

2 Sheets-Sheet 1



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3,217,804

FORMATION FLUID SAMPLER

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2 Sheets-Sheet 2

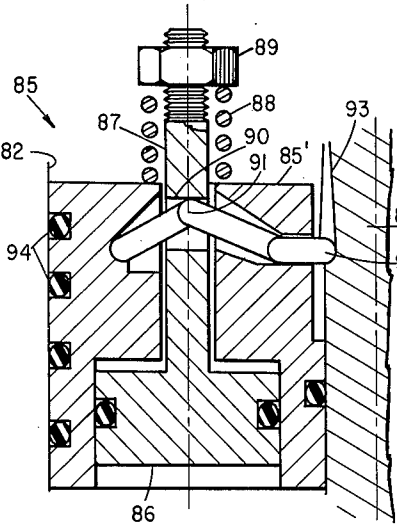


FIG. 5

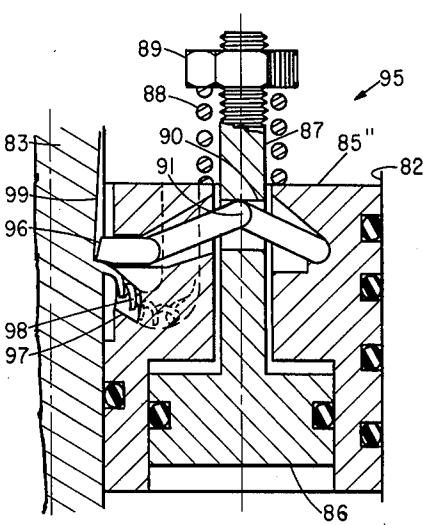


FIG. 6

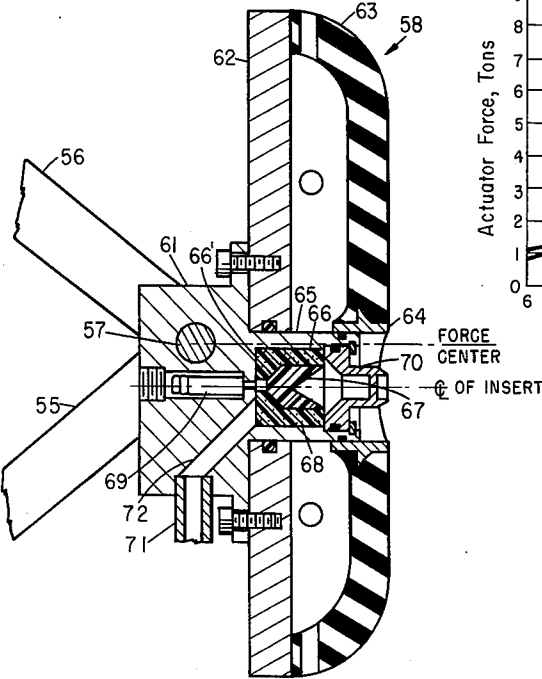


FIG. 7

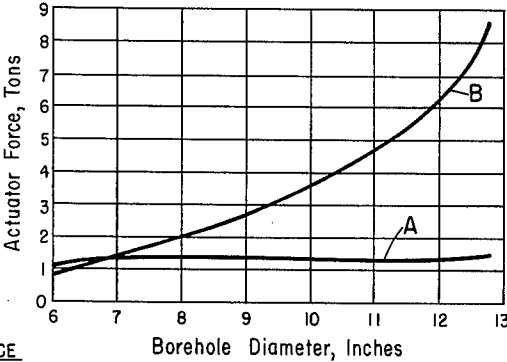


FIG. 8

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FORMATION FLUID SAMPLER

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The present invention relates to sampling the fluid content of earth formations, and, more particularly, to wireline apparatus for taking samples laterally of a borehole piercing the earth's formation of interest.

Such a device is useful in that formations about a borehole at various depth zones may be selectively sampled to determine fluid content. Information derived from such samples is useful, in turn, in evaluating the probable fluid productivity of such zones, and, hence, is a valuable aid in selecting from such zones, those having the best production potential for final completion.

Apparatus of this general type adapted for lowering into a borehole by means of a wireline and having provision for utilizing the hydrostatic energy of its sampling environment for actuating power is well known and has been long recognized as potentially providing a more facile, efficient, and economic means of formation sampling than similar apparatus lowered by means of tubing string, for example. However, the prior art has not enabled the attainment of a sampling success efficiency commensurate with this potential because of the tendency of devices thus far provided to fail somehow during a sampling sequence. These failures in the main, may be traced to the design complexity of the prior art sampling devices.

Among the many causes of failure experienced with the rather complex prior art sampling devices of this general type, leakage past fluid seals predominates. Leakage, wherever it occurs, can cause failure of the immediate operations in which the tool is employed, either by rendering the actuating system of the device inoperative or by the loss of the fluid sample which the operation is to obtain. A failure of the actuator system, especially in the latter stages of the sampling sequence, when the device is still in anchored sealed engagement with the borehole wall, may disable the device to the extent that it may not be removed from the borehole without an expensive fishing operation. It will be appreciated that fishing operations are not sure of success, and therefore, that the failure may result not only in the abortion of the sampling operation and the loss of the rather expensive sampling device, but possibly in the effective loss of the entire well.

Accordingly, it is the principal object of this invention to provide a new wireline formation fluid sampler device of improved general effectiveness, efficiency and reliability, and having a new construction and mode of operation not provided in prior art devices.

Another object of the invention is the provision of a new and improved sampler device initially controllable from the earth's surface in its sample taking sequence by a first control link and ultimately controllable in the latter portion of the sample taking sequence by a second control link different in kind from the first link, whereby said latter portion of said sequence may be successfully carried out without regard for failure of said first control link.

Still another object of the invention is the provision of a formation fluid sampler device having a mode of actuation tending to assure more effective sealing engagement with the wall of the borehole.

A still further object of the invention is the provision of a formation fluid sampler device of simple maintenance and service requirement to thereby promote operating efficiency and economy.

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Another object of the invention is the provision of a formation fluid sampler device having a pack-off actuating system adapted to produce a substantially uniform initial pack-off sealing force against the wall of the borehole independently of the size of the borehole or of the hydrostatic pressure of the fluid therein.

Still another object of the invention is provision of a formation fluid sampler embodying features which result in formation fluid sampling equipment smaller in size than comparable prior art tools of approximately the same capacity and general capability.

A further object of the invention is provision of a formation fluid sampler incorporating a new and improved sample chamber and sample flow control system.

A still further object of the invention is the provision of a formation fluid sampler device employing a new and improved formation isolation pack-off means.

Another object of the invention is provision of a new and improved actuation system for employment within a borehole environment which is adapted to produce substantially uniform forces independently of the borehole depth.

Still another object of the invention is the provision of a formation fluid sampler device which produces an operative force of substantially constant magnitude without regard for the degree of movement involved, but which on its retractive stroke produces a different magnitude of force.

A further object of this invention is the provision of an actuator system for employment in a borehole environment which incorporates means for shock and acceleration control on both its active stroke and retractive stroke.

An object of the invention is the provision of a new and improved jet charge carrier assembly adapted for operation in a high pressure borehole environment and which may be employed with great efficiency in a formation fluid sampler device, for example.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for purposes of illustration and description. The preferred embodiment is not intended to be exhaustive nor to limit the invention to the precise form disclosed. It is chosen and described in order to best explain the principles of the invention and their application in practical use to thereby enable others skilled in the art to best utilize the invention in various embodiments and modifications as are best adapted to the particular use contemplated.

In the accompanying drawings:

FIGURE 1 is a schematic illustration of a wireline formation fluid sampling device embodying the features of the present invention and showing the same actuated and otherwise disposed for sample taking;

FIGURE 2 is a transverse sectional view taken along line 2-2 of FIG. 1;

FIGURE 3 is a transverse sectional view taken along line 3-3 of FIG. 1 and showing the disposition of the wall engaging members of the device with respect to the walls of the borehole;

FIGURE 4 includes a number of illustrations or views which schematically illustrate the operative sequence of the actuator system employed in the device of FIG. 1;

FIGURE 5 is an enlarged partial sectional view of a sample chamber piston assembly with pressure responsive braking system which may be employed in the sample chamber of the device of FIG. 1;

FIGURE 6 is an enlarged sectional view of a sample

chamber piston assembly with a pressure responsive braking system which may be alternately employed or employed in conjunction with the braking system illustrated in FIG. 5;

FIGURE 7 is an enlarged detailed sectional view of the pack-off assembly of FIG. 1, illustrating the same as it may be disposed during movement toward the sidewall of the borehole but not yet engaged therewith; and

FIGURE 8 is a graph illustrating the manner in which the setting force varies with borehole diameter on the actuation stroke. Also illustrated is a graph of the manner that the force available for retracting the wall engaging members varies with borehole diameter under the influence of an arbitrarily selected borehole fluid pressure of 2000 p.s.i.

Described generally, the formation fluid sampler device of the present invention, as shown in FIG. 1, comprises a downhole unit generally indicated as 10 (and including a body 11) shown suspended from the earth's surface within a borehole 12 by means of the wireline 14 from sheave 17 and winch 18. The downhole unit 10 is adapted for actuation under control from the earth's surface exerted over wireline 14 to move wall engaging members or elements thereof into engagement with the wall of the borehole opposite a formation zone of interest and to isolate a portion of such zone and take a sample therefrom into a chamber provided in the unit. Actuation of the wall engaging members is provided for by an actuating system which is adapted to displace the wall engaging members outwardly with respect to the tool body by a first or actuation stroke powered by a pressurized gaseous medium contained in the unit and to withdraw the wall engaging members from the wall of the borehole after the sampling operation by a retractive stroke which is powered by the pressure of the column of fluid which normally exists within a borehole.

It is to be understood that the showing of borehole 12 as an open hole is merely for the purpose of illustration and that the borehole unit 10 is equally useful in cased holes penetrating the earth's surface provided an isolation member suitable for employment in casing, i.e., without the snorkel feature, is substituted for the open hole snorkel type formation isolation and sealing means illustrated and described.

With further reference to the drawing, the body 11 of the downhole unit 10, beginning at its upper end, is comprised of a cable head section 20, a gas actuator section 30, a formation isolation section 50, a hydraulic actuator section 75, and a sample chamber section 80.

These sections generally divide the downhole unit 10 in a somewhat functional manner and, for that reason, will be useful in connection with the present description of the construction and operation of the formation fluid sampler of the invention.

Cable head section

The cable head section 20 has as its function the provision of means for attaching the downhole device to its suspending wireline 14, the provision of means for connection of electrical power and control circuits (not shown) within the downhole unit 10 to the central conductor 15 of wireline 14, in order that electrical power and control signals may be communicated to such circuits from the earth's surface, and the provision of means for exerting surface control over certain functions of the downhole unit by mechanical tension signal transmitted over the wireline 14.

The body 11, within the portion defined by the cable head section 20, is provided with a longitudinally extending bore 21 which communicates from the upper end of the body to a transversely extending bore 22 which admits any fluid which may be present in the borehole. The bore 21 threadedly receives a sealing plug member 23 which serves to exclude borehole fluids from the bore 21 and thus provides, as will appear, an atmospheric pressure

compartment 24 within the cable head section. The sealing plug 23 is also provided with a longitudinal bore which forms a portion of the atmospheric compartment 24. A cable socket member 25 extends in sealed slidable engagement through the bore 21 and sealing plug 23, longitudinally of atmospheric compartment 24 and further in sealed slidable engagement with the bore 21 into the transversely extending bore 22. The wireline 14, of course, is mechanically socketed within the upper end of the socket member 25. The socket member in so extending from the atmospheric compartment is exposed at both its upper and lower ends to the pressure of borehole fluid.

The end portions of the cable socket member which extend from the atmospheric compartment and are exposed to borehole fluids are of the same cross-sectional area in order that there will be no tendency for the socket member 25 to be shifted vertically because of pressure exerted thereon by borehole fluids. The cable socket member 25 is provided with a flange 26 having an upper surface defining a seat for a spring 27 which is maintained in biased relation between the seat and the upper end of the atmospheric compartment 24. The cable socket member 25 is, in addition, provided with a stop flange 26', which is spaced from the flange 26. Flange 26' is normally maintained in biased contact with the lower end of the atmospheric compartment 24 by the spring 27. The central conductor 15 of the wireline 14 extends in insulated relation through an axial bore in the cable socket member 25 and laterally outwardly into the atmospheric compartment between the flanges 26 and 26', where it is suitably connected with control and power circuits (not shown). The connection of the wire within the atmospheric compartment is provided with sufficient slack to allow axial movement of the cable socket member 25. This occurs, as will appear, when the control function of the cable head section is activated.

The spring 27 provided in the atmosphere compartment is of a size such that, when properly biased by adjustments of the longitudinal position of the sealing plug 23 within the threaded longitudinally extending bore 21, it maintains the cable socket in its normal position with its stop flange 26' in biased contact with the lower surface of the compartment 24, with a force in excess of that required to support the entire weight of the downhole unit 10.

The cable socket member 25 is provided at its lower end with a transversely extending bore normally positioned in generally coaxial relation with the transversely extending bore 22. The bore 22 terminates at a blind end in which is provided a threaded receptacle which is also disposed generally coaxially thereof which communicates with a fluid flow passageway 28 within the body 11. A break valve 29 is provided in sealed threaded engagement with the threaded receptacle and extends therefrom into the bore 22 and through the transverse bore in the lower end of the cable socket member 25. The break valve 29 normally excludes borehole fluid from entering the passageway 28 and the cable socket member 25, in its normal disposition, imposes no load on the valve. However, when the downhole unit 10 is in anchored engagement with the borehole wall, as will be hereinafter described, upward tension applied over the wireline above a predetermined amount moves the cable socket member 25 upwardly with respect to the body of the downhole unit 10 and the lower end of the socket applies a load to break the valve 29 at a notch 29' provided therein. When the valve is broken, the passageway 28 is communicated with borehole fluids within the transversely extending bore 22. The transversely extending bore 22 is provided with a screen 22' which serves to retain the distal end portion of the break valve 29 when the same is broken off at the notch 29' as just now described. As will appear from the description of the operation of the downhole unit 10, the break valve 29 functions responsive to wireline tension to bring about

the retraction sequence of the downhole device subsequent to the obtaining of the desired sample of formation fluids.

Gas actuation section

As may be seen in FIG. 1, the gas actuation section 30 is disposed immediately below cable head section 20. The function of the gas actuation section is to provide force and power for urging wall engaging elements of the formation isolation section against the walls of the borehole so that a fluid sample be taken therefrom.

The gas actuation section 30 includes a generally cylindrical buffer fluid chamber 31 and a gas expansion chamber 32 coaxially disposed with respect to one another and spaced apart by a portion of the body 10 forming an end wall common to both chambers. A piston 31' is disposed for sealed slidable engagement within the chamber 31 and a piston 32' is disposed for sealed slidable engagement within the gas expansion chamber 32. The pistons 31' and 32' are mechanically coupled together by a piston rod 33 which extends in sealed slidable engagement through the common end wall of the two chambers. A rod 33', an extension of rod 33, depends from the face of piston 32' opposite the rod 33 and extends through the lower end wall of the chamber 32, in sealed slidable engagement therewith, where it is exposed to fluids of the borehole.

The piston 31' defines a buffer fluid space 31'' at its rod end and a space 31''' for receiving borehole fluid at its other end within the chamber 31. The space 31''', within the buffer fluid chamber 31, communicates with the fluid flow passageway 28 previously described.

The piston 32' defines, at that end from which the rod 33' depends, a gas expansion space 32'' and, at its other end, a gas equalization space 32''' within the gas expansion chamber 32. The function of these spaces will be described hereinafter in connection with the description of the operation of the downhole unit 10.

A chamber 34 is provided within the body of the downhole device 10 for receiving a charge of pressurized gas for powering the active stroke of the downhole unit. A charging valve 35 is provided for convenience in charging the chamber 34 with a desired amount of gas for a given set of operating conditions. The valve 35 may be of any manually operated high pressure type such as a stop cock, for example. A passageway 36 is provided for admitting the gas charge to the space 32''. However, passageway 36, although shown communicating gas in FIG. 1 of the drawing, is normally blocked by a setting valve 36'. Although the valve 36' may be of any type suitable for electric remote control from the earth's surface, a normally closed valve of the type disclosed in commonly assigned Patent No. 2,982,130 to McMahan may be employed.

An equalization valve 37 is provided in the gas actuation section for the purpose of communicating the gas expansion space 32'' with the gas equalization space 32''' during the retraction sequence. Equalization valve 37 is piloted in its operation by the operation break valve 29. Equalization valve 37 includes a number of elements housed in a valve bore 38. The valve bore 38 communicates, by means of openings 38' and 38'', with the gas equalization space 32''' and the gas expansion space 32''. In addition, the valve bore 38 communicates, at its upper end, with the previously described passageway 28.

The bore 38 is sealed at its lower end by means of a plug member 39 which defines a cavity in communication with the opening 38'. The plug member 39 is also sealed with respect to the valve bore 38 at a point intermediate the opening 38' and the opening 38''. The upper end wall of the plug member 39, intermediate the upper end thereof and the cavity space defined therein, constitutes a diaphragm thin enough to be perforated in a manner to be described, but strong enough to withstand the pressures within the gas expansion space 32''. It

is to be noted that the upper end of the plug member 39 extends within the valve bore 38 to a point short of blocking the opening 38'' which communicates from the valve bore into the gas equalization space 32'''.

A valve operator piston 40 is disposed within the valve bore 38 in sealed slidable engagement therewith. The valve operator piston has an upwardly extending projection 41 which abuts the end of the valve bore 38 in the normal position of the piston. The piston also has a tubular perforator extension 42 which depends from the lower surface of the piston and is somewhat smaller in diameter than the diameter of the piston per se. The perforator extension is suitably sharpened on its distal end to adapt the same to breach the upper end of the plug member 39 when forced thereagainst in the manner to be described. The juncture of the perforator extension 42 and the body of the piston 40 defines a shoulder which functions as a upper seat for a valve spring 43 which, at its lower end, bears on the upper surface of the plug member 39 to maintain the piston 40 in its normal position biased against the upper end of the valve bore 38. A radial groove 44 communicates the bore of the perforator extension 42 with the valve bore 38.

The structure of the equalization valve 37, just now described, is such that fluid communication between the spaces 32'' and 32''', although normally blocked by the end of the plug member 39, is established pursuant to the operation of break valve 29. This admits the pressure of borehole fluid to the upper end of the valve operator piston 40 to force the same downwardly, overcoming the bias of the valve spring 43, to breach the upper end wall of the plug member 39 by forcing the perforator extension 42 therethrough. When the equalization valve has thus been operated, fluid communication is established from the gas expansion space 32'', via the opening 38', the cavity within the plug member 39, through the bore of the perforator extension 42, the radial groove 44, and thence, through the opening 38'' into the gas equalization space 32''' above the piston 32'. Once this communication has been established, the pressure of the gas at either side of the piston 32' is equalized, and thus, exerts no tendency to displace the piston one way or another. The advantages of this equalizing function as well as its place in the sequence of the operation of the downhole unit 10 will be brought out hereinafter in connection with the description of the operation of the downhole unit 10.

Formation isolation section

Within the portion of the downhole unit 10 designated as the formation isolation section 50, the body 11, which is otherwise generally cylindrical in form, bifurcates to provide two laterally spaced longitudinally extending members 51.

The members 51 provide structural continuity of the downhole unit 10 within the formation isolation section and connect the upper sections of the tool with those which are desirably located therebelow, and at the same time, provide an open structure providing space for housing the wall engaging elements of this section as well as linkage provided for their actuation.

The portion of the rod 33', which extends from the gas expansion chamber 32 and is exposed to the fluid within the borehole, extends between the members 51 within the formation isolation section. The rod 33' is provided with a cross-head enlargement 54, having projections 52 which laterally engage longitudinal grooves 53 provided in the members 51 for sliding engagement therein and for providing lateral support to the rod 33'. A set of lower actuator links 55 are pivotally pinned and end connected to the cross-head enlargement 54. In the normal retracted or unactuated disposition of the downhole unit 10, the rod 33', including the cross-head enlargement 54, is disposed at the somewhat lower position indicated by the dotted outline 54'. A set of upper actu-

ator links 56, similar to the lower links 55, are pivotally pinned and end connected to the inner surfaces of the members 51 at points longitudinally spaced from the pins which connect the lower actuator links 55 to the enlargement 54. A pair of upper links 56 and a pair of lower links 55 extending to the right of the body of the downhole unit 10 are pinned together at their other ends by a pin 57 which provides an articulated mounting for a formation isolation pack-off assembly 58. A pair of upper links 56 together with a pair of lower links 55, extending to the left of the downhole unit 10, are pinned together at their other ends by a pin 59 which provides an articulated joint mounting for a back-up plate 60. The linkage pairs which respectively provide the articulated mounting for the pack-off assembly 58 and for the back-up plate 60 comprise toggle mechanisms for applying actuating force to urge the pack-off assembly 58 and back-up plate 60, respectively, into sealed and anchored engagement with the walls of the borehole.

When the formation isolation section is in its normally retracted disposition with the pack-off assembly 58 and back-up plate 60 maintained in close proximity to the members 51 and the enlargement of the rod 33' in its lowermost disposition as indicated at 54', the links 55 and 56 of both mechanisms are initially disposed at an angle θ of about 10° with respect to the centerline of the downhole unit 10. This initial angle of the links assures that, when the linkage mechanisms are operated in unison pursuant to upward movement of the rod 33' and enlargement 54, the pins 57 and 59 will be displaced outwardly with respect to the downhole unit 10 in a positive fashion.

The outward displacement of the pins 57 and 59 is a function of the angle θ , as is the upward movement of the rod 33' and piston 32. Thus, the volume in space 32'' related to the outward displacement of the pins 57 and 59, and, hence, to the diameter of the particular borehole in which the unit may be set.

Curve A of FIG. 8 shows the forces exerted against the borehole wall during the actuating stroke with variations in borehole diameter for a typical design wherein (a) the links 55 and 56 are effectively 5 inches long, (b) the piston 32 has an effective area of 10 square inches, (c) the unit is charged with gas such that when the valve 36' is opened (before any movement of the piston 32), the gas occupies a volume of 8.4 cubic inches at 1200 p.s.i. pressure, and (d) the upper surface of the piston 31 has an effective area of 5 square inches. Curve B of FIG. 8 shows the manner that the force available for retracting the wall engaging members varies with borehole diameter upon the admission of borehole fluids at 2000 p.s.i. to the space 31'''. This pressure would, of course, increase with borehole depth, as does the plastering force which must be overcome initially during the retraction stroke.

Curve A of FIG. 8 shows that the setting force produced on the actuation stroke by the typical design is substantially constant within 7"-12" borehole diameter range. This substantially constant setting force approaches the magnitude of about 3000 pounds. Such a magnitude has proven satisfactory for producing good initial pad seals without damaging the borehole wall formation face under a wide variety of borehole and formation conditions. However, it will be apparent that if the downhole unit were charged to a greater or lesser gas pressure, a correspondingly greater or lesser substantially constant setting force would be produced upon actuation. This choice of charging pressure, of course, lends great flexibility to the use to which the actuation device of the invention may be put.

The pack-off assembly 58, best shown in FIG. 7, is mounted to links 55 and 56 of one of the toggle mechanisms, in pinned connection relation thereto, by means of the pin 57, as previously described. In making this con-

nection, the pin 57 extends through a jet charge carrier and inlet member 61 which comprises a portion of the pack-off assembly 58. The member 61 is fastened to a carrier plate 62 which, in turn at its peripheral edges, is connected with a sheet-like sealing element 63 of generally curved configuration having a front face adapted to engage and isolate a portion of the borehole wall. This sheet-like sealing element may be made of rubber, for example. The pin 57 is disposed with respect to the longitudinal extent of the carrier plate 62 and sealing element 63 such that when the sealing element is urged into forced engagement with the wall of the borehole, a center of applied force is established which bisects the longitudinal extent of the sealing element as shown in FIG. 7.

A rigid insert 64 is molded in the material of the sealing element 63 at a location such that the centerline of the insert is off-set with respect to the center of force just now described. The member 61 is provided with a jet charge carrier and inlet extension 65 which extends in sealed relation through the carrier plate 62 and in sealed slidable engagement within a bore provided in the insert. The extension 65 is provided with a bore 66 for housing a shaped charge 67 and a shaped charge holder 68 for spacing the shaped charge from the walls of the extension 65. The shaped charge 67 is disposed within the extension with its hollow or shaped portion disposed toward the face of the sealing element 63 and its booster end in abutting relation to a shoulder 66' defined within the bore 66. The shaped charge may be of any suitable high explosive material such as an RDX compound. The holder 68 generally fills the space between the exterior of the shaped charge 67 and the walls of the bore 66. The holder 68 is made of porous material characterized by offering high impedance to the transmission of shock waves from the shaped charge to the walls of the extension 65. The porous material may be a suitably low density foam plastic material having sufficient dimensional stability to space the explosive within the bore 66. Although a foamed plastic material may be preferable, any other suitable material such as a foamed aluminum or sintered metals having high porosity and high impedance to transmission of shock waves may be employed.

The bore 66 is greatly reduced in size as it extends rearwardly within the member 61 beyond the shoulder 66'. At a point beyond the shoulder 66', the bore 66 is again enlarged slightly to receive a blasting cap 69 which is electrically fired by a signal transmitted from the earth's surface over the suspending wireline 14. The rear end of the bore 66 is threaded to receive a sealing plug to exclude borehole fluids from entering the same. The end of the bore 66 extending forwardly of the shaped charge and holder is counterbored to sealingly receive a snorkel member 70 which is adapted at its forward end for penetrating an earth formation when urged thereagainst. The snorkel member is secured in the counter-bore of bore 66 by means of a spring type locking ring. The bore 66 is communicated with a flexible formation fluid sample line 71 by means of a passageway 72 extending therebetween.

The various parts of the pack-off assembly 58 are shown in FIG. 7 as they would be disposed prior to engaging the wall of the borehole and prior to the firing of the shaped charge 67. When the sheet-like sealing element 63 contacts the wall of the borehole, it is distorted to conform therewith by the substantially constant force exerted through pin 57 through the force center as has been described. The application of force then causes the extension 65 to move forwardly within the bore of the rigid insert 64 and force the snorkel member 70 to penetrate the surface of the formation within the area sealed off from borehole fluids by the sealing element 63. With the pack-off assembly 58 thus deployed in penetrating sealing engagement with the walls of the borehole, it is only necessary to fire the blasting cap 69 in

order to detonate the shaped charge, to in turn, produce a characteristic jet stream and perforate the closed end of the snorkel member 70, as well as the formation therebeyond to establish drainage communication from the formation into the bore 66.

With the detonation and combustion of the charge 67, the outwardly radiating shockwaves radially compress the porous material of the holder 68 to form a dense liner within the bore 66. The bore 66, which is normally blocked by the presence of the charge 67 and the holder 68, is opened for fluid to flow therethrough and, thence, into the passageway 72 and the sample line 71.

Hydraulic power section

Immediately below the formation isolation section 50, the longitudinal members 51 merge with a cylindrical portion of body 11 which houses the hydraulic power section 75. The hydraulic power section 75, together with the buffer fluid chamber 31 located in the gas actuation section, is a part of a shock absorbing system which moderates the shock forces incident to setting and retraction of the wall engaging members of the formation isolation section, i.e., pack-off assembly 58, and back up plate 60. Also, the hydraulic power section functions as the proximate means for retraction of the wall engaging members from the walls of the borehole. This section includes a generally cylindrical fluid chamber 76 coaxially disposed with respect to the centerline of the downhole unit 10. The rod 33', which extends through the formation isolation section 50, extends in sealing slidable engagement through the upper wall of the just-mentioned fluid chamber 76. A piston 76' is disposed in sealed slidable engagement within the chamber 76 and is mechanically coupled to the end of the rod 33'.

The piston 76' defines, toward its rod end within the chamber 76, a space 76'' and, at its other end, a space 76''' which contains a gas at negligibly low pressure. The space 76'' is communicated upwardly through the formation isolation section 50 and into the gas actuation section 30 by means of a fluid passageway 77 to the space 31' defined below the piston 31' in buffer fluid chamber 31. As shown in FIG. 1, the passageway 77 may extend coaxially through the rod 33', the piston 32', and the rod 33 in making this communication. It will be noted that the passageway 77 is provided with a restriction 78 to impede the rate at which fluid may transfer through the passageway 77. This fluid transfer, as will be brought out hereinafter in the description of the operation of the downhole device 10, takes place with and in proportion to vertical displacement of the mechanically connected movable elements which include piston 31', rod 33, piston 32', rod 33', and piston 76'.

At the upper surface of the hydraulic power section 75, the flexible sample line 71 connects with a passageway 79 which extends downwardly through the hydraulic power section to communicate with a cylindrical chamber 82 in the sample chamber section 80, located therebelow.

Sample chamber section

The passageway 79, in entering the sample chamber section 80, communicates through a normally open remotely controllable valve 81 which, responsive to a suitable signal communicated from the earth's surface over the wireline, may be actuated to shut in any sample fluid which has been received within the chamber 82 during a sample taking operation. Although the valve 81 may be of any suitable type, it has been found that a normally open valve such as disclosed in commonly assigned U.S. Patent No. 2,982,130 to McMahan may be employed to advantage.

A rod member 83 extends longitudinally within the chamber 82 in parallel relation to the walls thereof and is securely fastened to the upper or fluid inlet end thereof. Although this fastening may be accomplished by any means which is capable of withstanding tensile loads ap-

proaching the yield strength of the rod member, a threaded fastening, as illustrated, is to be preferred because of its simplicity. The lower end of the rod member is maintained in alignment with the upper end thereof by a recess provided in a closure cap 84 which seals the lower end of the chamber 82. The cap 84 is removable to provide a convenient access to the chamber in order that the same may be cleaned and redressed as will be described.

A piston assembly 85 is provided in sealed slidable engagement with the cylindrical walls of the chamber 82 as well as with the exterior of the rod member 83. The function of the piston assembly, in conjunction with the rod member 83, is to constrain sample fluids entering the chamber 82 thereabove to do work in overcoming a braking resistance provided by the piston in proportion to the pressure of sample fluids within the chamber.

For the purpose of performing this function, the piston assembly 85 is provided with one or more pressure responsive force mechanisms for urging a cold working tool into working engagement with the rod member 83 to a depth in proportion to the pressure of the fluid within the chamber. Three pressure responsive force mechanisms (only two are shown) are incorporated in the piston body 85' in angularly spaced disposition about the rod member 83 to secure a distributed braking force and minimize any tendency for the piston assembly to cock or bind.

The type of pressure responsive force mechanisms employed in piston assembly 85 is best seen in FIG. 5 to comprise a bore within the body 85' in which a pressure sensing piston 86 is disposed in sealing slidable engagement. The piston 86 has a rod extension 87 which extends through the body 85' and receives a biasing spring 88 and retainer nut 89. These latter elements serve to maintain the sensing system 86 in sealed relation within its bore and yet permits its relative movement therein. The spring may desirably vary in rate with displacement in a manner to compensate for variations in mechanical advantage of the toggle linkage to which the piston 86 provides a motivating force input as will appear.

A transverse slot with load-bearing surface 90 is provided in the rod extension 87 for the purpose of applying the differential force developed across piston 86 through a knee joint 91 of a toggle linkage system disposed within the body 85', generally transversely of the rod extension. One link of the toggle has its distal end socketed in the body 85' in a manner to permit angular displacements of the link, but to oppose further radially outward displacement of that end relative to the rod extension 87. The other toggle link bears on an indenter 92 which is guided for movement within body 85' in a radial direction with respect to the rod member 83. The indenter is preferably made of sintered carbide so as to minimize the tendency to gall the rod member.

The indenter 92 preferably has a generated curved end which, responsive to the thrust developed in the toggle linkage, brinells the rod member 83 to a degree proportionate to the differential pressure force developed across the piston assembly 85 between sample fluid pressure in the inlet end of the chamber 82 and the pressure of compressible gas of negligible value at the other end of the chamber. As the piston assembly is displaced with respect to the rod member 83, the indenter 92 cold works a groove 93 into the surface thereof and imposes a braking load on the piston in proportion to the degree of brinelling of the rod member 83.

The generated curved indenter shape provides a two-fold advantage in the piston braking system in which it is incorporated. First, the generated curved end may be shaped so as to tend to compensate for non-linear force effects introduced by the toggle linkage. Second, the generated curved end positively reduces indenter depth in proportion to reductions in sensed pressure by riding up the curve formed at the leading edge of the groove

in a cam-like manner as the piston assembly traverse causes relative movement therebetween.

As the piston assembly 84 is displaced downwardly within the chamber 82, the indenter 92 forms a cold work groove 93 in the rod 83. This forming imparts a braking force which varies with the pressure of sample fluids between the piston assembly 84 and the chamber 82 which subtracts from the force otherwise available for displacing the piston assembly.

Thus, at any given pressure of fluid within the chamber 82, indenter 92 is forced to brinell the rod member 83 to an extent such that this same pressure acting on the effective area of the piston assembly 85 is resisted by a braking force arising from the longitudinal displacement of the indenter 86 along the axis of the rod member to form the cold working groove 93 therein. The net force tending to displace the piston downwardly within chamber 82 is equal to the sample fluid pressure times the effective area of the piston assembly 84 minus the braking force thus applied by the pressure responsive mechanism incorporated within the piston assembly. Since the displacement of the piston assembly with time is a function of this net force which tends toward a constant value, the flow of fluids entering the sample chamber will vary in a substantially uniform manner. If the pressure of the fluid within the chamber increases during the displacement of the piston, the braking force will correspondingly increase and tend to maintain this uniform manner. Conversely, if the pressure in the chamber decreases, the indenter tool will withdraw from the member 83 a proportionate amount, thus reducing the braking force, and tend to maintain the uniform manner.

The piston assembly 84 is provided about its exterior periphery with a plurality of O ring type seals 94 which assure a frictional resistance to displacement of the piston assembly 84 which is substantial to the extent that the piston will not displace downwardly in the cylinder 82 responsive solely to the force of gravity. This frictional resistance to displacement of the piston within the cylinder also assures that indenter 92, by virtue of there being less frictional resistance to movement of the sensing piston 86, will respond to changes in the pressure of fluid in the chamber 82 prior to the displacement of the piston assembly responsive thereto.

It will be apparent that the braking force is transferred from the piston assembly 84 to the upper end of the chamber 82 by a tensile loading developed within the rod member 83. The rod member 83 must have a tensile yield strength to withstand any such loadings as is likely to occur in service. Further, the material of the rod member 83 should have a brinell hardness or resistance to penetration of the indenter such that when the indenter is actuated by the sensing pistons and toggle linkages of a particular design, the braking forces developed will approach, but fall somewhat short of, the product of the fluid sample pressure within the chamber times the effective area of the piston assembly. The rod member 83 is deformed by the cold working to a point where it is not again usable. Consequently, the rod member 83 should not only exhibit the aforementioned qualities, but should be of justifiable expense. Cold rolled steel rods have been found to provide the required physical properties and the desired surface smoothness for obtaining an O ring seal.

A modified form of piston assembly, which may be used interchangeably with the piston assembly 85, is shown in FIG. 6 to be comprised of a piston body 85'', a pressure sensing piston 86, a spring 88, a nut 89, and a toggle linkage identical to that employed in the assembly of FIG. 5. Although the construction of the piston assembly of FIG. 6 is generally similar to that of FIG. 5, the piston body 85'' is slightly modified to provide for the guidance of a cutting tool 96 in a radial direction with respect to the rod member 83 in the stead of the indenter 92 provided in FIG. 5. The guidance passageway, as

well as the cutting tool 96 guided thereby, is desirably of square cross-section so that rotation of the cutting tool with respect to the guidance passage is prevented. The cutting tool 96 bears the same relation to the toggle linkage as the indenter 92 bears thereto in FIG. 5. The toggle linkage of FIG. 6 is actuated by a pressure differential developed across the sensing piston 86 in the same manner as has been described in connection with its counterpart of FIG. 5 to move the cutting tool 96 into varying degrees of cutting engagement with the rod 83 of FIG. 6 responsive to variations in pressure sensed by the sensing piston. The cutting tool 96 is preferably made of a sintered carbide material and is sharpened to provide a conventional relief angle and a slightly negative rake angle. The negative rake angle is advantageous, not only because it necessitates the application of more force to make a given cut, but in addition, enables the tool bit to back out of the cut when the axial force on the tool bit is reduced in the manner explained in connection with the indenter type brake mechanism of FIG. 5.

In addition to the tool bit 96 in the mechanism of FIG. 6, the piston body 85'' is provided with a passageway 97 which functions to curl the chip as it is removed by the rake surface of the tool bit 96 and to convey the curled chip through the piston and into the sample fluid end of chamber 82.

The piston assembly 95 of FIG. 6 functions to cold work the rod member 83 by removing a chip 98 therefrom as the piston assembly is displaced downwardly in the sample chamber responsive to the in flow of formation sample fluid. As the piston is displaced, the depth of cut of the tool 96 varies in accordance with the pressure of formation fluids exerted on the sensing piston 86 to machine a longitudinal groove 99 in the material of rod member 83. It will be appreciated that the braking resistance applied to the piston will be proportionate to the depth of the cut being made by the cutting tool 96 which is, in turn, proportionate to the pressure of the sample fluid within the chamber 82.

It will be apparent that the two methods of cold working shown, i.e., cutting and displacing the metal of the rod member 83, may be employed together within the same piston body to provide a piston assembly which cold works the rod 83 both by brinelling with indenters such as 92, as well as by cutting a groove therein by means of cutting tool such as 96. Such combinations including other methods of cold working may be desirable in tailoring the braking resistance offered to the traverse of the piston assembly to best fit the requirements occasioned by borehole conditions in different operating areas.

Operation

Assuming that the downhole unit 10 has been previously employed in a sample taking operation, before it can be again so employed, it should be cleaned and redressed to replace the previously spent expendable elements. These expendable elements include break valve 29, plug member 39, the explosive and expendable elements associated with the jet charge carrier and inlet member 61, as well as those associated with setting valve 36' and sample shut in valve 81. In addition, the sample chamber should be thoroughly cleaned and a new rod member 83 installed therein with the piston assembly 85 positioned at the upper end thereof. The piston assembly is maintained in this disposition by the frictional engagement of its various O ring seals. Further, the chamber 34 would be charged with an appropriate amount of gas through charging valve 35 in order that pressure energy will be available for powering the actuating stroke of the gas actuator section 30 to a desired degree. Assuming that all the foregoing necessary redressing steps have been taken, the downhole unit 10 is then lowered within the borehole by means of the wireline 14 to the point where the pack-off assembly 58 is disposed opposite the formation from which a test is desired.

Next, the downhole unit is actuated by opening the setting valve 36' pursuant to an electrical signal transmitted to the earth's surface over the wireline 14. This communicates the charge of gas within the chamber 34 to the space 32'' beneath the piston 32', and the pressure of the gas moves the piston 32', as well as the pistons 31' and 76' which are respectively interconnected therewith by rods 33 and 33', in an upward direction with respect to the body 11. With this movement, the cross-head 54 is displaced upwardly from its initial position, indicated as 54', into the position shown to actuate the toggle linkages and force the back up plate 60 and pack off assembly 58 respectively into anchoring and sealing engagement with the walls of the borehole 12 as shown in FIG. 1. During the displacements of the various parts of the downhole unit 10 during the actuating stroke, the acceleration or shock forces imposed by the displacement are limited in magnitude by the metered transfer of the buffer fluid initially filling the space 76'', from within the hydraulic power section 75 into the space 31'' beneath the piston 31'. The displacements of the parts continue, within limits, until the wall engaging members, i.e., back up plate 60 and pack off assembly 58, contact and respectively set and seal against the wall of the borehole.

The details of the actuating stroke including the manner of coaction of the various pistons and cylinders involved, as well as movements of fluids with respect to these various coacting cylinders, is perhaps more clearly, albeit more schematically, shown in FIG. 4, views A through C. In these views of FIG. 4, the same reference numerals have been applied to parts which are the counter parts of similarly numbered elements in FIG. 1. In view A, which schematically shows the various pistons in their normal unactuated position within their respective chambers, it will be noted that the setting valve 36' is closed and that the various pistons are disposed toward the lower end of their respective chambers and that the space 76'' above the piston 76' is filled with the buffer fluid. The buffer fluid, of course, may be any suitable substantially incompressible fluid. Views B and C of FIG. 4, respectively, schematically show the device of view A in successive dispositions which the same might assume during a typical actuating stroke. It will be noted that in these later two views, the setting valve 36' is open, the charge of gas is being admitted therethrough from the chamber 34 into the space beneath the piston 32' to exert a force thereon and move all the various pistons and rods in an upward direction. It will also be noted in views B and C that the buffer fluid in the space 76'' is being transferred, at a metered rate determined by the restriction 78 in the transfer path, upwardly into the space 31'' beneath the piston 32'. The upward displacement of the pistons and rods will, of course, be halted as soon as the toggle linkages bring the back up plate 60 and pack off assembly 58 into forced engagement with the walls of the borehole.

When the pack off assembly (see FIG. 7) is moved into actual engagement, the sealing element 63 will contact the wall first in being urged thereagainst by the carrier plate 62. The toggle linkage will continue to move the carrier plate 62 outwardly and tend to compress and conform the sealing element 63 into sealing engagement with the borehole wall. With this latter movement, the jet charge carrier and inlet extension 65 will be moved with respect to the insert 64 in the face of the sealing element 63, and displace the snorkel member 70 beyond the face of the sealing element and cause the snorkel member to penetrate any borehole wall filter cake and the formation of the borehole wall to establish a good, albeit closed, fluid communication therewith.

Next in the operating sequence, blasting cap 69 is fired pursuant to electrical signal transmitted from the earth's surface to detonate the shaped charge 67 which, in turn, forms a penetrating jet stream directed along the axis of the snorkel member 70. The jet stream penetrates that portion of the snorkel member and the formation there-

beyond to establish a laterally extending formation drainage or flow passageway communicating the jet charge carrier and inlet extension 65.

Of the total energy released with the detonation of a jet charge such as 67, the amount of energy which is concentrated in the directed jet stream is a rather small percentage of total, on the order of less than 10% of the total energy. The balance of the released energy emanates a spherically divergent shock wave which, in the instant application, must be contained within the confines of the rather small jet charge carrier and inlet extension 65 without damage thereto which would destroy its utility as a fluid conducting element of the fluid flow path between the formation and the sample chamber 82. Because the shock wave impedance of the holder 68 is high in comparison to the characteristic shock wave impedance of the explosive, there is an impedance mismatch, and thus the holder 68 functions during the detonation as a shock wave reflector, at its interfaces in common with the jet charge, which reflects the radial shock wave and tends to contain the same within the material of the charge. Secondly, the holder 68 functions as an inefficient shock wave transmission media, i.e., one offering high impedance to the transmission of shock waves therethrough. Thirdly, the holder 68 functions as a means for extracting work and energy from the shock waves by forcing them to do work in compressing and compacting its porous material against the inner walls of the sample inlet and jet charge carrier section. All three of these effects work to effectively protect the sample inlet and jet charge carrier extension from the full brunt of the shock wave energy it must contain.

With the compaction and compression of the porous material against the inner walls of the carrier extension, the porous material is transformed into a dense thin liner therein to open fluid communication from the formation into the fluid sample path communicating with the sample chamber 82.

With the fluid flow path thus opened to the sample chamber, formation fluid may communicate thereto to the top side of the piston assembly 85 which is initially positioned near the upper end of the chamber 82. As formation fluid enters the chamber above the piston and develops pressure therein, the piston assembly will be urged downwardly under the influence thereof. However, the pressure in the chamber will also be sensed by the sensing piston 86 within the piston assembly and exert a resisting or braking force on the rod member 83 to oppose the force of formation fluid urging the piston assembly 85 downwardly. Although the resisting braking force is proportionate to the force urging the piston assembly 85 in a downwardly direction, it never exceeds it, and consequently, the braking force merely reduces the net effective force which displaces the piston downwardly as the sample enters. This reduction in the net force moving the piston assembly 85 works to limit or moderate the rate that sample fluids may enter the sample chamber 82. This moderation of the flow rate tends to minimize the problem of plugged sample lines arising from formation being carried into the sample line by high fluid velocities which would otherwise be developed across the formation pad seal interface.

After the piston assembly has made its full traverse of the chamber 82 responsive to the filling of the same with formation sample fluids, the shut in valve 81 is closed responsive to an electrical signal communicated thereto from the earth's surface to complete the sample taking phase of the operation of the downhole unit 10. However, prior to removal of the downhole unit 10 from the borehole, the wall engaging members of the downhole unit, i.e., back up plate 60 and pack off assembly 58 must be disengaged from the borehole wall and retracted to their initial disposition adjacent the longitudinal members 51.

To initiate the retraction, a predetermined tension is exerted on the wireline 14 in excess of the weight of the

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downhole unit 10. This tension is resisted by the anchored engagement of the wall engaging members and works to displace the cable socket 25 upwardly to compress the spring 27 and break the break valve 29 at the point defined by the notch 29'. The breaking of the valve permits borehole fluid pressure to communicate with the space 31''' and the upper surface of the piston 31'. The breaking of the valve 29 also pilots the operation of the equalizing valve 37, in that the borehole fluid pressure is also communicated to the upper surface of the valve operator piston 40 to force the same downwardly, compressing the valve spring 43, and causing the perforator extension 42 to penetrate the upper end wall of the plug member 39. This penetration establishes a gas flow communication between the gas expansion space 32'' and the gas equalization space 32''' to equalize the pressure force of gas across the piston 32'.

The force of formation fluid exerted on the top side of piston 31' is communicated mechanically through the piston to create within the buffer fluid in the chamber 31'', immediately therebelow, a fluid pressure on the order of magnitude of the pressure of borehole fluids. This created pressure then causes the buffer fluid in space 31'' to transfer back over the restricted path into the space 76'' within the hydraulic power section 75 from whence it was displaced during the actuation stroke. Because the buffer fluid contained below the piston 31' is substantially incompressible, no appreciable mechanical force is directly applied to this piston insofar as motivation of the retraction stroke is concerned. However, as the buffer fluid transfers back to the space 76'', responsive to the created pressure under the piston 31', the pressure in the space 76'' builds up and acts on the top surface of the piston 76' to exert a tension force in the rod 33' and pull the cross head 54 downwardly to retract the wall engaging members. The coaction of the various cylinders and pistons and rods, including their movements occasioned by the just now described transfer of buffer fluid back to the space 76'', is perhaps more clearly shown in the simplified schematic view of the retraction stroke of FIG. 4D.

Of course, with the downward stroke of the piston and rod members, the toggle linkages will be restored to their retracted dispositions as shown by the dotted outline in FIG. 1 with a force proportionate to the hydrostatic pressure of borehole fluids. It is to be noted that although the borehole fluid is admitted to the space 31''', the actual motivating force during the retraction stroke is applied by the pressure of the buffer fluid within the space 76'' above the piston 76' to thereby place the rod member extending through the formation isolation section under a tensile loading. Rod member 33' is also under a tensile loading on its upward or actuating stroke as motivated by the pressure of the gas within the chamber 32''. The fact of tensile loading in the rod 33' on both its actuating and retraction stroke permits the employment of a rod of much smaller diameter and slenderness than would be required if loaded in compression.

The retraction stroke just now described completes the sampling operation so that the downhole unit 10 may be withdrawn from the borehole by means of the wireline 14. At the earth's surface, the sample contained in the chamber 82 may be removed by any convenient well known means (not shown), e.g., a drain cock.

It will be apparent in the light of the foregoing description of the structure and operation of the actuator-retractor and connected toggle linkages that the system provided by this invention extends the wall engaging elements of the formation isolation section into engagement with the wall of the borehole with the force which is substantially uniform regardless of the size of the borehole in which it may be set. The force necessary to provide an initial seal between the pad assembly 58 and the wall of the borehole is generally significantly less than the force required to remove the same therefrom after a

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sampling operation. The force to remove is directly related to borehole depth, in that the differential force between hydrostatic pressure of the borehole fluid and the pressure of formation fluid is exerted on the back face of the sealing element 63 to, in effect, plaster the same against the wall with high force. Because of this plastering force, a higher force is required to break the seal of the pad assembly than is initially required to set the same. The device of the invention provides an actuator-retractor mechanism which produces the relatively low force required to obtain an initial seal on its actuating stroke and which produces force which varies with the hydrostatic pressure of the borehole on its retracting stroke.

During the retraction stroke, the actuator initially moves the carrier plate 62 with respect to the sealing member 63 and withdraws the jet carrier and inlet extension 65 from the insert 64 enough to break the fluid seal therebetween. This performs the function of equalizing the pressure of the area sealed off by the seal member with the pressure of borehole fluids. This equalization tends to destroy or reduce the plastering force and thus facilitates retraction of the pack off assembly. Borehole fluids communicate to the space between the carrier plate 62 and the sealing member 63 through passageways provided in the sealing member near its attachment to the carrier plate.

Thus, it has been seen that the present invention provides a new and improved formation fluid sampler of improved performance, efficiency, economy, and safety, which incorporates an actuator-retractor mechanism which yields forces better suited for the service requirements. Further, it has been seen that the mechanism is shock buffered on both its strokes to minimize any destructive shock effects due to accelerations in its movement. Further, it has been seen that the sampler of the invention enables the construction of devices which are smaller in overall physical size than prior art devices, but yet have comparable sample taking capacities. It has been further seen that because of the reduction of the number of control functions which must be exerted over the downhole unit via the cable from the earth's surface, particularly as to control functions involved during the preparing of the downhole device for removal from the borehole, a simpler and consequently more reliable unit has been provided.

As various changes may be made in the form, construction, and arrangement of the elements herein disclosed without departing from the spirit or scope of the invention, and without sacrificing any of its advantages, it is to be understood that all matters herein are to be interpreted as illustrative and not in any limited sense.

What is claimed is:

1. A device for obtaining samples of the fluid content of formations traversed by a borehole containing a column of fluid comprising: a support adapted to be suspended in a borehole by means of a wireline from the earth's surface; a chamber in said support for receiving a fluid sample; means mounted on said support adapted to isolate an area of borehole wall when engaged therewith; motive means in said support for moving said means into engagement with the wall of the borehole; an inlet member in the first-mentioned means having walls adapted for exposure to and for withstanding the pressure of said column of fluid; a charge of explosive material, shaped for producing a jet stream when detonated, said charge being housed in said inlet member in spaced relation to said walls and normally closing said inlet member and preventing borehole fluids from entering said chamber; means in said inlet member for detonating said charge; a spacer disposed about said charge within said inlet for maintaining said spaced relation comprised of porous material; and a fluid channel communicating between said inlet member and said chamber, said charge when detonated adapted to radially compress said porous material

against the walls of said inlet member, whereby fluid communication is established through said inlet member between the formation within said isolated area and said chamber.

2. A device for obtaining samples of fluid content of formations traversed by a borehole comprising: a support adapted to be suspended in a borehole by means of a wireline from the earth's surface; a cylinder in said support for receiving a fluid sample; means mounted on said support for isolating an area of borehole wall when said means is engaged therewith; a fluid inlet in said means for admitting said fluid sample from the isolated area of borehole wall; a fluid channel communicating between said inlet and said cylinder; motive means in said support for moving said means into engagement with the wall of the borehole in response to signal communicated from the earth's surface; a piston in said cylinder displaceable therein in response to formation sample fluids entering said cylinder, said piston including means responsive to the pressure of formation sample fluid exerted thereon in said cylinder to variably opposed displacement of said piston in direct proportion to said pressure.

3. A device for obtaining samples of the fluid content of formations traversed by a borehole comprising: a support adapted to be suspended in a borehole from the earth's surface; a cylinder in said support for receiving a fluid sample; means mounted on said support for isolating an area of borehole wall when engaged therewith; a fluid inlet in said means for admitting a fluid sample from that portion of the borehole wall engaged by said means; a fluid channel communicating between said inlet and said chamber; motive means in said support for moving the first-mentioned means into engagement with the wall of the borehole in response to signal communicated from the earth's surface; a piston in sealed relation within said cylinder and displaceable with respect thereto in response to entry of formation sample fluid into said cylinder; and means responsive to pressure of sample fluids in said cylinder and connected with said piston for applying a braking force between said piston and cylinder which varies directly with said pressure, to the end that displacement of said piston in said cylinder is opposed and said sample fluid is constrained to do work in proportion to its pressure energy upon entering said cylinder.

4. A device for obtaining samples of the fluid content of formations traversed by a borehole comprising: a support adapted to be suspended in a well borehole by means of a wireline from the earth's surface; a cylinder in said support for receiving a fluid sample; means mounted on said support for isolating an area of borehole wall when engaged therewith; a fluid inlet in said means for admitting a fluid sample from that portion of the borehole wall engaged by said means; a fluid channel communicating between said inlet and said chamber; motive means in said support for moving the first-mentioned means into engagement with the wall of the borehole in response to signal communicated from the earth's surface; a member extending longitudinally within said cylinder and secured to one end of the same; a piston in sealed relation to said cylinder and said member and displaceable with respect to both in response to entry of formation sample fluid into said cylinder; and means in said cylinder actuable in response to the pressure of sample fluid therein for applying a cold working force between said piston and said member which varies directly with said pressure, to the end that a braking force is applied intermediate said piston and member to impede displacement of said piston and constrain said sample fluid to do work in proportion to its pressure energy in entering said cylinder.

5. An actuator adapted for lowering within a borehole in connection with a device for engaging the borehole wall and for securing the operation thereof comprising: a support adapted for lowering in a borehole; a toggle mechanism, for connection with said device, connected with said support for movement and operation of said

device; a quantity of pressurized gas contained in said support; and means in said support connected with said toggle mechanism for expanding and reducing the pressure of said gas in proportion to said movement and for applying the force thereof to said toggle mechanism, whereby said device is operated with substantially uniform force without regard for the magnitude of said movement, said means including a piston rod mounting three pistons, a first of said pistons operating in a first piston chamber, a second of said pistons operating in a second piston chamber, a third of said pistons operating in a third piston chamber, means for applying said gas to said first chamber to act on one side of said first piston to move said piston rod, conduit means interconnecting said second and third chambers, fluid within said second and third chambers transferred between said second and third chambers, upon movement of said piston rod, said fluid acting on one side of said second piston, said toggle mechanism being connected to said piston rod.

6. An actuator as set forth in claim 5, in which said toggle mechanism is connected to said piston rod at a point intermediate said second and third pistons.

7. An actuator as set forth in claim 5, in which fluid flow restriction means is interposed in said conduit means.

8. An actuator as set forth in claim 5, in which said conduit means comprises a passageway through said piston rod.

9. An actuator as set forth in claim 5, including means for intercommunicating opposite sides of said first piston in said first piston chamber.

10. An actuator as set forth in claim 5, including means for intercommunicating the other side of said second piston with borehole fluid.

11. A device for establishing fluid communication between a formation traversed by a borehole and a fluid chamber in said device comprising: a support adapted to pass through a borehole; a fluid chamber in said support; means on said support for engaging the wall of the borehole, for isolating a portion thereof from the fluid of said column and for establishing fluid communication between said portion and said means when the same is so engaged; a fluid channel connecting said means and said fluid chamber; a toggle mechanism connected with said support and the first-mentioned means for movement thereof toward engagement with the wall of the borehole, said toggle mechanism being characterized by a mechanical advantage which increases with increases in said movement; a quantity of gas contained in said support; and means in said support responsive to surface control for expanding and reducing the pressure of said gas in proportion to said movement and for applying the force thereof to said toggle mechanism whereby the first-mentioned means is urged into engagement with the borehole wall with substantially uniform force and with substantial independence of the amount of said movement, the last mentioned means including a piston rod mounting three pistons, a first of said pistons operating in a first piston chamber, a second of said pistons operating in a second piston chamber, a third of said pistons operating in a third piston chamber, means for applying said gas to said first piston chamber to act on one side of said first piston to move said piston rod, conduit means interconnecting said second and third chambers, fluid within said second and third chambers transferred between said second and third chambers upon movement of said piston rod, said fluid acting on one side of said second piston, said toggle mechanism being connected to said piston rod.

12. An actuator device adapted for employment within a borehole containing a column of fluid comprising: a support adapted for lowering within said borehole; first, second, and third cylinders in said support; first, second, and third pistons, in sealed slidable engagement respectively in said first, second, and third cylinders and defining first and second space portions in each; a force transmitting member extending within all of said cylinders in

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sealed slidable engagement with the walls of each and mechanically coupling said pistons; a quantity of gas contained in said support; means in said support for expanding said gas in the first space portion of said first cylinder to power a first stroke of said first piston and force transmitting member; a normally open fluid channel including fluid throttling means communicating between the first space portions of said second and third cylinders and defining therewith a space substantially filled with a buffer fluid adapted to meter between said second and third cylinders responsive to movement of said force transmitting member; a normally blocked fluid channel interconnecting the first and second space portions of said first cylinder; means in said support for unblocking said normally blocked channel and communicating the first and second space portions of said first cylinder to equalize any pressure force of said gas therein and for admitting the pressure of borehole fluid to the second space portion of one of said second or third cylinders, whereupon said buffer fluid is displaced from the first space portion of

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said one cylinder to the first space portion of the other of said second or third cylinders to act on the piston therein and effectuate a reverse stroke of said force transmitting member; and means coupled to said force transmitting member for extracting useful force from a stroke thereof.

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