Dec. 1, 1959 M. P. LEBOURG 2,915,123

FORMATION FLUID SAMPLERS

Filed Aug. 17, 1955 2 Sheets-Sheet 1

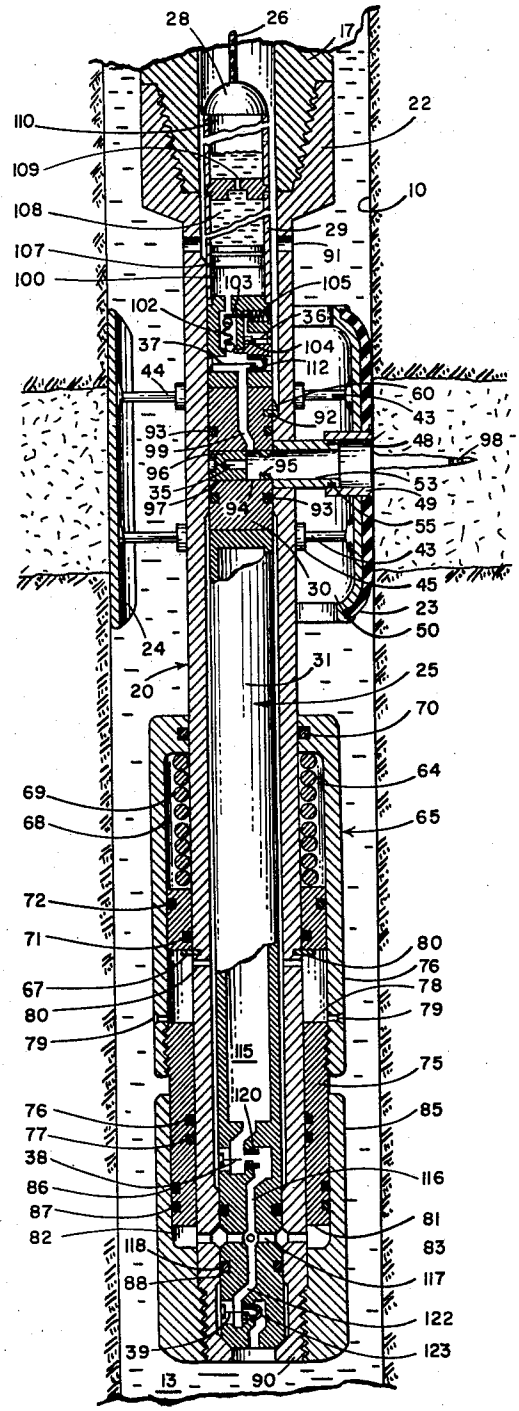


Fig. 5

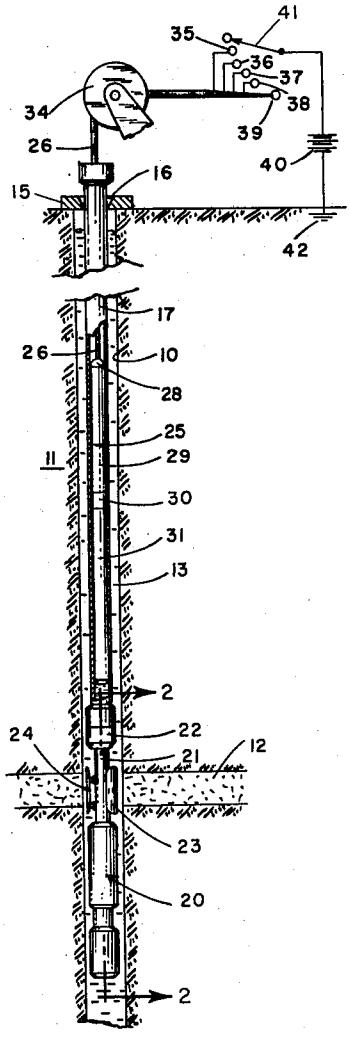


Fig. 1

INVENTOR.
MAURICE P. LEBOURG.

BY William R. Sherman

HIS ATTORNEY.

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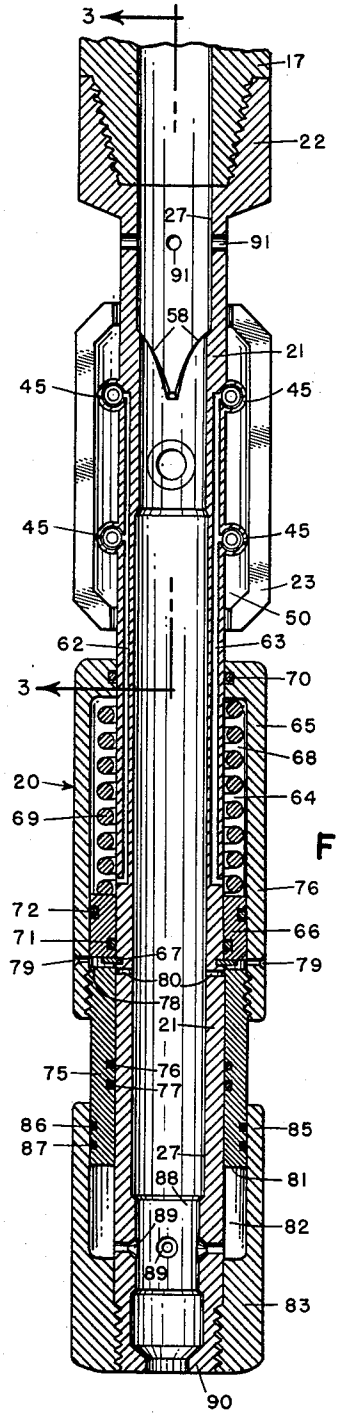


Fig. 2

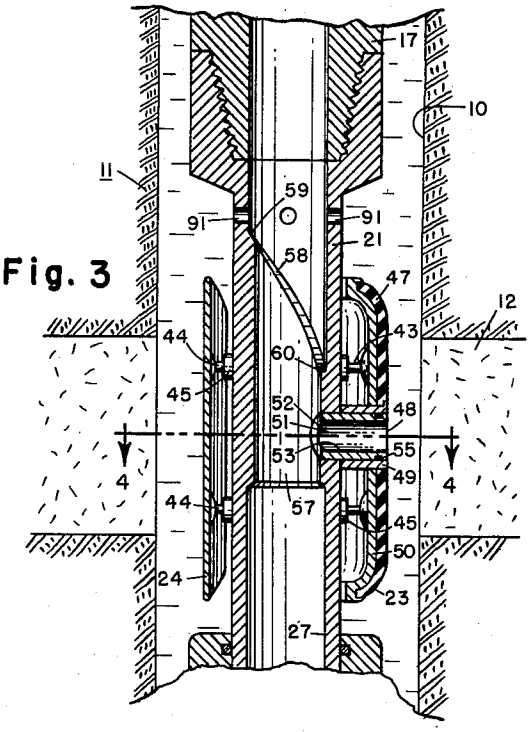


Fig. 3

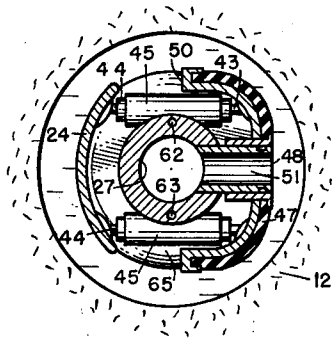


Fig. 4

INVENTOR.
MAURICE P. LEBOURG
BY William P. Sherman
HIS ATTORNEY

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2,915,123

FORMATION FLUID SAMPLERS

Maurice P. Lebourg, Houston, Tex., assignor, by mesne assignments, to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Application August 17, 1955, Serial No. 528,882

11 Claims. (Cl. 166—63)

This invention relates to fluid samplers and more particularly to apparatus for obtaining samples of the fluid content of formations traversed by a bore hole.

In present practice, a sample of fluid contained in a formation beneath the surface of the earth may be obtained by packing off a portion of a bore hole opposite the formation. Thereafter, formation fluids are withdrawn into the packed-off portion to provide a sample which may be brought to the surface for examination and study. In uncased bore holes, fluid samples are commonly obtained with so-called "drill stem testers." Such testers generally employ one or more annular packers to isolate a zone to be tested and include a valve for admitting fluid samples into the drill stem or drill pipe after setting of the packer or packers. When closed, the valve serves to exclude from the drill stem weighting liquids such as drilling muds with which a bore hole is normally loaded to overcome formation pressures. The drill pipe thus serves as a large reservoir at a low pressure such as atmospheric pressure for receiving a fluid sample when the valve is opened. After a sample has been taken, it is generally necessary to release the packers and remove the drill pipe from the bore hole before another sample may be taken.

Because considerable time and effort is required in moving and in resetting drill pipe in a bore hole, presently used drill stem testers, which have to be brought back to the surface after each test, are not well adapted for taking successive samples although a plurality of samples at varying depths may commonly be desired. As samples are withdrawn into the drill pipe, the low pressure which is encountered induces a phase separation, that is, a separation of gases present in the sample from liquids therein. Not only does this alter the character of the sample, but also it frustrates an accurate measurement of formation fluid pressures. Frequently, an imperfect seal of the packers will result from irregularities of the bore hole wall, allowing drilling mud to contaminate the sample obtained. A further disadvantage is encountered in the use of present-day drill stem testers in that circulation of drilling mud through the bore hole must be interrupted during the entire course of a fluid sampling operation. Thus, the drill pipe, rather than being supplied with drilling mud, is closed off from the drilling mud by means of the usual valve. In bore holes in which drilling mud is adversely affected, such as those having salt water inflow or excessive mud cake formation, a conventional drill stem sampling operation may be so risky to undertake that the safer course is to proceed without securing a sample from a promising zone.

It is an object of the present invention, accordingly, to provide new and improved apparatus for obtaining samples of formation fluids in a highly advantageous and effective manner.

Another object of the invention is to provide new and improved apparatus for obtaining successive samples of formation fluids without requiring removal of drill pipe from a bore hole after each sampling operation.

Another object of the invention is to provide new and improved apparatus for obtaining samples of the liquids or gases contained in a formation and maintaining the samples at substantially formation pressure to permit accurate analysis and pressure measurement.

A further object of the invention is to provide new and improved fluid sampling apparatus by which a restricted region of a bore hole wall may be packed off in a highly effective manner to exclude drilling mud or other well liquid from the sample obtained.

Yet another object of the invention is to provide new and improved apparatus for obtaining a formation fluid sample without precluding circulation of drilling mud through drill pipe used in the sampling operation.

Still another object of the invention is to provide new and improved apparatus for obtaining formation fluid samples by a remote operation from the surface without requiring manipulation of the drill pipe for packing off a portion of the bore hole wall.

Yet a further object is to provide new and improved fluid sampling apparatus of the drill-stem type whereby a selected formation may be perforated to promote recovery of a sample.

These and other objects are attained, in accordance with the invention, by coupling a pack-off section of fluid sampling apparatus to a string of pipe for positioning in a bore hole and lowering into the pack-off section a retrievable sampling tool. On the side of the pack-off section, a pack-off shoe is mounted for movement into sealing engagement with a selected formation. An actuator carried by the pack-off section serves to force the shoe outwardly, preferably, in response to a pressure differential between the high pressure drilling liquid in the bore hole and fluid contained in a low pressure chamber within the sampling tool. For withdrawal of formation fluids, an open channel connects an inlet in the face of the pack-off shoe with the bore of the pack-off section. A sample receiving chamber in the sampling tool communicates with the open channel via a gun bore which is alined with the open channel. Communication is first effected between the low pressure chamber and the hydraulic actuator to force the pack-off shoe into sealing engagement with the selected formation. An explosive charge is then ignited in the gun bore of the sampling tool to perforate the formation opposite the open channel. The sample receiving chamber in the sampling tool is thereby placed in fluid communication with the interior of the selected formation. Inflow of formation fluids is at a rate governed by an hydraulic cushioning device contained in the sample receiving chamber. After an interval the sample chamber is closed and the pressure differential across the hydraulic actuator is relieved, permitting withdrawal of the sampling tool to the surface. Without withdrawing the drill pipe from the bore hole, the pack-off shoe may be set opposite successively selected formations and the sampling tool run in and out of the drill pipe to obtain samples in the foregoing manner. After any sampling operation, the drill pipe may be withdrawn.

Additional objects and advantages of the invention will become apparent from the following detailed description of a representative embodiment thereof, taken in conjunction with the accompanying drawings in which:

Fig. 1 is an elevational view of fluid sampling apparatus in accordance with the invention, a portion of the drill pipe above the pack-off section being cut away to show the sampling tool being lowered therethrough;

Fig. 2 is a cross-sectional view of the pack-off section of Fig. 1 taken along the line 2—2 thereof;

Fig. 3 is a cross-section view taken along the line 3—3 of Fig. 2 and illustrating the pack-off shoe in its retracted position;

Fig. 4 is a cross-sectional view taken along the line 4—4 of Fig. 3; and

Fig. 5 is an elevational view of fluid sampling apparatus in accordance with the invention with the pack-off section shown in cross section, the pack-off shoe shown in its extended position, and the sampling tool shown partially in section with portions thereof cut away for convenience of illustration.

In the figures, like reference numerals are employed to designate similar elements.

In Fig. 1 there is shown a bore hole **10** extending downwardly from the surface of the earth to traverse earth formations **11** including a selected formation **12** from which a fluid sample is desired. As a recovery of fluid samples generally is desired during drilling operations, the bore hole and associated equipment are illustrated in a manner typical of drilling conditions. Thus, in an exemplary application of the invention, the bore hole **11** may be uncased, although the invention may be used with bore holes in which a casing has been set. A weighting fluid **13**, such as a drilling fluid, is contained within the bore hole **10** to provide a hydrostatic pressure opposite the formations overcoming the formation pressure therewithin. The drilling fluid **13** is so constituted that, opposite a permeable formation, a so-called "mud cake" is deposited on the bore hole wall as filtrate from the drilling fluid flows into such formation. In order to obtain a representative sample of the fluid content of permeable formations, this mud cake generally must be penetrated.

Suspended in the bore hole **10** from a rotary table **15** in which slips **16** are set is a string of pipe **17** which may comprise coupled joints of drill pipe. Other portions of a drilling rig which are commonly used in a drilling operation are not shown, being unnessary to an understanding of the invention. It may be noted, however, that a drilling rig generally comprises hoisting equipment for raising and lowering the drill pipe and a system for circulating drilling fluids down the drill pipe and upwardly through the annulus thereabout.

In accordance with the invention, there is coupled to the bottom joint of drill pipe **17** a pack-off section **20**. The pack-off section **20** comprises a tubular body **21** for continuing the bore of the drill string, a threaded "box" or coupling **22** being provided at the upper end of the body **21** for connection with the bottom joint of the drill pipe. On the side of the body **21** is carried a pack-off shoe **23** in a normally retracted position and a similarly retracted back-up plate **24** for extension in opposite directions against the bore hole wall.

In order that successive samples may be taken without necessitating successive removals of the drill pipe from the bore hole, a sampling tool **25** is provided which may be lowered by an electric cable **26** into the bore **27** of the pack-off section **20**. The housing of the sampling tool **25** is accordingly cylindrical and, for convenience in handling, includes separate subassemblies which may conveniently be coupled together by the usual threaded connections. Thus, the housing is divided into a cable head **28**, a sample receiving section **29**, a gun section **30**, and low pressure section **31**.

To introduce and to remove the sampling tool **25** from the pack-off section **20**, the electric cable **26** which supports the tool is spooled on a winch **34** at the surface. Cable **26** may be a conventional insulated multiconductor type, including a plurality of insulated conductors **35**, **36**, **37**, **38**, and **39**. These conductors **35–39** may be connected through conventional slip-rings mounted on the winch **34** selectively to a current source such as a battery **40**, by means of a switch **41**, a ground return **42** being provided.

As seen in Figs. 2–4, the pack-off shoe **23** and back-up plate **24** of the pack-off section **20** are mounted on oppositely extending shafts **43** and **44**, respectively, of hydraulic power cylinders **45**. There may be four such power cylinders **45** mounted on the tubular body **21** of the pack-off section with their axes transverse to the axis of the body **21**. The power cylinders **45** are thus arranged for exerting radial outward thrust simultaneously upon the pack-off shoe **23** and the back-up plate **24** to force them into engagement with opposite portions of the bore hole wall. The back-up plate **24** may simply be a rigid, cylindrically contoured member to provide a bearing surface for the exertion of a high thrust upon the pack-off shoe **23**. This thrust is imposed upon the pack-off shoe **23** to effect a seal between its face and the bore hole wall.

In order that the seal may be perfected despite irregularities in the bore hole wall, the pack-off shoe **23** is preferably faced with a sheet **47** of flexible material such as rubber in the manner taught in copending application Serial No. 418,650 filed March 29, 1955, now Patent Number 2,821,256, by Harry B. Boller and assigned to the assignee hereof. Considering a projection of the sheet or face **47** on a plane transverse to its direction of movement, its configuration is generally oval so as to extend on all sides about a center aperture **48** serving as an inlet for formation fluids. The aperture **48** is defined by a sleeve **49** extending through the pack-off shoe **23** and secured to a rigid curved plate **50** underlying the flexible sheet **47** and coextensive therewith. The plate **50** together with the sleeve **49** serves to position the flexible face sheet **47** about the inlet **48** for sealing engagement with the bore hole wall. The shafts **43** of the power cylinders **45** are secured to the plate **50** for transmission of their thrust to the flexible face sheet **47**.

A straight, open channel **51** (see Fig. 3) extending radially from the inlet **48** inwardly to a port **52** in the bore **27** of pack-off section **20** is provided by tubular barrel **53** fastened, as by threading, in the body **21**. The tubular barrel **53** is sized to receive the sleeve **49** telescopically thereabout, a seal ring **55** being carried by the barrel **53** toward its outer end for sealing engagement with the inner wall of sleeve **49**. The open radial channel **51** provided by the barrel **53** and sleeve **49** is seen to be extensible by an outward movement of the pack-off shoe **23** so as always to terminate at inlet **48** in the plane of the face **47**. At the inner terminus of the radial channel **51**, the bore **27** of the body **21** is offset inwardly to define an annular nipple portion **57** extending above and below the port **52**. The upper edge **58** of the nipple portion **57** is contoured to define a cam surface having an apex **59** removed by 180° from a dwell **60** spaced in axial alignment with the port **52**. As will be explained more fully hereafter, the camming edge **58** serves to aline the sampling tool **25** with respect to the channel **51**.

The power cylinders **45** are paired on either side of the body **21** for communication through longitudinally extending conduits **62**, **63** in the body **21** with an actuating chamber **64**. The inner wall of the chamber **64** is defined by the body **21**, its upper and outer walls being defined by a setting sleeve **65** and its lower wall defined by a collar **66**. As the setting sleeve **65** is slidable longitudinally about the body **21**, while the collar **66** is secured against relative movement by a split ring **67** received in the body **21**, the chamber **64** has a variable, annular volume. To communicate forces applied by the setting sleeve **65** through the power cylinders **45** to the pack-off shoe **23** and back-up plate **24**, the chamber **64**, the conduits **62**, **63** and the power cylinders **45** are completely filled with an incompressible liquid, such as a suitable hydraulic oil. Thus, when downward movement of the setting sleeve **65** causes the chamber **64** to contract, the shafts **43**, **44** of the power cylinders **45** are thrust outwardly to force the flexible face **47** of the pack-off shoe **23** into pressure engagement with the bore hole wall. However, the pack-off shoe **23** and also the back-up plate **24** are normally held in a retracted posi-

tion by the force of ambient pressure overcoming the pressure within the power cylinders 45. The pressure in the power cylinders is reduced by suitable biasing means such as a coil spring 69 within the chamber 64 acting between the collar 66 and the setting sleeve 65 to expand the chamber 64. To prevent an escape of hydraulic liquid 68 from the chamber 64, the setting sleeve 65 carries an O-ring 70 for sealing engagement with the body 21, while the collar 66 carries O-rings 71, 72 in sealing engagement respectively, with the body 21 and the setting sleeve 65.

The setting sleeve 65 includes a piston portion 75 of annular configuration coupled as by a threaded connection to portion 76 defining the chamber 64. The piston portion 75 is slidably fitted about the body 21 and carries O-rings 76, 77 for sealing therewith. While the upper face 78 of the piston portion 75 is exposed to the pressure of drilling fluid 13 communicated through ports 79 in the sleeve portion 76 and ports 80 in the body 21, the lower face 81 of the piston portion 75 is exposed to the pressure in an annular piston chamber 82 in which a pressure different from the drilling fluid pressure may be established. The annular chamber 82 is defined by the outer wall of the body 21, the fixed interior walls of a bell-like collar 83 and the movable face 81 of the piston portion 75. The bell-like collar 83 may have a fluid-tight, threaded connection with the body 21 at its lower terminus, an axial flange portion 85 of the collar 83 extending upwardly in spaced relation to the body 21 for sealing engagement with O-rings 86, 87 carried by the piston portion 75. Inwardly offset from the bore 27 of the body 21 is a lower nipple portion 88 having ports 89 therein communicating with the annular chamber 82.

At the bottom end of the body 21 an annular shoulder 90 extends inwardly to form a stop for arresting downward travel of the sampling tool 25. When the sampling tool is received in the bore 27 of the body 21, seals are perfected between the tool and each of the nipple portions 57, 88, in a manner hereafter described. In order to provide for a circulation of drilling fluid, when such seals are perfected, by-pass ports 91 through the body 21 are located immediately above the upper nipple portion 57.

Turning now to Fig. 5, the sampling tool 25 is shown within the bore 27 of pack off section 20, engaged against the stop 90. As illustrated, the fluid sampling apparatus is conditioned for entry of fluids from the formation 12 into the sample containing section 29. Whereas the stop 90 serves to position the sampling tool 25 vertically in the pack-off section 20, a pin 92 carried by the gun section 30 has a slight outward extension to engage the camming edge 58 angularly to position the sampling tool relative to the pack-off section. Pin 92 is thus engaged in the dwell 60. Between a pair of O rings 93 carried by the gun section below the pin 92 is the opening of a gun bore 94 extending transversely through the gun section 30. This opening is normally sealed with a frangible plug 95 which is capable of resisting the hydrostatic pressure in the bore hole. To the rear of the plug 95 within the bore 94 is a removable perforating unit 96 which may comprise a breech 97 threaded in bore 94, a projectile 98 directed axially of the bore 94 toward the plug 95, and a suitable explosive charge and electrical igniter (not shown). Insulated conductor 35 connects with one side of the igniter, the other side being grounded. As shown in Fig. 5, the pin 92 serves to aline the gun bore 94 with the open channel 51 extending through the pack-off shoe 23 so that the projectile 98 when fired from the breech 97 may rupture the plug 95 and pass through the channel and into the adjacent formation 12 to a position such as that illustrated. When the frangible plug 95 is broken, the gun bore 94 provides a communication for formation fluids to a passage

99 extending upwardly therefrom into the sample receiving section 29.

While the sample receiving section 29 of the sampling tool 25 may have a variety of forms, conveniently an arrangement similar to that described in L. S. Chambers Patent No. 2,674,313 issued April 6, 1954, is employed. Thus, the passage 99 communicates with a sample receiving chamber 100 through a two-way ball-type check valve 102. Seating of the valve 102 against flow of formation fluids is normally prevented by a plunger-like detent 103. The valve 102 may be closed from the surface when desired by energizing insulated conductor 36 to ignite a small explosive charge 104, whereby to retract the detent 103 in opposition to a bias spring 105.

In order that formation fluids may be withdrawn while maintaining the generally high formation pressures, thereby to prevent phase separation of the fluids, a free piston 107 divides the chamber 100 into a lower portion communicating through the valve 102 with the formation and an upper portion containing an hydraulic liquid 108 which may slowly be forced through a constricted orifice 109 into a reservoir 110. The quantity of liquid 108 is sufficient to fill the volume between the piston 107 and the orifice 109 when the piston is in its lowermost position. Upward motion of the piston 107 is thus retarded to limit the expansion of formation fluids and consequent reduction in their pressure.

When the check valve 102 is closed against further inflow of fluid, it is desirable to increase the pressure within the passage 99, the bore 94 and the channel 51 to the hydrostatic pressure of drilling fluid 13 surrounding the pack-off shoe 23. Such equalization of pressures about the pack-off shoe 23 facilitates its retraction from the bore hole wall. To provide for pressure equalization, a communication between the passage 99 and the exterior of the sample receiving section 29 is provided which is normally blocked off by a frangible plug 112. This plug 112 is proximate to a small explosive charge which is adapted to be ignited by energization of the insulated conductor 37.

In the foregoing description of the pack-off section 20, development of an outward thrust upon the pack-off shoe 23 was stated to require a pressure differential across the piston portion 75 of the setting sleeve 65. Since the upper face 78 of the piston portion 75 is exposed to the hydrostatic pressure of drilling fluid 13, contraction of the actuating chamber 64 to produce the outward thrust requires the application of a low pressure to the lower face 81 of the piston portion 75. In order to provide the necessary pressure differential, the low pressure section 31 of the sampling tool 25 includes a low pressure chamber 115 which may be placed in selective communication with the piston chamber 82. The chamber 115 may, to this end, contain a suitable low pressure gas such as air at atmospheric pressure. To afford a fluid communication between the low pressure chamber 115 and the piston chamber 82, a passage 116 in the low pressure section extends from the low pressure reservoir 115 to side ports 117 positioned for registry with the ports 89 in the pack-off section 20 which communicates with the chamber 82. O rings 118 carried by the low pressure section above and below the side ports 117 seal with the nipple portion 88 to prevent intrusion of drilling liquid 13.

Prior to utilizing the low pressure in chamber 115 to establish a pressure differential, the passage 116 is blocked by a frangible plug 120, which is illustrated in its ruptured condition. Rupturing of the plug 120 may be accomplished remotely from the surface by energization of insulated conductor 38, an explosive charge and igniter (not shown) being located adjacent the plug 120 for this purpose.

When it is desired to equalize the pressure across piston portion 75 to enable retraction of the pack-off shoe 23 under the influence of bias spring 69, a passage 122 open-

ing at the bottom of the sampling tool to drilling fluid 13 therebeneath is unblocked. Like the passage 116, the passage 122 is normally blocked by a frangible plug 123 adjacent a small explosive charge and an igniter (not shown). Rupturing of the plug 123 is caused at the surface by energization of insulated conductor 39 leading to the igniter. This conductor 39 as well as conductors 35–38 are preferably disposed in a protected slot (not shown) spiraling around the sampling tool 25 up to the cable head 28.

In an exemplary operation of fluid sampling apparatus constructed in accordance with the invention, the pack-off section 20 is coupled to a suitable length of drill pipe 17 and lowered into the bore hole 10. By the action of biasing spring 69 in the actuating chamber 64, the pack-off shoe 23 and the back-up plate 24 are retained in a retracted position while the pack-off section 20 is lowered to a desired depth. Measurements may be taken in any suitable manner to ensure positioning of the pack-off shoe 23 opposite the selected formation 12, whereupon the drill pipe is held in position, as by setting slips 16 in the rotary table 15.

The sampling tool 25 is then lowered on the electric cable 26 with switch 41 in its opened position until the bottom end of the low pressure section 31 engages the stop or shoulder 90 in the bore 27 of the pack-off section 20. Since the cable 26 allows the sampling tool 25 to take any angular position as it is lowered into the pack-off section, alignment of the gun bore 94 of the gun section 30 with the barrel 53 is accomplished by engagement of the pin 92 with the sloping upper edge 58 of the nipple portion 57. Regardless of the original angular position of the sampling tool, the pin 92 will come to rest in the dwell 60 when the tool engages the shoulder 90. Accordingly, a proper alignment of bore 94 with barrel 53 for passage of projectile 98 is ensured. A sealed communication between the sampling tool and the pack-off section is then perfected at the nipple portions 57 and 88, respectively, by seal rings 93 and 118.

When the sampling tool 25 is thus received in the pack-off section 20, each of plugs 95, 112, 120 and 123 is unbroken and valve 102 is held open to entering fluids by detent 103. By force of gravity, the free piston 107 in the sample receiving chamber 100 is at its lowermost position. Switch 41 is first thrown to connect the current supply 40 with conductor 38, thereby to rupture the plug 120 by which the low pressure chamber 115 is sealed from communication with the piston chamber 82. The pressure acting upon the lower face 81 of the piston portion 75 is thereby reduced to the low pressure of gas contained in the low pressure chamber 115, yet the high hydrostatic pressure of drilling fluid 13 is still effective against the upper face 78 of the piston portion 75. By reason of this pressure differential, a very large force is developed resulting in downward movement of the setting sleeve 65 and consequent communication of force through the incompressible liquid 68 in actuating chamber 64 to the hydraulic cylinders 45. In this manner, outward forces pressing the pack-off shoe 23 against the bore hole wall have been developed on the order of many thousand pounds. Despite irregularities in the bore hole wall, therefore, the flexible face 47 of the pack-off shoe 23 provides a fluid tight seal about the inlet 48.

While in isolated instances formation fluids may be recovered without perforating the formation opposite the inlet 48, withdrawal of a satisfactory sample generally requires a penetration of the formation to an appreciable depth. Accordingly, the switch 41 is thrown to connect the current supply 40 with conductor 35, thereby to fire the perforating unit 96. In leaving the breech 97 projectile 98 first ruptures the plug 95, then passes through the barrel 53 and sleeve 49 to a depth in the formation 12 where it remains embedded. Behind the projectile 98 a passage is formed in the formation through which formation fluids may drain through the open channel 51 into the bore 94 and thence to passage 99 through check valve 102 into the sample receiving chamber 100. The initial fluid reaching the sample chamber 100 may be a small amount of drilling fluid 13 contained in the channel 51, this small amount serving to prevent expansion and phase separation during the initial withdrawal of formation fluids. Thereafter, the retarded rise of the free piston 107 precludes any phase separation.

After an interval has elapsed sufficient for obtaining a representative sample of formation fluid, the switch 41 is thrown to connect current supply 40 with conductor 36. Energization of conductor 36 ignites explosive charge 104 to retract the detent 103 allowing valve 102 to close against further entry of fluids into the sample receiving chamber 100. The next step in preparing the sampling tool for withdrawal from the pack-off section is the energization of the conductor 37 by a further throw of switch 41, thereby to rupture the plug 112, allowing drilling fluid 13 about the sample receiving section 29 to flow into the passage 99, thence through the bore 94 into the channel 51 to the exposed surface of formation 12. In this manner, the differential pressure existing by reason of the lower value of formation pressure relative to the hydrostatic pressure of drilling fluid 13 is removed, i.e., by pressure equalization. Thereupon, switch 41 is thrown into connection with conductor 39 to supply current for explosively rupturing the plug 123. With passage 122 no longer blocked, the drilling fluid 13 is free to pass through the sampling tool into piston chamber 82, thus to equalize pressures across the piston portion 75. Under the influence of biasing spring 69, the sleeve 65 is raised to its upper position, thereby to expand the chamber 64 and to relieve pressure from the liquid contained therein. The force of ambient pressure effectively acting on piston shafts 43, 44 then overcomes the pressure within the power cylinders 45 and the pack-off shoe 23 as well as the back-up plate 24 are restored to their retracted position. At the same time, the seal rings 118 and 93 carried by the sampling tool 25 are relieved of any pressure differential so that the sampling tool may more readily be withdrawn from the pack-off section 20. When the sampling tool is brought to the surface of the earth, the sample receiving section 29 may be completely removed from other portions of the tool for convenience in handling the sample of formation fluids. If a further sampling operation is to be undertaken at a different depth, the drill pipe 17 is moved to bring the pack-off section to the new depth and the sampling tool, after being restored to its initial condition, is lowered into the pack-off section.

Should a circulation of drilling fluid be necessary at any time during the course of sampling operation, such circulation may be established. When the sampling tool is not in the drill pipe, of course, the circulation may occur in the customary manner, the bore 27 of the pack-off section 20 providing a through passage for the drilling fluid. When the sampling tool is positioned in the pack-off section, on the other hand, drilling fluid may circulate about the sample receiving section and flow outwardly from the pack-off section through ports 91. If necessary, a riser may be coupled at the upper length of drill pipe receiving the cable 26 to avoid a loss of drilling fluid.

Noteworthy is the fact that the pack-off shoe is set and released and a sample recovered without requiring any manipulation of the drill pipe 17. Consequently, the face of the pack-off shoe 23 is not subjected to shearing forces which tend to reduce the life of the flexible sheet 47 and to destroy the effective seal provided between the face and the bore hole wall. Moreover, because of the generally oval configuration of the pack-off shoe face, the face is able to conform readily to irregularities in the bore hole wall. A good fluid seal may thus be perfected along the surface of the face radially of the inlet 48.

It will be understood that the illustrated embodiment

of the invention is subject to various modifications which are within the principles of the invention. Thus, to reduce the number of conductors in the electric cable **26**, switch **41** may be placed in the sampling tool and operated remotely in a manner shown, for example, in Fig. 11 of Patent No. 2,048,451, issued July 21, 1936. To permit use of a cable containing no conductors, such as a conventional wire line, a source of current may be placed in the sampling tool and a suitable switch advanced by a time clock mechanism may serve to successfully connect the described igniter circuits in a manner shown, for example, in Patent No. 2,252,270, issued August 12, 1951.

In instances where a drilling operation may be required in the course of sampling operations, a suitable drilling tool may be coupled to the lower end of the pack-off section **20**. For example, a reaming tool such as that shown in Patent No. 2,441,894 issued May 18, 1948, may be coupled beneath the pack-off section **20** to obtain a prescribed diameter for the bore hole **10**. While the pack-off section has been described as supported by drill pipe, production tubing or other conveniently available pipe may instead be employed. For setting the pack-off shoe, different actuating means may be employed such as means of the type employing a combustible fuel for generating a setting force.

In lieu of a perforating unit which fires a bullet, there may be used a jet perforating unit incorporating a shaped charge. For applications where the mud cake does not unduly inhibit recovery of a sample, the perforating unit may, of course, be omitted.

Accordingly, the invention is of a scope not limited to the illustrated embodiment but as defined in the appended claims.

I claim:

1. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a tubular body including means for coupling said body with a string of pipe to be lowered into a borehole; sealing means carried by said body adapted to move relative to said tubular body to engage and isolate a portion of the borehole wall; channel means opening upon the bore of said body and said sealing means to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; means carried by said body and responsive to a pressure differential for moving said sealing means into sealed engagement with the borehole wall; and a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, said passage means including a perforator bore, means for aligning said perforator bore with said barrel means, means in said perforator bore for perforating a formation adjacent to said sealing means, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said pressure responsive means to establish said pressure differential with respect to the pressure in the borehole.

2. In apparatus for sampling the fluid content of formations traversed by a bore hole, the combination as recited in claim 1 further comprising a frangible plug for closing said perforator bore, said means for aligning including cooperating means on the exterior of said sampling tool and in the bore of said body for angularly alining said perforator bore with said barrel.

3. In apparatus for sampling formations traversed by a borehole, the combination comprising: a tubular body including means for coupling said body with a string of pipe to be lowered into a borehole; sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall; channel means opening upon the bore of said body and said sealing means to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; means carried by said body and responsive to a pressure differential for moving said sealing means into sealed engagement with the borehole wall; and a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, said passage means including a perforator bore, means for aligning said perforator bore with said channel means, means in said perforator bore for perforating a formation adjacent said isolated wall portion to said sealing means, a frangible plug for normally closing said perforator bore, means for defining a low pressure chamber, means for defining a normally closed passage between said low pressure chamber and said pressure responsive means; and means for opening said last-mentioned passage to establish said pressure differential with respect to the pressure in the borehole.

4. In apparatus for sampling the fluid content of formations traversed by a borehole containing a weighting liquid, the combination comprising: a tubular body including means for coupling said body with a string of pipe to be lowered into a borehole; sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; said body being ported above said channel means to provide for circulation of said weighting liquid; means carried by said body and responsive to a pressure differential for moving said sealing means into sealing engagement with the borehole wall; and a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said sampling tool including means for defining a sample receiving chamber, means for defining a fluid passage between said sample chamber and said channel means, means for selectively admitting weighting liquid into said fluid passage while said sealing means is in sealing engagement with said borehole wall, thereby to relieve any pressure differential across the face of said pack-off shoe, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said pressure responsive means to establish said pressure differential with respect to the pressure of weighting liquid in the borehole.

5. In apparatus for sampling the fluid content of formations traversed by a borehole, a pack-off section comprising a tubular body including means for coupling said body with a string of pipe, said body having an open bore sized to continue the bore of the string of pipe, sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening, channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body, hydraulic motive means mounted transversely on said body and operative to urge said sealing means toward the borehole wall, a setting sleeve carried by said body for movement therealong and having opposite surfaces in communication respectively with the interior and exterior of said body, said sleeve and said body including complementary portions defining a chamber containing hydraulic fluid, and means for placing said

chamber in fluid communication with said hydraulic motive means for actuating the same.

6. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a tubular body including means for coupling said body with a string of pipe to be lowered into a borehole; sealing means carried by said body adapted to move relative to said tubular body to engage and isolate a portion of the borehole wall; channel means opening upon the bore of said body and said sealing means to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; hydraulic motive means carried by said body for moving said sealing means towards the borehole wall; actuating means carried by said body responsive to a pressure differential between the interior and exterior of said body for actuating said hydraulic motive means; and a sampling tool of slightly less diameter than the bore of said body adapted to be lowered into the bore of said body, said tool including means for defining a sample receiving passage in fluid communication with said channel means, said sample-receiving passage including a perforator bore positioned for alignment with said channel means, means for aligning said perforator bore with said channel means, means in said perforator bore for perforating a formation opposite said opening, means for defining a low pressure chamber; and means for defining a passage between said low pressure chamber and said actuating means.

7. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a string of pipe; a tubular body coupled to said string of pipe adapted to be lowered into a borehole therewith; sealing means including a pack-off shoe carried by said body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; means carried by said body and responsive to a pressure differential for moving said forward face of said shoe into engagement with the borehole wall; and a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body when said body is in the borehole, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said pressure responsive means to establish said pressure differential with respect to the pressure in the borehole.

8. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a string of pipe; a tubular body coupled to said string of pipe and adapted to be lowered into a borehole therewith; sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; hydraulic motive means carried by said body for moving said sealing means towards the borehole wall; actuating means carried by said body responsive to a pressure differential for actuating said hydraulic motive means, said actuating means including a setting sleeve arranged concentrically about said body, said sleeve and said body further including complementary portions defining a first chamber; and a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said first chamber.

9. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a string of pipe; a tubular body coupled to said string of pipe and adapted to be lowered into a borehole therewith; sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; hydraulic motive means carried by said body for moving said sealing means toward the borehole wall; actuating means carried by said body responsive to pressure differential for actuating said hydraulic motive means, said actuating means including a setting sleeve arranged concentrically about said body, said sleeve and said body including complementary portions defining a first chamber, other portions of said sleeve and said body defining a second chamber, said body having a passageway for fluidly connecting said second chamber to said hydraulic motive means; biasing means between said sleeve and said body for normally maintaining said second chamber in an expanded condition; a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said first chamber to establish said pressure differential with respect to the pressure in the borehole thereby to move said sealing means toward the borehole.

10. In apparatus for sampling the fluid content of formations traversed by a borehole, the combination comprising: a string of pipe; a tubular body coupled to said string of pipe and adapted to be lowered into a borehole therewith; sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the isolated portion of the borehole wall and the bore of said body; hydraulic motive means carried by said body for moving said sealing means toward the borehole wall; actuating means responsive to a pressure differential for actuating said hydraulic motive means, said actuating means including a setting sleeve arranged concentrically about said body, said sleeve and said body including complementary portions defining a first chamber, other portions of said sleeve and said body defining a second chamber, said body having a passageway for fluidly connecting said second chamber to said hydraulic motive means; biasing means between said sleeve and said body for normally maintaining said second chamber in an expanded condition; a retrievable sampling tool of slightly less diameter than the bore of said body adapted to be removably disposed within the bore of said body, said tool including means for defining a sample receiving chamber, means for defining a passage between said sample chamber and said channel means, means for defining a low pressure chamber, and means for defining a passage between said low pressure chamber and said first chamber to establish said

pressure differential with respect to the pressure in the borehole thereby to move said sealing means toward the borehole wall, means for defining a normally closed passage for admitting liquid under hydrostatic pressure to said low pressure chamber, and means for opening said normally closed passage.

11. In apparatus for sampling the fluid content of formations traversed by a borehole, a string of pipe, a pack-off section comprising a tubular body coupled to said string of pipe and having an open bore sized to continue the bore of the string of pipe, sealing means including a pack-off shoe reciprocally mounted on said body and adapted to move relative to said tubular body, said shoe having a forward face arranged to engage and isolate a portion of the borehole wall, said forward face having an opening; channel means opening upon the bore of said body and connected to said opening in said forward face to permit fluid communication between the

isolated portion of the borehole wall and the bore of said body, hydraulic motive means carried by said body for moving said sealing means towards the borehole wall, and actuating means carried by said body responsive to a pressure differential for actuating said hydraulic motive means.

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