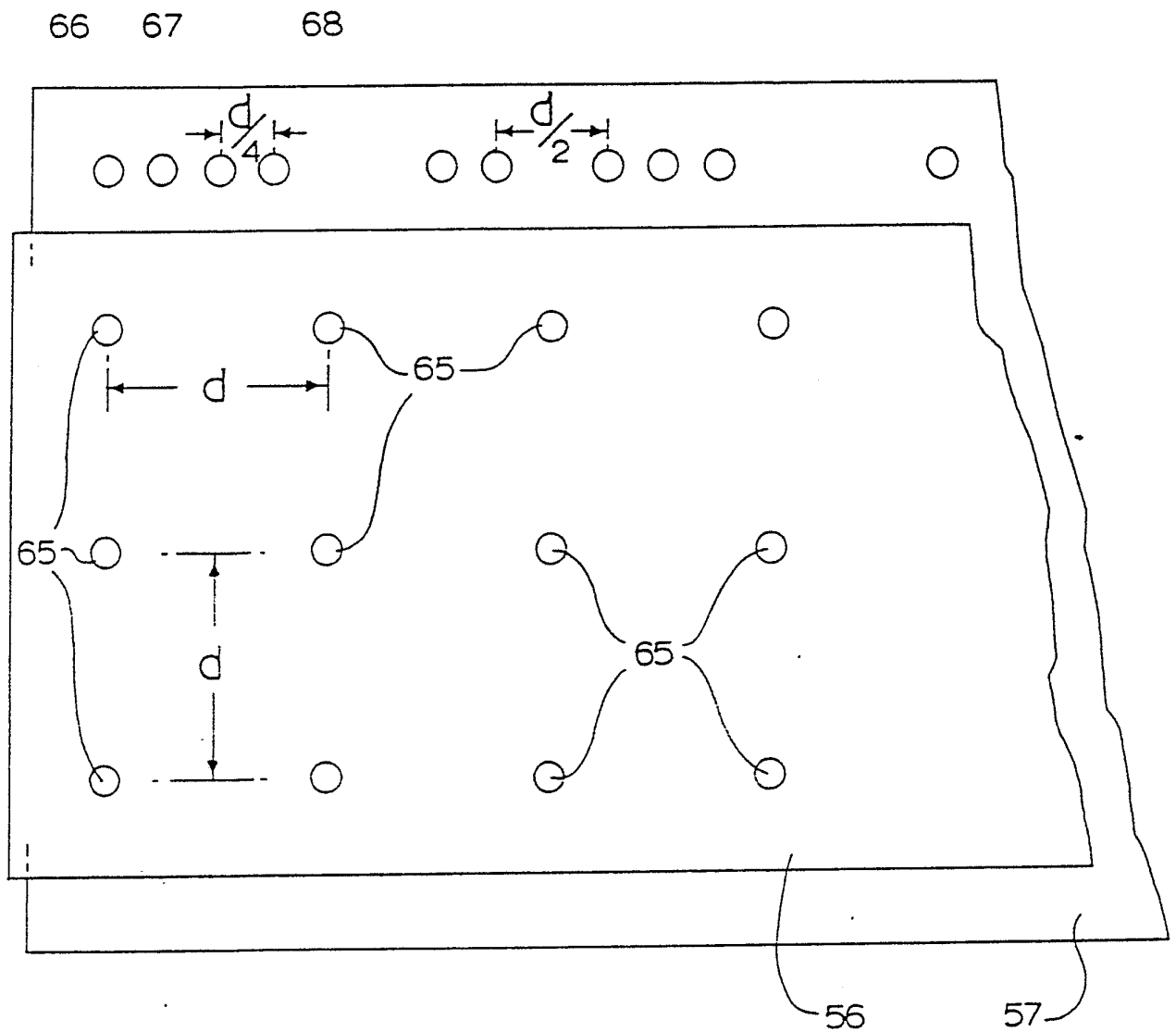


FIG. 6

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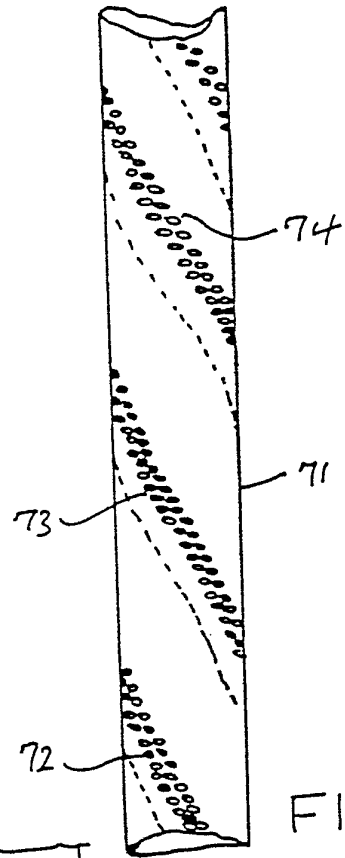


FIG 7

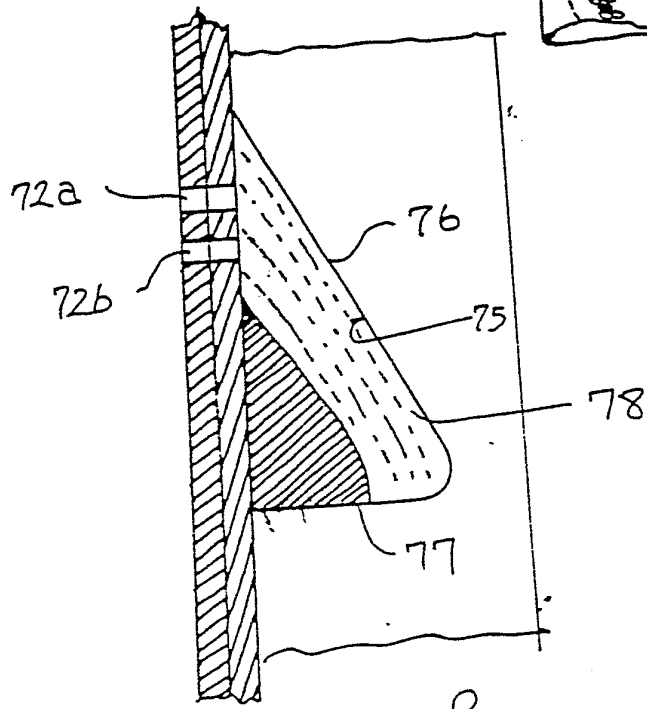


FIG 8

# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 82/00182

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>3</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC <sup>3</sup> : B 01 D 19/00; E 21 B 43/36; E 21 B 34/04; E 21 B 34/16		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>4</sup>		
Classification System	Classification Symbols	
IPC <sup>3</sup>	B 01 D; E 21 B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>5</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category *	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
A	FR, A, 2340121 (MESSERSCHMITT BOLKOW-BLOHM) 2 September 1977 see page 2, lines 17-40; figure --	1,3,4
A	US, A, 3318383 (P.L. SISSON) 9 May 1967 see column 2, lines 45-66; figure 6 --	1,4
A	DE, C, 713354 (DEUTSCHE-SCHIFF- UND MASCHINENBAU) 9 October 1941 see page 2; figures --	1
A	GB, A, 2063108 (D. BETHUNE) 3 June 1981 --	
A	US, A, 3731742 (P.S. SIZER) 8 May 1973 see figures 15,16 --	
A	US, A, 2705053 (C.W. MORRIS) 29 March 1955 --	
A	DE, B, 1180884 (VEREINIGTE GLANZSTOFF FABRIKEN) 5 November 1964 --	
A	DE, C, 891227 (B.M.W.) 13 August 1953 --	./.
<p>* Special categories of cited documents: <sup>15</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"Z" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>1</sup>	Date of Mailing of this International Search Report <sup>2</sup>	
8th September 1982	21st September 1982	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>20</sup>	
EUROPEAN PATENT OFFICE	G.L.M. Krüdenberg	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No <sup>18</sup>
A	US, A, 3386230 (K.D. RIESBERG) 4 June 1968  -----	