United States Patent

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[72] Inventors **Robert J. Blackwell;**
Robert C. Rumble, Houston, Tex.

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[73] Assignee **Esso Production Research Company**
a corporation of Delaware

[54] **PRESSURE CORE BARREL**
11 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **175/233,** 175/25, 175/242
[51] **Int. Cl.** **E21b 25/00**
[50] **Field of Search** 175/25, 233, 236, 235, 242, 226; 166/226

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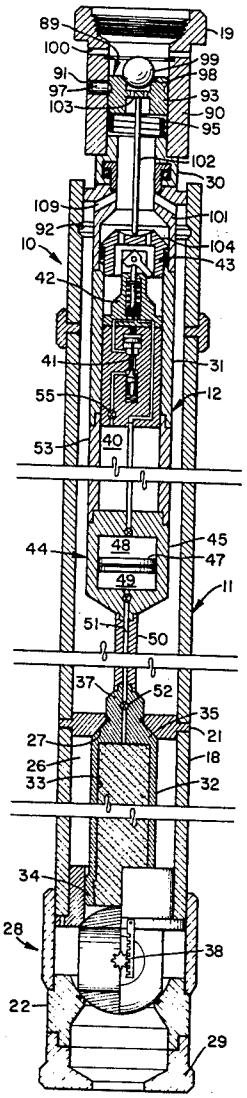
Primary Examiner—David H. Brown
Attorneys—James A. Reilly, John B. Davidson, Lewis H. Eatherton, James E. Gilchrist, Robert L. Graham and James E. Reed

ABSTRACT: A pressure core barrel assembly for recovering cores at formation pressure. The assembly is equipped with a pressure control system for maintaining a controlled pressure on a core contained in the pressure barrel chamber. The control system includes a high-pressure gas supply, a pressure regulator, a shutoff valve, and an accumulator which in combination function to maintain a controlled pressure on the core during surfacing operations.



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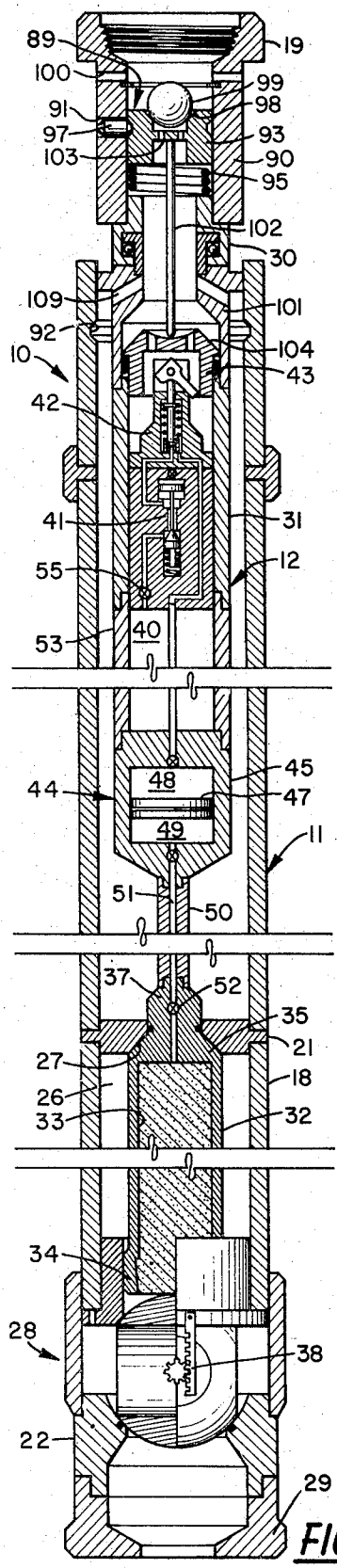

FIG. 2

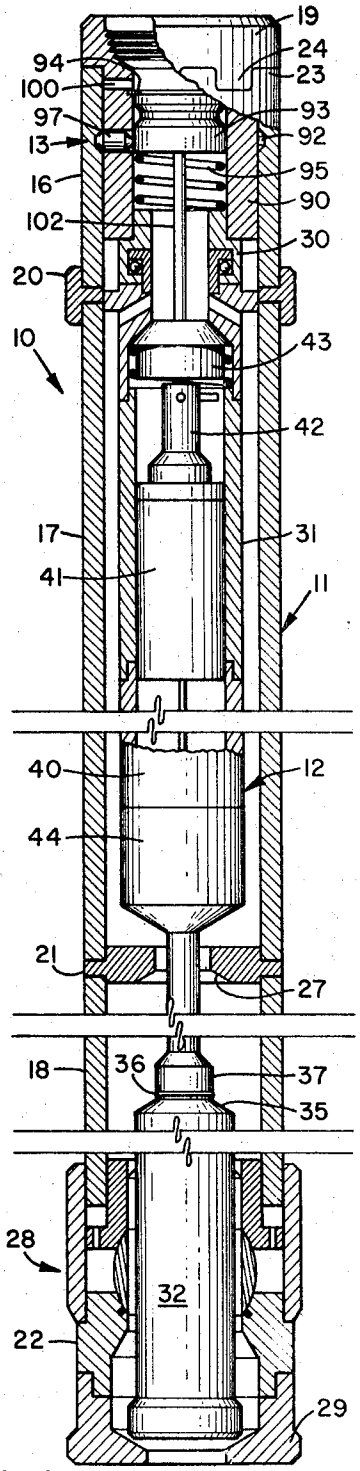

FIG. 1

INVENTORS
ROBERT J. BLACKWELL
ROBERT C. RUMBLE
BY Robert J. Graham
ATTORNEY

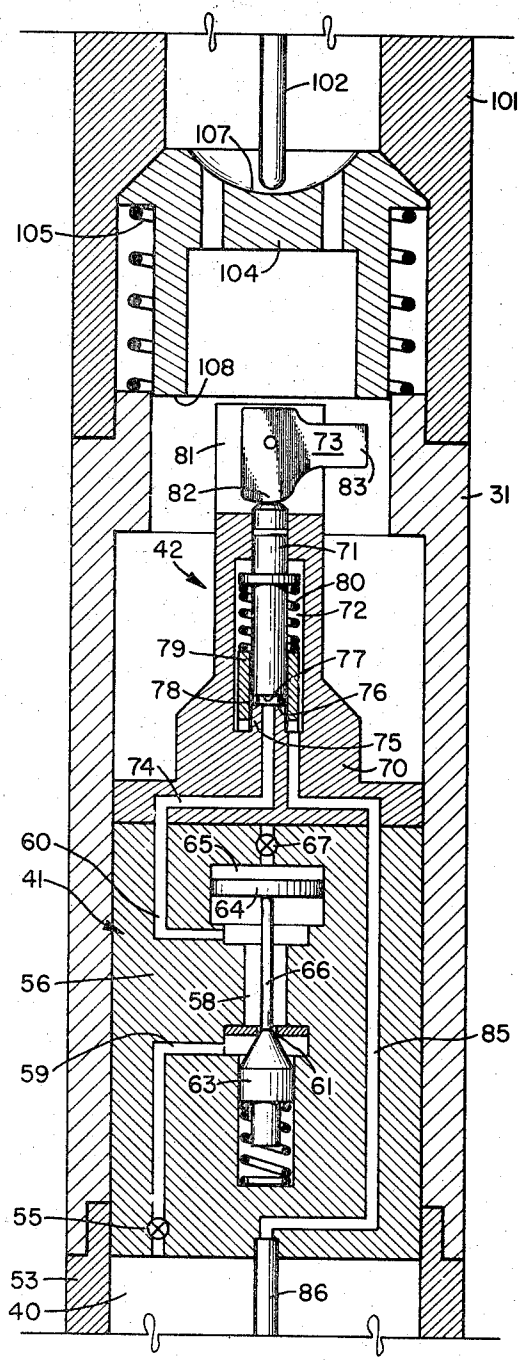

FIG. 3

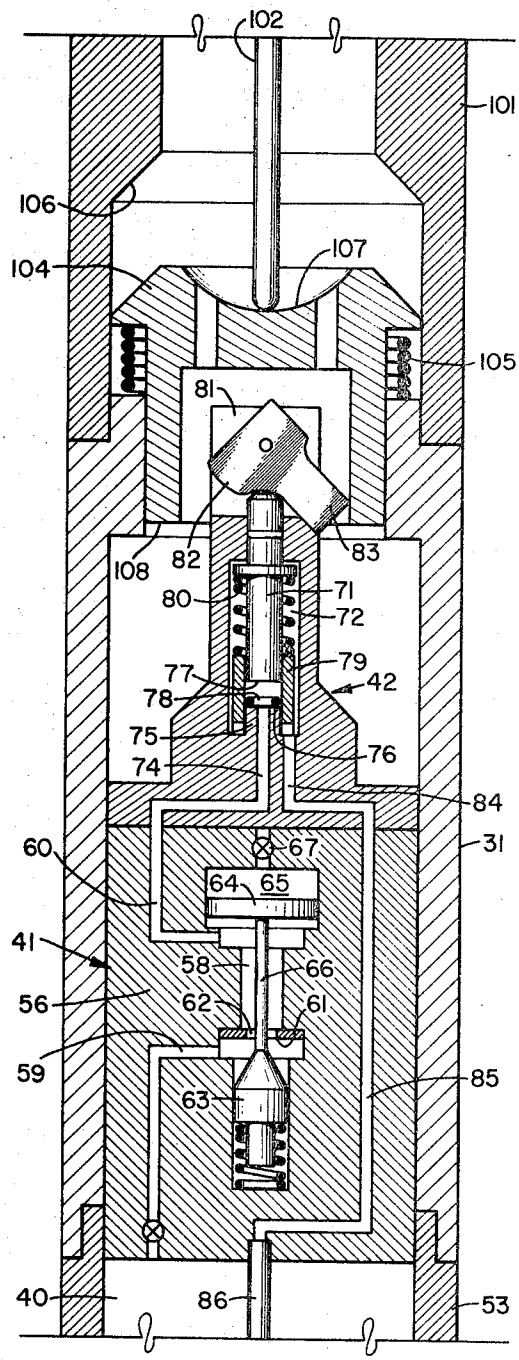

FIG. 4

INVENTORS
ROBERT J. BLACKWELL
ROBERT C. RUMBLE
BY
ATTORNEY

PRESSURE CORE BARREL

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates generally to core barrels and more specifically to pressure core barrels used to recover samples of subterranean formations.

In order that the data obtained from core analyses have significance, the core must be representative of the reservoir rock. The changes in environmental conditions of the core between the formation and the laboratory tend to alter the fluid content and saturation values. The pressure core barrel was developed to recover cores at pressurized conditions by pressure sealing the cut core prior to surfacing operations. This technique was not entirely successful principally because the reduced ambient pressure and temperature conditions at the surface resulted in the dissolution and expansion of gases which altered the quantitative and qualitative values of fluids contained in the core. Subsequently, the pressure core barrel was equipped with a gas accumulator. The purpose of the accumulator was to provide a pressure-charged expansion chamber which acted as a pneumatic spring to counteract pressure loss from core barrel expansion and thermal expansion of gases. Because of the restrictive dimensions of the core barrel, the capacity of the expansion chamber was small. This, coupled with the fact that the expansion chamber pressure (control pressure) could not exceed formation pressure, meant that any expansion of the chamber resulted in corresponding diminution of the control pressure in accordance with the gas laws governing the relationship of pressure, volume and temperature. Moreover, it was found that even small leaks of liquid from the pressure-sealed chamber and of gas from the accumulator significantly reduced the control pressure. In summary, then, the presently-known pressure core barrels are inherently sensitive to environmental changes and to accumulator gas leakage, which cumulatively effect pressure reductions on the cores contained therein.

The purpose of the present invention is to provide a pressure core barrel capable of retrieving cores at a controlled pressure and which is operatively insensitive to changes in environmental pressure, temperature, and liquid and gas leakage. The control pressure is normally set at or near the pressure imparted on the formation during coring operations. Basically, the core barrel contemplated by the present invention is an improvement over the previously described pressure core barrel and includes a high-pressure gas supply in pressure communication with the accumulator chamber through a pressure regulator. The pressure regulator functions to supply a reduced, constant-pressure gas to the accumulator thereby compensating for volumetric expansion of the barrel, gas shrinkage, and liquid and gas leakage.

The apparatus constructed according to the present invention comprises a core tube, a closure means for pressure sealing the tube, and a pressure control system in communication with the tube for maintaining a constant preset-pressure therein. Since the need for maintaining the pressure does not arise until the core is cut, it is desirable from an operational standpoint to maintain the pressure control system inactive until the core tube is sealed. If the system were active during running-in and core-cutting operations, a considerable amount of gas leakage would occur which would substantially reduce the control capacity of the system. Accordingly, an added feature of the present invention is the provision of a mechanical actuator for activating the control system at the proper time in the coring operation. In the preferred embodiment of the invention, the control system is operatively responsive to actuation of the closure means.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view diagrammatically illustrating the core barrel assembly in the open, core-cutting position.

FIG. 2 is a view similar to FIG. 1 illustrating the core barrel assembly in the closed, pressure-sealing position.

FIG. 3 is an enlarged fragmentary view of portions shown in FIGS. 1 and 2 illustrating the pressure control system in the inoperative position.

FIG. 4 is a view similar to FIG. 3 illustrating the control system in the operative position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIGS. 1 and 2, a core barrel assembly 10 constructed according to this invention is seen to include generally an outer barrel 11 and an inner barrel 12 interconnected by a slip joint assembly 13. The outer barrel 11 is made up of sections 16, 17, and 18 and connecting subs 19, 20, 21, and 22. The upper section 16 houses the slip joint release assembly 13 and includes upper lugs 23 for mating with lugs 24 formed in sub 19. Sub 19 is threaded for connection to a drilling string (not shown). With the slip joint assembly 13 locked, the core barrel assembly 10 is in the core-cutting condition. Actuation of the slip joint assembly 13 permits relative axial movement of the outer barrel 11 and inner barrel 12 placing the assembly 10 in the core-retaining condition. Sections 16 and 17 house the pressure control system described in detail below. Section 18 in combination with portions of the inner barrel 12 provide a pressure chamber 26 for pressure sealing the cut core following the cutting operation (See FIG. 2). More specifically, the upper limit of the pressure chamber 26 is defined by sub 21 having a downwardly-facing valve seat 27 formed therein. The lower extremity of the pressure chamber 26 is closed by a ball valve shown generally as 28. Sub 22 interconnects the ball valve 28 and a core bit 29.

The inner barrel 12 is suspended from a swivel connection 30 and includes an upper section 31 which houses a portion of the pressure controls and a lower core tube 32. Core tube 32 defines a core receiving chamber 33 closed at the top and open at the bottom. Tube 32 terminates in a core shoe 34 which serves to retain and break the cut core. An upwardly-facing annular shoulder 35 formed in the head 37 of the tube 32 is sized to mate with the valve seat 27. O-ring 36 disposed circumferentially around the tube head and immediately above shoulder 35 provides a fluid seal between tube 32 and sub 21.

During running-in and cutting operations, the disposition of the assembly 10 is that shown in FIG. 1 wherein core tube 32 extends through the open ball valve 28 placing shoe 34 in the proximity of the core bit 29 with their respective openings being in axial alignment. The slip joint assembly 13 is in the locked position preventing relative axial movement of the outer and inner barrels 11 and 12. During the cutting operations the outer barrel 11 is rotated by the drill string while the inner barrel 12 remains stationary. The swivel connection 30 permits the relative rotation of the two barrels 11 and 12. The cutting operation proceeds until a cylindrical core substantially fills the coring chamber 33. The core barrel assembly 10 is then lifted a few feet off bottom. Upward movement of the assembly 10 separates the core received in chamber 33 from the uncut formation. Note that the pressure on the core at this stage of the operation is equal to the hydrostatic pressure in the wellbore annulus. Next the slip joint assembly 13 is actuated permitting relative axial movement of the outer and inner barrels 11 and 12, respectively. The outer barrel 11 gravitates downward until core barrel seat 27 engages the core tube shoulder 35 with the O-ring 36 providing the top pressure seal for pressure chamber 26 (See FIG. 2). The final increment of downward movement of the outer barrel 11 closes the ball valve 28 through action of a rack and pinion device 38 thereby sealing the lower end of the pressure chamber 26. Thus the core contained in the tube 32 is pressure sealed at or near formation pressure.

The core barrel described to this point represents a conventional pressure core barrel, the function of which is to pressure seal the core at or near bottom-hole pressure. The difficulty with this apparatus has been the maintenance of the pressure in chamber 26 when the assembly 10 is raised to the surface. The surfacing operation brings into play several factors which

cumulatively tend to reduce the pressure in chamber 26. For example as the hydrostatic pressure surrounding assembly 10 decreases, outer barrel section 18 expands increasing the volume in chamber 26 causing a decrease in pressure therein. Also temperature decreases tend to reduce the chamber pressure. The effect of the pressure reduction in chamber 36 is to alter the fluid content and saturation of the core.

The present invention provides a control system, which functions to maintain a controlled pressure in the pressure chamber as the assembly 10 is withdrawn from the wellbore.

Briefly, the system includes a high-pressure gas chamber 40, a pressure regulator 41, a shutoff valve 42, a valve actuator 43, and an accumulator 44. In operation, the regulator 41 receives a high-pressure gas from the supply in chamber 40 and delivers a constant-pressure gas to the accumulator 44 which through the action of a free piston transmits that pressure to the pressure chamber 26. Now, when the pressure barrel section 18 expands owing to the decrease in external hydrostatic pressure, the accumulator 44 compensates for the increased volume thereby maintaining pressure in the chamber 26. The regulator 41 provides a continuous supply of controlled-pressure gas to compensate for gas leakage from the accumulator 44 and pressure reduction caused by piston movement.

As shown diagrammatically in FIG. 2, the components 40—44 of the control system are assembled in stacked relation forming the upper part 31 of the inner barrel 12.

The accumulator 44 includes a housing 45 which defines an internal cavity. A member such as a piston 47 is sealingly mounted for free axial movement in the accumulator 44 dividing it into upper and lower compartments, 48 and 49, respectively. The accumulator 44 is connected to the core tube 32 by a link 50 which joins the lower end of housing 45 and the core tube head 37. A passage 51 traverses housing 45, link 50, and core tube head 37, providing fluid communication between compartment 49 and core chamber 33. Valve 52 mounted in tube head 37 provides means for closing passage 51 to facilitate surface handling of the assembly. During running-in and cutting operations, drilling fluid such as mud, water, or other suitable liquid fills passage 51 and compartment 49 so that the pressure in compartment 49 is transmitted undiminished to the core chamber 33 and hence the pressure chamber 26.

Mounted on the upper end of housing 45 and extending upwardly therefrom is a hollow tube 53 which provides the gas supply chamber 40. The tube 53 must have sufficient structural strength to contain gas at relatively high pressure. The capacity and pressure requirements of the gas chamber 40 will depend upon particular applications. Allowing for leakage and gas expansion, a 2 liter chamber charged to 4,000 p.s.i.g. with nitrogen should serve satisfactorily for applications to depths up to 6,000 feet. Of course, for deeper boreholes, the precharge pressure must be increased in accordance with increased anticipated bottom-hole pressures. A valved outlet port 55 extending through the top closure of chamber 40 supplies high-pressure gas to the regulator 41 described below.

Regulator 41 operates to receive a variable, high-pressure gas from the supply and deliver a reduced, constant-pressure gas to the accumulator 44. One type of pressure reducing regulator that is particularly adaptable to the core barrel service is the dome-loading, pressure-reducing regulator such as the Series 26-2000 Dome Loaded Regulator manufactured by Tescom Corporation of Minneapolis, Minnesota. As diagrammatically illustrated in FIGS. 3 and 4, the regulator 41 includes a body 56 supported internally of section 31 which is threadedly connected to the upper end of tube 53. The body 56 has formed therein a valve cavity 58, inlet port 59, and outlet port 60. A valve seat 61 defining orifice 62 is mounted in the cavity 58. A spring-loaded valve stem 63 is urged against the upstream side of seat 61 and in combination therewith accurately meters flow through orifice 62. The upper end of cavity 58 is enclosed by piston 64 forming dome chamber 65. Rod 66 interconnecting piston 64 and stem 63 provides the means for positioning stem 63 in relation to seat 61 responsive to pressure in dome chamber 65. Dome chamber 65 is precharged with a suitable gas, e.g. nitrogen, to about the pressure imparted by the hydrostatic head of the mud column on the formation to be cored. Now, because of the opposed forces acting on the stem 63, the flow area through orifice 62 is a function of the pressure downstream of seat 61. Valved port 67 provides access to chamber 65 for pressure charging thereof. Inlet port 59, in registry with high-pressure gas supply outlet port 55, conducts high-pressure gas to valve cavity 58. Thus high-pressure gas is received in regulator 41 at the supply pressure and delivered via outlet port 60 to the shutoff valve 42 at the dome pressure.

The shutoff valve 42 is functionally located between the high-pressure gas supply chamber 40 and the pressure chamber 26 and operates to pressure seal the high-pressure gas until the pressure chamber 26 is closed. In this embodiment of the invention the valve remains closed until the means for closing the pressure chamber 26 is actuated. The valve 42 includes a body 70 secured to the top of regulator 41, a valve stem 71 movably mounted in a valve cavity 72 formed in the body, and an actuator 73 for axially moving the stem 71. Inlet port 74 discharges into cavity 72 through upset extension 75. Extension 75 provides an annular seat 76 aligned with the lower end 77 of stem 71. An O-ring 78 is interposed between seat 76 and end 77 and, with the valve 42 in the closed position, is compressively held against seat 76 by the stem 71. A loose-fitting sleeve 79 maintains the O-ring 78 in proper alignment. The stem 71 is urged upwardly against the actuator 73 by a compression spring 80.

The actuator 73 is pivotally mounted on a tab 81 secured to valve body 70 and is configurated to provide a lobe 82 and arm 83. With the valve 42 in the normally closed position (FIG. 3), the upper end of stem 71 bears against the lobe 82 maintaining the arm 83 in a generally horizontal attitude. The valve 42 is opened by downward pivotal movement of the arm 83 which angularly removes the lobe 82 from engagement with the stem 71. The compression spring 80 forces the stem 71 upwardly displacing it from O-ring 78 to the open position shown in FIG. 4. The gas enters the cavity 72 and exits through an outlet port 84 which is in fluid communication with the upper compartment 48 of the accumulator 44 via passage 85 and tube 86.

As mentioned previously, actuation of the slip joint assembly 13 permits relative axial movement of the inner and outer barrels 11 and 12, the effect of which is to close and pressure-seal chamber 26. In this embodiment, the shutoff valve 42 is designed to open in response to actuation of the slip joint assembly 13 whereby the control system is activated simultaneous to the closing of the pressure chamber 26.

With reference to FIG. 2, the slip joint assembly 13 includes a sleeve 90 integrally formed with sub 19 and a detent assembly 89 for maintaining the outer and inner barrels 11 and 12 in locked relation. Sleeve 90 is normally disposed internally of outer barrel section 16 and has its lower end threadedly connected to the swivel 30 from which the inner barrel 12 is suspended. The sleeve 90 has four circumferentially-spaced apertures, one shown as 91, which are normally in registry with an internal groove 92 formed in the section 16 (See FIG. 1). Pins 97 inserted through apertures 91 and received in groove 92 prevent axial movement of the outer barrel 11 and sleeve 90. A hollow release pool 93 slidably mounted in sleeve 90 is urged upwardly into abutting engagement with a snap ring 94 by compression spring 95. The lower end of the spool 93 is enlarged providing an outer annular surface which fits in close conformity in the sleeve 90. With the spool 93 in engagement with the snap ring 94, the annular surface confronts the apertures 91 thereby holding pins 97 in their respective apertures and groove. Formed in the upper end of spool 93 is an upwardly-facing beveled seat 98. The slip joint assembly is actuated by ball 99 pumped down the drilling string. When ball 99 sealingly engages seat 98, pressuring up of the mud column in the drilling string forces the release spool 93 downwardly

against the bias of spring **95**. This removes the annular surface out of confining relation with pins **97** thereby unlocking the slip joint connection between the inner and outer barrels, **11** and **12**. Bypass ports **100** formed in sleeve **90** are closed off with the slip joint assembly locked (FIG. **1**) so that the drilling fluid is conducted through the barrel assembly **10** during running-in and coring operations. Axial downward movement of the outer barrel **11** opens the ports **100** permitting passage of the drilling fluid as the core barrel assembly **10** is withdrawn from the hole.

The valve actuator assembly **43** is operatively responsive to the tripping of the slip joint assembly **13**. A hollow linkage **101** interconnects the swivel **30** and the upper section **31** of the inner core barrel **12**. Ports **109** formed in linkage **101** directs drilling fluid to the annulus between the outer and inner barrels **11** and **12**. A rod **102** suspended from the release spool **93** by a spider **103** extends downwardly through the spool **93**, the swivel **30** and linkage **101** and has its lower terminus proximate an inverted cuplike member **104**.

As shown in FIGS. **3** and **4** the member **104** is yieldably mounted in the lower end of linkage **101**, spring **105** urging it into abutting engagement with a shoulder **106** formed internally of linkage **101**. The top of the member **104** is provided with a concave surface **107**, the bottom of which is aligned with the rod **102**. An annular surface **108** of member **104** is aligned to trip the arm **83** of valve actuator **73** attendant to downward axial movement of member **104**. Thus as the spool **93** is moved downward, the rod **102** engages concave surface **107** of member **104** forcing it downwardly against the bias of spring **105**. The member **104** in turn engages arm **83** pivoting it about the pin connection and thus opening valve **42**. Opening of valve **42** actuates the control system which sends a pressure signal to the accumulator **44** via passages **84**, **85**, and **86**. The overcenter position of the stem **71** in relation to the lobe **82** maintains the valve **42** in the open position even when the member **104** returns to its normal position.

While at the surface, the core barrel assembly **10** is prepared for operation as follows: the supply chamber **40** is pressurized; the dome chamber **65** is charged to the pressure giving the proper control pressure; the shutoff valve **42** is placed in the closed position; and the slip joint assembly **13** is placed in the locked position (FIGS. **1** and **3**). With the components thus arranged, the assembly **10** is run in the hole on the drilling string and the core cut in the usual manner. Following cutting operations, the assembly **10** is lifted a few feet off bottom and the ball **99** is pumped down the drilling string. When the ball **99** seats on the spool **93**—which will be evidenced by an increase in pump pressure—the assembly **10** is in condition for closing the pressure chamber **26** and actuating the control system. This is accomplished by pressuring up the mud column in the drillings string by operation of the surface pumps. The spool **93** is forced downwardly actuating the slip joint assembly **13** and opening shutoff valve **42** in the manner described above. The outer barrel **11** drops, pressure sealing the chamber **26** and energizing the control system (FIGS. **2** and **4**). With this accomplished the core barrel assembly **10** is in a condition for withdrawal from the wellbore. As the assembly **10** is raised, the hydrostatic pressure and temperature in the wellbore gradually decrease. The consequent expansion of chamber **26** and changes due to thermal effects are counteracted by expansion of the accumulator compartment **48**. The pressure in compartment **48** is maintained at a constant value by operation of the regulator **41**. Thus, when the assembly reached the surface, the confining pressure on the core contained in tube **32** is substantially the same as the bottom-hole closed-in pressure.

Summarizing the effect of the improved pressure core barrel constructed according to the present invention, then, the novel control system enables the recovery of subterranean formation cores at a controlled pressure. The fluid content data obtained from such cores, accordingly, are representative of actual formation values.

We claim:

1. In a core barrel assembly for coring subterranean formations and having a core receiving chamber and closure means for pressure-sealing said chamber, an improved pressure control system for maintaining a controlled pressure in said chamber in the pressure-sealed condition, said control system comprising: a control gas supply having a pressure higher than said controlled pressure; a pressure regulator adapted to receive high-pressure gas from said supply and to deliver said gas at said controlled pressure; and means for transmitting said controlled pressure from said regulator to said chamber.

2. The invention as recited in claim **1** and further comprising a valve functionally located between said accumulator and said supply and being normally disposed in a closed position thereby preventing the transmission of control pressure to said chamber, and means for moving said valve to an open position permitting the transmission of control pressure to said chamber.

3. The invention as recited in claim **2** wherein said valve is functionally disposed between said regulator and said accumulator.

4. The invention as recited in claim **2** wherein said closure means of said core barrel assembly includes actuating means for effecting a closure of said chamber and wherein said means for moving said valve to an open position is operatively responsive to actuation of said actuating means.

5. The invention as recited in claim **1** wherein said means for transmitting said controlled pressure to said chamber includes an accumulator having a cavity formed therein and a member sealingly and movably mounted in said cavity dividing it into a gas compartment and a liquid compartment, said gas compartment being in fluid communication with said regulator for receiving gas at said controlled pressure, said liquid compartment being in fluid communication with said chamber whereby the controlled pressure is transmitted to said chamber.

6. The invention as recited in claim **5** wherein said regulator is a dome-type, pressure-reducing regulator having a dome chamber charged at a predetermined pressure such that said regulator delivers gas at said controlled pressure.

7. The invention as recited in claim **6** wherein said predetermined pressure is such to provide a control pressure substantially equal to the pressure imparted on the formation during coring operations.

8. A pressure core barrel assembly comprising: an inner barrel adapted to be connected to the lower end of a drilling string and including a core tube; an outer barrel slidably mounted around said inner barrel; a slip joint assembly for lockingly interconnecting said inner and outer barrels in a core-cutting condition; means for tripping said slip joint assembly thereby permitting relative axial movement of said barrels to a core-retaining condition, said barrels in said core-retaining condition defining an enclosed pressure chamber, said core tube being disposed in said pressure chamber with said barrels in said core-retaining condition; and a pneumatic control system carried by said inner barrel for maintaining a controlled pressure in said pressure chamber and including a gas supply, a pressure-reducing regulator in fluid communication with said gas supply and operative for delivering gas at said controlled pressure; and means for transmitting said controlled pressure from said regulator to said pressure chamber.

9. The invention as recited in claim **8** wherein said control system further comprises: a valve having a closed position for preventing the transmission of said controlled pressure to said pressure chamber, and a valve actuator for moving said valve to an open position thereby permitting the transmission of said controlled pressure to said pressure chamber.

10. The invention as recited in claim **9** wherein said valve actuator is operatively connected to said tripping means and is actuably responsive to actuation thereof.

11. The invention as recited in claim **10** wherein said tripping means include a detent assembly normally locked for locking said barrels together, and a ball adapted to be pumped

through said drilling string and to forcibly engage said detent assembly for moving said assembly to an unlocked position, said valve actuator being operatively responsive to actuation

of said detent assembly whereby said valve is moved to the open position by the forcible engagement of said ball on said detent assembly.