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SEARCH ROOM

Feb. 19, 1957 G. P. MALY ET AL 2,781,663

WELL FLUID SAMPLING DEVICE

Filed Jan. 16, 1956 2 Sheets-Sheet 1

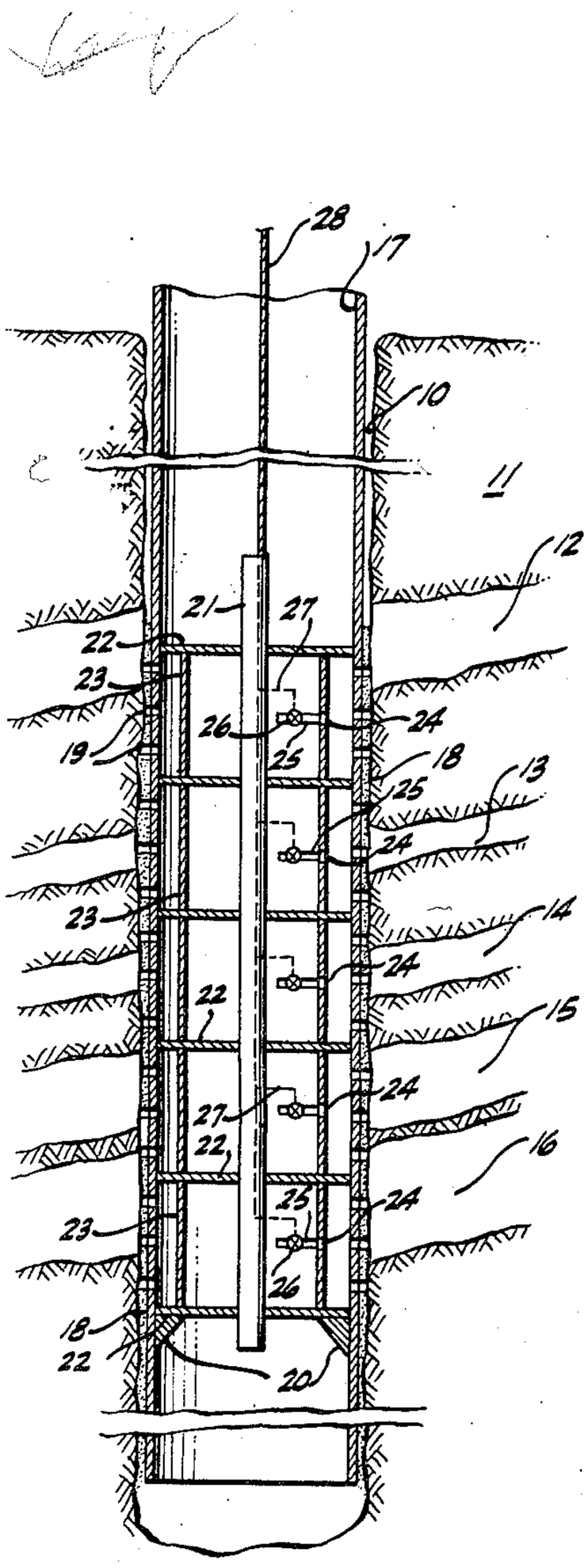


FIG. 1.

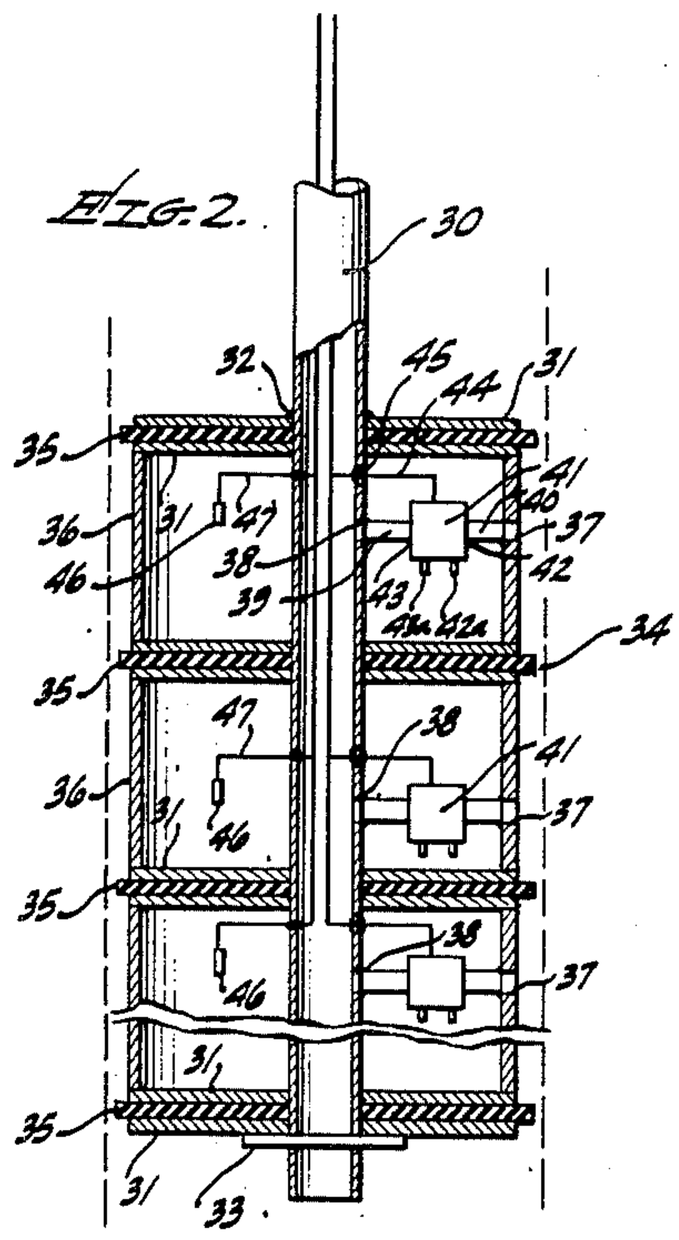


FIG. 2.

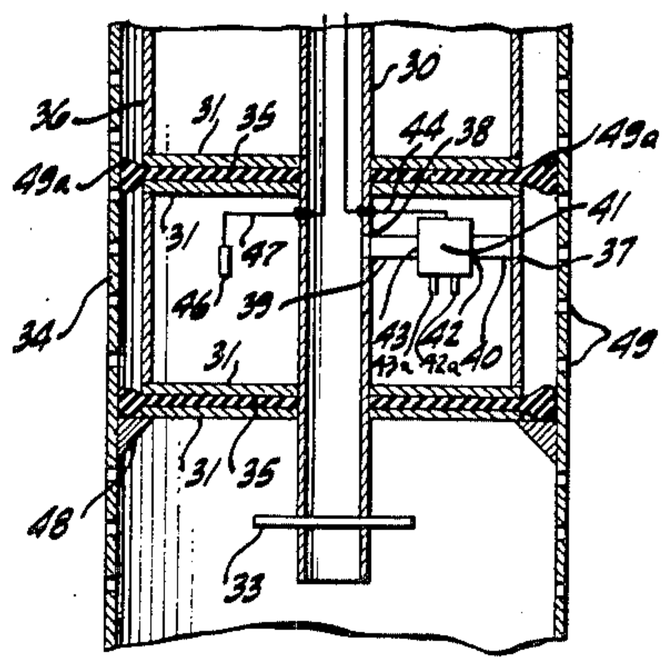


FIG. 3.

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2 Sheets-Sheet 2

FIG. 4.

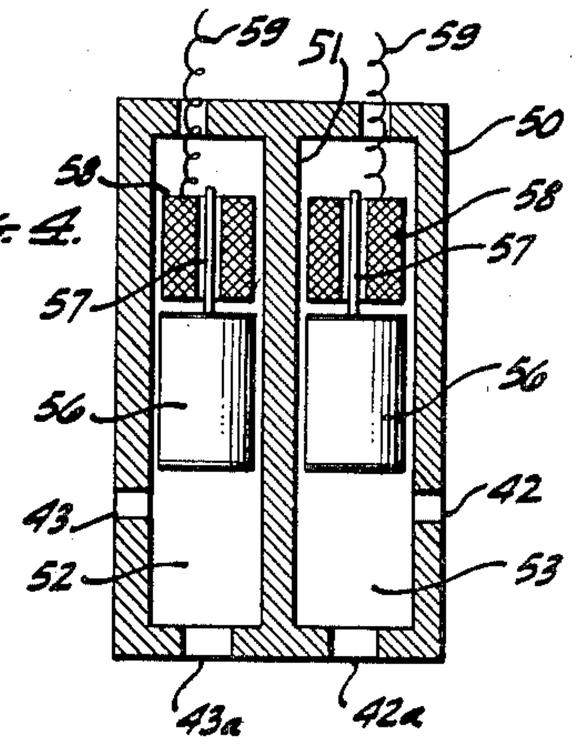
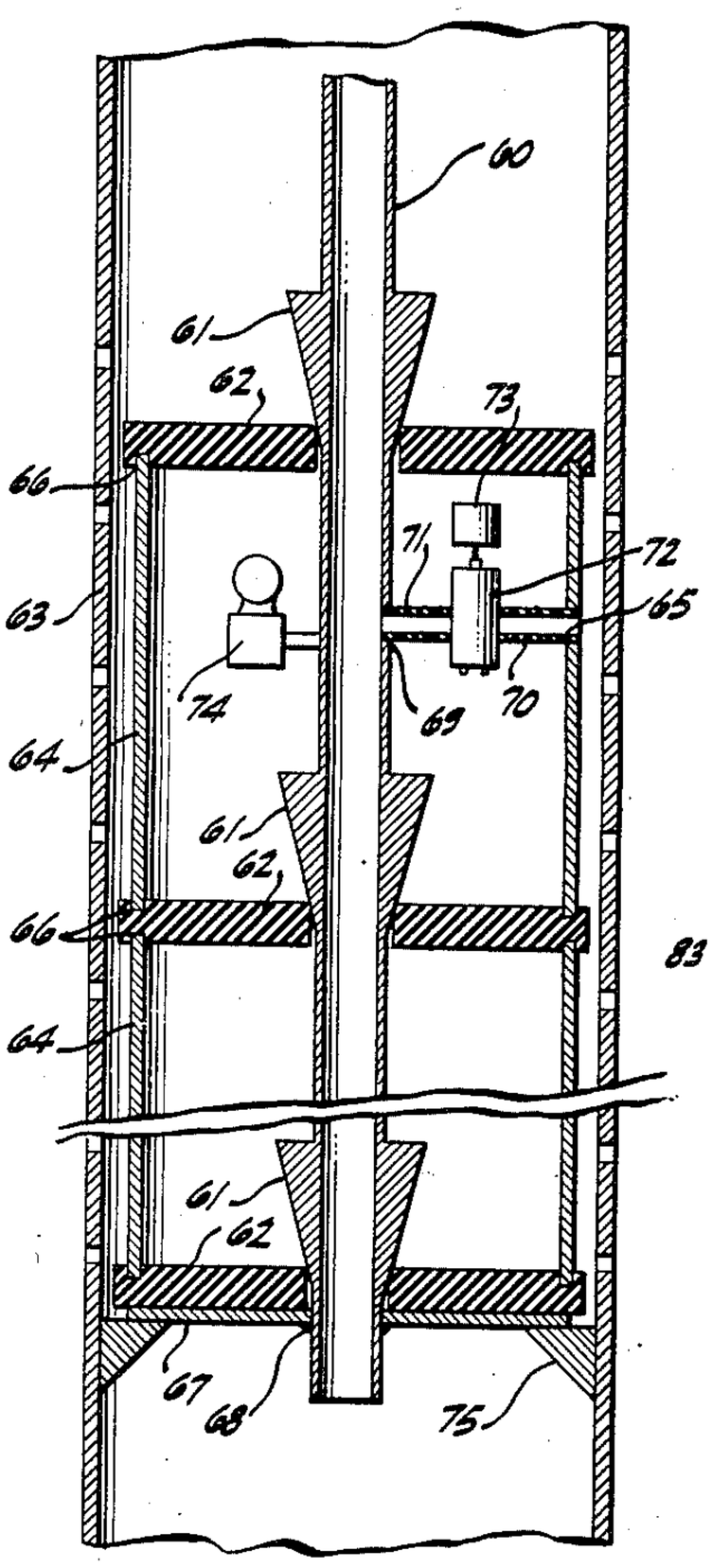


FIG. 5.



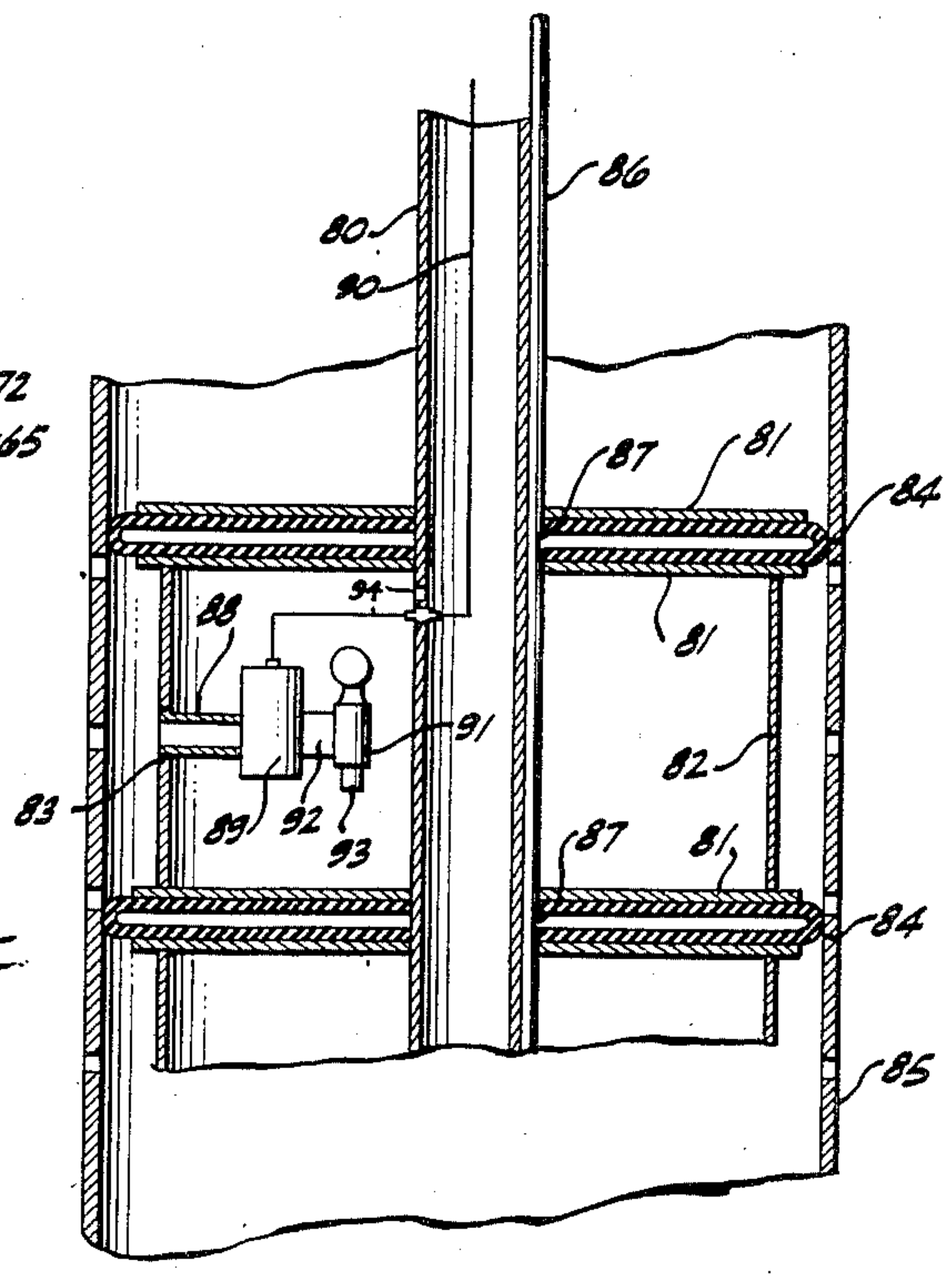


FIG. 6.

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WELL FLUID SAMPLING DEVICE

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15 Claims. (Cl. 73—151)

This invention relates to an improved device for obtaining samples of well fluids from a well bore, and in particular concerns a device for taking samples of well fluids from a plurality of fluid-producing strata penetrated by a well bore and transporting said samples to the earth's surface in substantially the same state as they occur in said strata.

In certain of the oil-producing areas of the world, the producing formation extends over a very considerable interval and comprises a relatively large number of fluid-producing strata which lie closely adjacent to each other. For example, in certain California fields it is not uncommon for the production interval to extend over 200 feet and to comprise 60–100 oil-producing, water-producing and non-producing strata all lying closely adjacent and even intermingled with one another. In producing oil from such type of formation it is very desirable that the location of the various strata and the nature of the fluid, if any, produced from each stratum be determined accurately. In the past, however, this has proved very difficult. Conventional methods for locating strata interfaces are not well adapted to use in such type of formation, and even if the individual strata be located accurately their close proximity prevents their being isolated, one from the other, by conventional well packing devices. Also, ordinary well fluid samplers can not conveniently be employed to take samples from a plurality of points within the well bore.

It is accordingly an object of the present invention to provide an improved well fluid sampling device.

Another object is to provide a device for accurately locating fluid-bearing strata traversed by a well bore.

A further object is to provide a device for isolating, one from the other, a plurality of fluid-bearing strata traversed by a well bore and simultaneously taking samples of the fluids produced by each of the isolated strata.

Other and related objects will be apparent from the following detailed description of the invention, and various advantages not specifically referred to herein will occur to those skilled in the art upon employment of the invention in practice.

We have now found that the above objects and related advantages may be realized by means of a device or tool which operates on the principle of laterally dividing a selected portion of the well bore into a plurality of isolated increments or sections of relatively short length and sampling the fluid which flows into each of such sections. Means are provided for regulating the flow of fluid into or out of each section so that after the device is lowered into the well bore to the desired depth each section can be placed into communication with that part of the bore hole which surrounds it, whereby whatever well fluids are produced from such portion of the bore hole flow into the section of the tool which corresponds thereto. Each section is then taken out of communication with the bore hole, and the tool is raised to the surface where each section may be examined for the presence of fluid and the nature thereof. Since the position which each of the tool sections previously occupied within the well bore is accurately known, the location of the fluid-bearing strata along the length of the bore subjected to investigation can accurately be determined and the exact nature of the fluid produced by each of such

strata can readily be ascertained. Also, since each section was taken out of communication with the bore hole at the exact point where the fluid flowed into such section, the fluid sample obtained at the earth's surface corresponds exactly to the fluid as it existed in the bore hole. Other means of employing the device of the invention are set forth hereinafter.

In the accompanying drawings which form a part of this specification: Figure 1 schematically illustrates the operating principle of the device provided by the invention; Figure 2 is a cross-sectional view of one form which the device may take; Figure 3 is a fragmentary view showing how the device of Figure 2 is positioned within the well casing; Figure 4 is a cross-sectional view of one form which one of the elements of the device may take; and Figures 5 and 6 are cross-sectional views of other forms of the device embodying the principle of the invention.

Referring now to Figure 1, and with particular reference to the manner in which the device operates rather than to its constructional details, bore hole **10** is shown extending through a producing formation **11** containing fluid-bearing strata **12–16**, inclusive. Well casing **17** is cemented within the bore by means of cement plug **18**, and perforations **19** (formed, for example, by conventional gun perforation) extend through the walls of casing **17** and plug **18**, thereby placing the inside of casing **17** in direct communication with the various strata traversed by bore **10**. The sampling tool of the invention rests within casing **17** on tool support **20** affixed to the inner wall of casing **17** at a known depth. Said tool consists essentially of an elongated vertical supporting member **21** carrying a plurality of spaced horizontal separators **22** which engage the inner wall of casing **17** at their peripheries to form fluid-tight seals therewith. Cylindrical shells **23** having an inside diameter larger than the diameter of supporting member **21** and provided with lateral perforations **24**, extend between adjacent separators **22** which form fluid-tight seals therewith. As will readily be seen, positioning the tool within the casing effects division of the bore hole into a series of vertically stacked chambers or cells, each of which is defined by two of the separators **22**, a shell **23**, and a portion of supporting member **21**, and each of which communicates with a corresponding thickness of the formation via perforation **24** in shell **23**. Within each of said chambers or cells, a short conduit **25** carrying a valve **26** is in register with perforation **24**, the operation of said valves being controlled via control means **27** which pass to the earth's surface through cable **28**.

In accordance with one method of employing the tool illustrated by Figure 1, tool support **20**, which may take the form of a casing packer set by means of a wire line device, is positioned in casing **17** immediately below the portion of formation **11** selected for investigation. When the bottom-most portion of the bore is to be investigated, the bottom of the hole itself may constitute the support for the tool. The well is then pumped dry and, if necessary, superimposed pressure may be applied to the casing to prevent well fluids from entering the same while the tool is being placed in position. The tool is lowered into the casing by means of cable **28** until it rests on tool support **20**. After the tool has been set, each of separators **22** is caused to expand radially (by means hereinafter described) so as to form a fluid-tight seal at its periphery with the inner wall of casing **17**. Valves **26** are then opened by suitable operation of control means **27** from the earth's surface, thereby putting each chamber or cell of the tool into communication with that portion of the formation which it spans and allowing the well fluids produced therefrom to enter the corersponding chamber. After a measured period of time, valves **26** are closed, the

tool is withdrawn from the bore, and each chamber or cell is examined for the quantity and nature of its contents. From these data, plus the dimensions of the tool and the location of tool support **20**, there can be calculated the location of the various strata spanned by the tool, the nature of the fluids produced thereby, and the rate at which such fluids are produced therefrom. For example, in Figure 1, let it be assumed that tool support **20** is positioned at a depth of 1600′ and that each cell is 1′ high. Let it further be assumed that after valves **26** have been opened to allow well fluids to flow into the tool and then closed and the tool withdrawn from the bore the contents of the cells (numbering from the top) are as follows:

Cell No.	Contents
1	Brine
2	Oil
3	Oil
4	Oil-brine
5	Brine

As will readily be seen, this information indicates that at 1595–1596 feet there occurs one or more brine-producing strata; at 1596–1598 feet there occurs one or more oil-bearing strata; at 1598–1599 feet there occur both oil- and brine-bearing strata; and at 1595–1600 feet there occurs one or more brine-bearing strata. It will be understood that the foregoing condsiderations are illustrative only, and do not necessarily represent the conditions in an actual producing formation; usually the production interval extends over a much greater length of the well bore and the tool employed will provide for considerably more than five cells.

Referring now to Figure 2, which illustrates one specific embodiment of the invention, the device therein shown consists of a central longitudinal conduit **30** which may be provided with means, not shown, for coupling to a well tubing string. Separators **31** are positioned along the length of conduit **30** in spaced pairs, the uppermost separator being welded or otherwise affixed to conduit **30**, as at **32**, but the remaining separators being free to slide along conduit **30**. The lowermost of separators **31** is retained on conduit **30** by a pin or other clamping means **33** which holds the entire assembly together while the tool is being lowered into the well casing. Each separator **31** conveniently takes the form of a flat disc having a center hole corresponding closely to the diameter of conduit **30** and having a diameter somewhat less, say ½″, than that of the internal diameter of the well casing in which the tool is to be employed. The latter is indicated by dotted lines **34**. A resilient sealing means **35**, in the form of a flat disc having a center hole closely corresponding to the outside diameter of conduit **30** and a diameter corresponding closely to the inside diameter of casing **34**, occupies the space between each two separators which constitute a pair. Each pair of separators **31** is separated, one pair from the other, by a cylindrical shell or tube **36** which is of substantially the same outside diameter as that of separators **31** and which engages opposed separators **31**. Preferably the edges of shells **36** and the faces of separators **31** are machined so that a fluid-tight seal is formed upon mere frictional engagement, thereby simplifying assembly and disassembly of the device, but if desired shells **36** may be positively sealed to separators **31**, as by welding. Each of shells **36** is provided with a lateral perforation **37**, and conduit **30** is provided with a similar perforation **38** between each pair of separators **31** As will readily be seen, the tool illustrated by Figure 2 consists of a longitudinal stack of isolated cells, each of which is defined by imperforate end portions constituted by opposed separators **31**, an outside wall constituted by shell **36** perforated at **37**, and an inside wall constituted by a portion of conduit **30** perforated at **38**, and each separated from its adjacent cell by resilient sealing means **35** in the form of a septum. Within each cell, conduits **39** and **40** are in register with perforations **38** and **37**, respectively, and lead to a double solenoid valve **41**. The latter is provided with ports **42**, **42***a*, **43**, and **43***a*, and is operated by electric energy supplied through conductor **44** which passes through the wall of conduit **30** via seal **45** and runs to switching means and a source of electrical energy located at the earth's surface. As is hereinafter more fully explained, operation of valves **41** places the interior of conduit **30** in communication with each of the cells via conduits **39** and ports **43** and **43***a*, and also places each cell in communication with the well bore via conduits **40** and ports **42** and **42***a*.

Also positioned within each cell is a telemetering device **46** for transmitting data to the earth's surface via electrical conductor **47**. Such device may take the form of a pressure tap or thermocouple to permit determining the pressure or temperature of the contents of each cell while the tool is positioned in the bore hole. The construction of such devices is well known in the art of bore hole measuring and testing. If desired, telemetering device **46** may be replaced by a recording thermometer or presure gauge in which the data are recorded on a chart driven by a clockwork or other timing mechanism.

Figure 3 illustrates the tool of Figure 2 positioned within a well bore. Tool support **48** is welded or otherwise affixed to the inside of well casing **34** which has been perforated as at **49**, and the device of Figure 2 has been run down the casing until the lowermost of separators **31** rests on support **48**. When the full weight of the tool and/or the tubing to which it is coupled rests on support **48**, resilient sealing means are compressed and expand laterally to form fluid-tight seals with well casing **34**, as at **49***a*. Thus, the well bore is divided laterally into a plurality of isolated cylindrical chambers of relatively short length, and the total flow of fluid from the strata spanned by the tool is subdivided into separate streams. When valves **41** are opened each stream of fluid enters a separate chamber of the tool via perforations **49** and **37**, conduit **40**, valve **41**, and ports **42** and **42***a*, driving out the air through port **43***a*, valve **41**, and conduit **39** into conduit **30**. The pressure and temperature of each stream of fluid is simultaneously taken by means of telemetering device or recording gauge **46**. As has been previously explained, valves **41** are subsequently closed and the tool is raised to the earth's surface where an examination of the contents of each chamber will establish the nature thereof and the rate at which it flowed into the tool. The location of each fluid stream with respect to the position of tool support **48** is readily determined from the dimensions of the particular tool.

Figure 4, to which reference is now made, illustrates one form which the solenoid valve **41** of Figure 2 may take. Said valve (shown in open position) consists of a hollow body portion **50** having an internal wall **51** dividing its interior into two chambers **52** and **53**. Each chamber communicates with the exterior via ports **42**, **42***a*, **43** and **43***a*. Within each chamber, a valve core **56** provided with an upwardly extending valve stem **57** is free to reciprocate in a vertical direction. The length of core **56** is such that at the lower limit of its travel it covers ports **42** and **43**, and its diameter is such as to form a fluid-tight fit with the walls of the chamber in which it is contained. If desired, packing rings (not shown) may be employed to insure such a fit. A hollow solenoid coil **58** is mounted in the upper part of each chamber in such manner that valve stem **57** is pulled upwardly by the magnetic field generated when the solenoid coil is energized. Conductors **59** supply electrical energy to solenoid coils **58** from an exterior source, not shown, and may be so connected through switching means that both of coils **58** can be energized separately or together. As will be apparent, when coils **58** are energized, cores **56** are pulled upwardly, as shown, thereby placing port **43** in communication with port **43***a* and port **42** in communication with port **42***a*. Accordingly, when valves **41** are connected

as shown in Figure 2 and solenoid coils **58** are energized, well fluids can enter the chamber of the tool via perforations **37**, conduits **40**, ports **42**, chambers **53** and ports **42***a*, while displacing air from the chamber into conduit **30** via ports **43***a*, chambers **52**, ports **43**, conduits **39**, and perforations **38**.

Figure 5, to which reference is now made, represents another form which the device of the invention may take. Central longitudinal conduit **60** carries conical wedges or cams **61** having their apexes directed downwardly spaced at intervals along its length. Said wedges may be integral with conduit **60**, as shown, or may take the form of conical collars affixed to conduit **60**, as by welding. Resilient sealing means **62** take the form of relatively thick circular discs having a diameter slightly less than the diameter of perforated well casing **63** in which the device is employed, and being provided with a central hole having a diameter slightly larger than the outside diameter of conduit **60**. Each of sealing means **62** is mounted on conduit **60** immediately below each of wedges **61** so that the apex of the latter is in register with the central hole of sealing means **62**. Cylindrical shells **64** having a diameter slightly less than that of sealing means **62** and having a perforation **65** extending laterally through their walls extend between the opposed faces of adjacent sealing means **62**, and register in peripheral grooves **66** cut in the faces of sealing means **62**. Bottom plate **67** is affixed at the lower end of conduit **60**, as by welding at **68**, and serves as clamping means to hold the assembly together. Perforations **69** extend laterally through the walls of conduit **60** between wedges **61**. The device of Figure 5 thus takes the form of a series of isolated fluid-tight cylindrical chambers strung along the length of conduit **60**, each of said chambers being defined by the opposed faces of adjacent sealing means **62**, the inner wall of shell **64**, and the outer wall of conduit **60**. Within each of said chambers flexible conduits **70** and **71** are in register with perforations **65** and **69** respectively, and extend therefrom to a valve **72** which is operated by a clockwork mechanism **73**. Valve **72** is of such construction that when opened it places conduits **70** and **71** in communication with the interior of the chamber. Also positioned within each of the chambers is a recording gauge **74** of the type in which data such as temperature and pressure are picked up by a sensing element and recorded on a clockwork-driven chart.

In employing the device of Figure 5, the assembly is lowered into the well bore until bottom plate **67** rests on tool support **75** which has previously been affixed to the inside of casing **63** at the desired depth. Conduit **60** is then moved downwardly with respect to sealing means **62** and shells **64**, said movement being effected either by the force of gravity acting on conduit **60** and/or tubing string to which it is attached at its upper end, or by a positively applied pressure. Said downward movement forces wedges **61** into the center hole of sealing means **62**, thereby causing the latter to expand laterally and contact well casing **63** at their peripheries to form fluid-tight seals therewith. The casing is thus divided vertically into a series of chambers, each of which is in communication with the strata traversed by the casing via the perforation therein, and the flow of fluids from the formation is caused to be subdivided by horizontal planes into a number of streams. When valves **72** are opened each of said streams flows into one or more of the chambers of the tool and upon subsequent closing of valves **72** and withdrawing the tool from the casing by a lifting force applied to conduit **60** the contents of each chamber can be examined as to quantity and identity. Also upon withdrawal of the tool the physical conditions under which the fluid sample was obtained can be ascertained by examining the chart of recording gauge **74**. As will readily be apparent, wedges **61** may be tapered upwardly and the central holes of sealing means **62** so in register therewith that the lateral expansion of the sealing means is effected by raising conduit **60** and attached wedges **61** with respect thereto.

Referring now to Figure 6, there is there shown a form of device in which hydraulic or pneumatic means are employed to seal off the bore hole into a plurality of chambers. Longitudinal conduit **80** has separators **81** rigidly affixed along its length inspaced pairs. A cylindrical shell **82** having a perforation **83** extending through its walls extends between adjacent pairs of separators **81** and forms fluid-tight seals therewith at its upper and lower edges. Sealing means **84** occupy the space between each two separators **81** which together constitute one of said spaced pairs, and takes the form of a flat inflatable hollow disc having relatively thin walls constructed of a resilient material such as rubber. The outer diameter of sealing means **84** in a deflated condition is somewhat less than the inner diameter of well casing **85** in which the tool is to be employed. Each of said sealing means has a center hole through which conduit **80** extends and is sealed to conduit **80** at the edges of said hole. Each sealing means thus resembles a tubeless automotive pneumatic tire mounted on conduit **80** between each two separators **81** which form a pair. Hydraulic or pneumatic line **86**, which is connected with a source of gas or liquid pressure, not shown, runs substantially parallel to conduit **80** and communicates via ports **87** to the hollow interior of each of sealing means **84**. Conduit **88**, in register with perforation **83** leads to the inlet port of solenoid valve **89** which operates upon being energized by a current of electricity supplied through conductor **90**. The outlet port of valve **89** communicates with recording flowmeter **91** via conduit **92**, and outlet **93** of flowmeter **91** opens into the interior of the tool. By energizing solenoid valve **89** that portion of the well bore between adjacent sealing means **84** is placed into communication via flowmeter **89** with the chamber of the tool lying between adjacent sealing means **84**, and the rate of flow of fluid into such portion of the bore hole is recorded by flowmeter **89**. A small weephole **94** is provided in conduit **86** to permit air to be displaced from the chamber as the fluid flows thereinto. In employing the device of Figure 6, it is positioned in casing **85** as previously described and gas or fluid pressure is applied to line **86**, thereby inflating sealing means **84** and causing them to expand laterally to meet and form fluid-tight seals with the inside wall of casing **85** at their peripheries. The fluid samples are then obtained by operating valves **89** as previously described.

As will be apparent to those skilled in the mechanical arts, many modifications other than those explained above may be made without departing from the scope of the invention. Thus, any of a wide variety of remotely or automatically controlled valves may be employed as the means of placing the separate chambers of the tool into communication with the bore hole in which the tool is placed. Similarly, any of a wide variety of instruments may be employed within each chamber to detect and transmit or record any desired physical condition therein. Also, while the central supporting member of the tool has been shown and described as a conduit which is coupled to the well tubing string, such element may be a solid body member provided with means for attaching it to a cable for lowering into the well bore. The tool may be employed simply as a sampling device, i. e., as a device for entrapping samples of the fluids produced by the strata spanned by the device and raising such samples to the surface, or it may be employed as a logging or testing device by positioning any of a variety of recording or remote-indicating instruments within any or all of the chambers comprised by the device. Thus, by providing a flowmeter, a pressure tap and a thermocouple in each such chamber, the permeability of the strata spanned thereby may be determined in situ. Usually, the measurements are taken dynamically, i. e., after allowing the well to flow through the device until equilibrium conditions have become established and during such equilibrium flow. If desired, there may be provided a small

by-pass conduit extending through each chamber of the tool through which flow may be initiated to establish equilibrium flow conditions prior to taking a fluid sample and/or taking data with respect to rate of fluid flow, pressure, temperature etc. In essence, the invention consists of a well fluid sampling tool comprising an elongated body member, a plurality of resilient fluid-tight sealing members coaxially spaced along the length of the body member and capable of being laterally expanded to form fluid tight seals at their peripheries with the walls of a well casing, means for so expanding said sealing members, a plurality of outer shells extending between adjacent sealing members, and controllable means for placing each of the chambers defined by adjacent sealing means, one of said shells and said body member into communication with the well bore in which the tool is employed.

Other modes of applying the principle of my invention may be employed instead of those explained, change being made as regards the means or elements employed, provided the apparatus stated by any of the following claims, or the equivalent of such stated apparatus, be produced.

We, therefore, particularly point out and distinctly claim as our invention:

1. A well fluid sampling device comprising, in combination, an elongated body member; a plurality of resilient fluid-tight sealing members coaxially spaced along the length of said body member in fluid-tight relationship therewith, each of said sealing members having a normal diameter less than that of the well bore in which the device is employed but capable of lateral expansion to form a fluid-tight seal at its periphery with the walls of said bore; means for so expanding said sealing members; tubular members extending between adjacent sealing means and registering therewith in fluid-tight relationship, each of said tubular members being coaxially positioned around said body member and having an internal diameter substantially larger than the diameter of said body member and an external diameter less than that of said sealing members with which it is in register; and controllable valve means in register with perforations in said tubular members for establishing and disestablishing communication between the exterior of the device and the annular spaces between said tubular members and said body member.

2. A device as defined in claim 1 wherein said valve means are electrically controlled from the earth's surface.

3. A device as defined in claim 1 wherein means for detecting and recording physical conditions within said annular spaces are positioned therein.

4. A device as defined in claim 1 wherein means for detecting physical conditions within said annular spaces and means for transmitting the detected information to the earth's surface are positioned within said annular spaces.

5. A well fluid sampling device comprising, in combination, a longitudinal central conduit; a plurality of resilient fluid-tight sealing members coaxially spaced along the outside of said conduit in fluid-tight relationship therewith, each of said sealing members having a normal diameter less than that of the well bore in which the device is employed but capable of lateral expansion to form a fluid-tight seal at its periphery with the walls of said bore; means for so expanding said sealing members; tubular members extending between adjacent sealing means and registering therewith in fluid-tight relationship, each of said tubular members being coaxially positioned around said central conduit and having an inside diameter substantially larger than the outside diameter of said central conduit and an outside diameter less than that of said sealing members with which it is in register, thereby forming a plurality of annular chambers defined by the opposed faces of adjacent sealing means, the inside wall of said tubular member and the outside surface of said central conduit; and controllable valve means in register with perforations in said tubular member and said central conduit for establishing and disestablishing communication between the exterior of the device and said annular chambers and between said central conduit and said annular chambers.

6. A device as defined in claim 5 wherein said valve means are electrically controlled from the earth's surface.

7. A device as defined in claim 5 wherein means for detecting and recording physical conditions within said annular chambers are positioned therein.

8. A device as defined in claim 5 wherein means for detecting pressure within said annular chambers are positioned therein.

9. A device as defined in claim 1 wherein means for detecting the rate of fluid flow through said valve means are positioned within said annular chambers.

10. A well fluid sampling device comprising, in combination, a longitudinal central conduit; a plurality of resilient fluid-tight sealing members coaxially spaced along the outside of said conduit in fluid-tight relationship therewith, each of said sealing members having a normal diameter less than that of the well bore in which the device is employed but capable of lateral expansion to form a fluid-tight seal at its periphery with the walls of said bore; relatively rigid disc-like members having a diameter less than that of said well bore coaxially mounted on said central conduit immediately above and below each of said sealing members to minimize longitudinal expansion thereof; means for laterally expanding said sealing members; tubular members extending between adjacent sealing members and registering therewith in fluid-tight relationship, each of said tubular members being coaxially positioned around said central conduit and having an inside diameter substantially larger than the outside diameter of said central conduit and an outside diameter less than that of said sealing means with which it is in register, whereby there is formed a plurality of annular chambers each of which is defined by the opposed faces of adjacent sealing members, the inside wall of one of said tubular members and the outside surface of said central conduit; and controllable valve means in register with perforations in said tubular members and said central conduit for establishing and disestablishing communication between the exterior of the device and said annular chambers and between said central conduit and said annular chambers.

11. A device as defined in claim 10 wherein said valve means are electrically controlled from the earth's surface.

12. A device as defined in claim 10 including means for detecting and recording physical conditions within said annular chamber.

13. A device as defined in claim 10 including means for detecting and recording the pressure within each of said annular chambers.

14. A device as defined in claim 10 including means for detecting and recording the rate of fluid flow through said valve means from the exterior of the device into each of said annular chambers.

15. A device as defined in claim 10 wherein each of said sealing members is a hollow inflatable member, the diameter of which when deflated is less than that of the well bore in which the device is employed but such that upon inflation said sealing members engage the wall of said well bore to form fluid-tight seals therewith; and including means for inflating said sealing members.

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