April 8, 1947. L. S. CHAMBERS 2,418,500

APPARATUS FOR SAMPLING FORMATION FLUIDS

Filed March 17, 1942 2 Sheets-Sheet 1

Fig. 1.

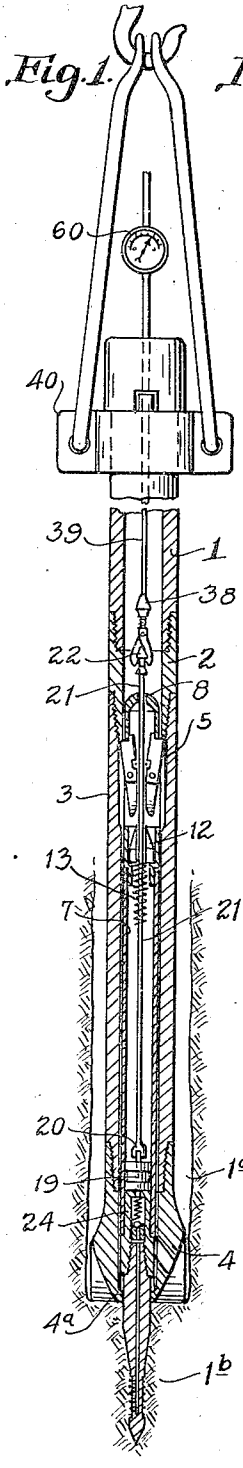


Fig. 3.

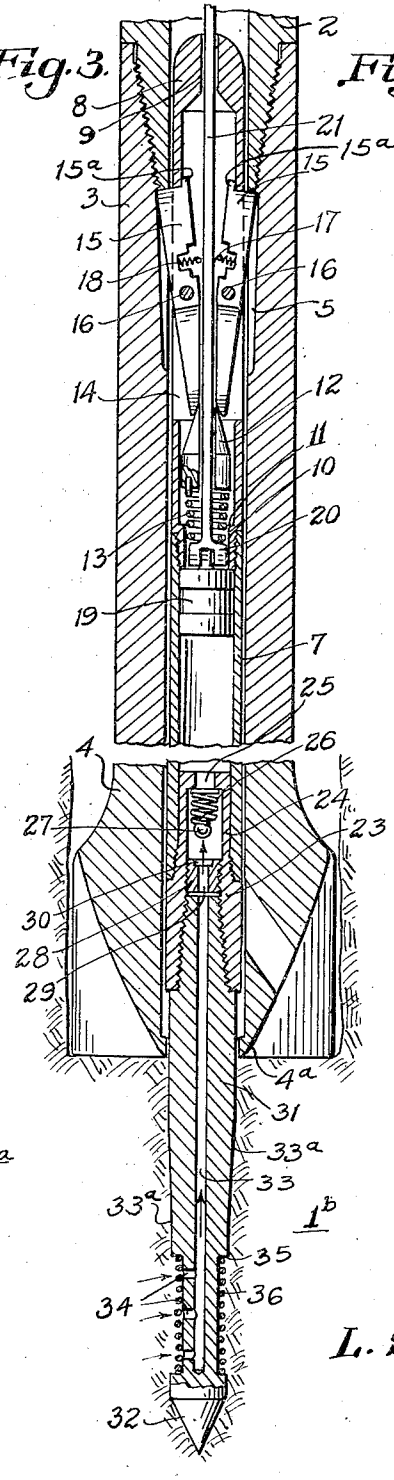
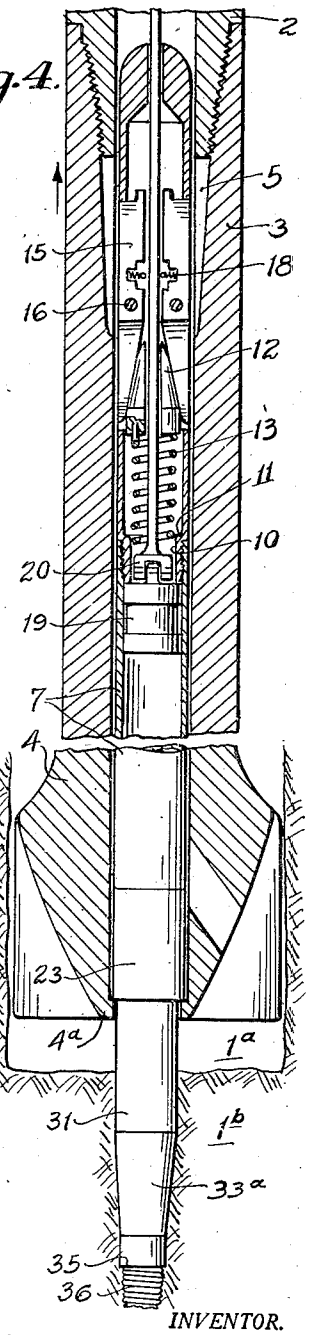


Fig. 4.



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Fig. 7.

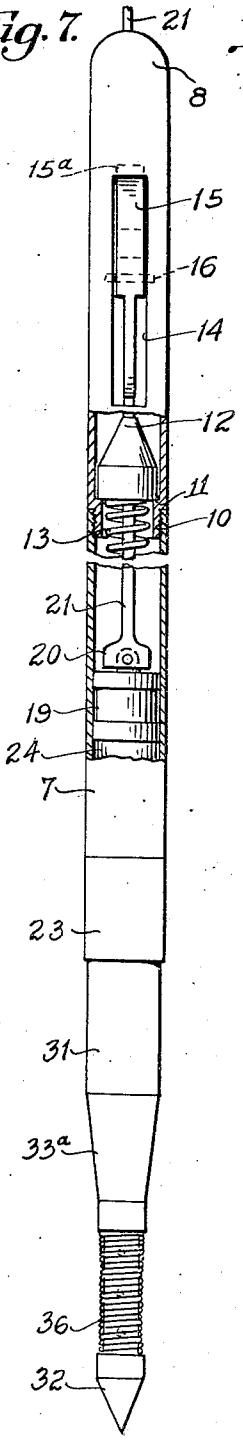


Fig. 2.

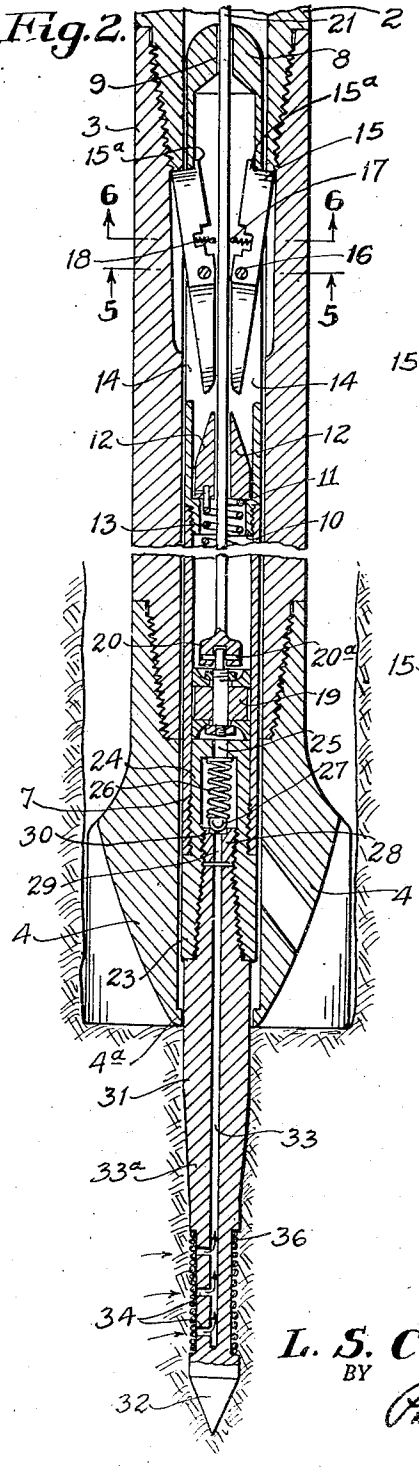


Fig. 5.

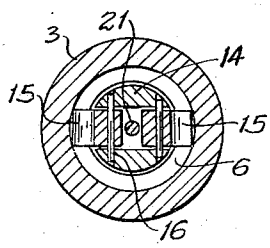
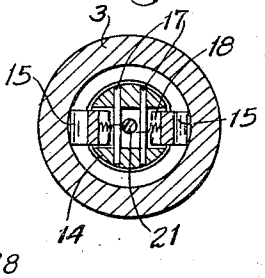


Fig. 6.



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APPARATUS FOR SAMPLING FORMATION FLUIDS

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5 Claims. (Cl. 255—1.4)

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This invention relates to an apparatus for evaluating the productivity of horizons such as oil, gas or water horizons. Of the many methods which are now available to petroleum engineers and geologists for determining the characteristics of the various subsurface beds for purpose of evaluation of their productivity, without actually producing fluid from them, there are but two methods for direct evaluation. These methods are the coring method and the production test method.

I have now devised a method and apparatus for evaluating the producing capacity of a formation without actually putting the well in production from the formation. This is based upon an entirely new principle constituting a departure from all other methods known to me. This method is based upon the discovery that formations containing fluid such as gas, oil or water, even though many thousands of feet beneath the surface, may be sampled by a tool which is driven under the weight of the string of drill pipe into this subsurface formation, to a sufficient depth to be sealed therein, and that fluid may be withdrawn from such formation at the pressure of the formation and sealed and withdrawn to the surface for analysis. Such sampling of this formation at the pressure thereof permits of the exact evaluation of the formation and the composition of the fluid in the formation. In contradistinction to all other methods involving the sampling of the fluid present in a formation, this method samples the fluid at the phase equilibrium conditions present in the formation and thus the fluid is sampled without phase separation.

This method has definite advantages over ordinary coring and over the pressure core barrel as a method of sampling the formation fluid, since in such a core barrel the sample is limited to the volume of fluid caught in the capillarities of the core. Additionally, as Bureau of Mines investigations have shown, the washing action of drilling fluid used in drilling to the zone at which the core is cut usually washes considerable formation fluid out of the formation which is cored, so that the analysis of the core gives an inaccurate evaluation of the amount and composition of the fluid in the formation.

By my apparatus, a large sample is taken from several inches below the bottom of the bore hole. I am able to sample the formation approximately 6 inches to 1 foot below the bottom of the hole and have avoided the influence of this washing action. Also by withdrawing fluid from such a

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relatively large section of formation in comparison with that removed, I am able to draw the fluid from a considerable region of formation in around the punch, and thus further avoid the influence of the washing action.

When such sampling is done by methods involving the flow of fluid into the well bore, or into a string of pipe attached to a sampler, there is a release of pressure at least equivalent to the difference in frictional resistance of the formation and the flow string. The pressure in the drill string is lower than the formation pressure and is lower at the top of the oil level in the pipe than it is at the bottom next to the formation. This reduction in pressure is avoided by my method.

In the bottom hole sampler, the fluid in the hole is the production of the formation and has been discharged from the formation into the well bore. The sample is taken after the oil has been put on production from a formation which has been drilled. The pressures existing in the well at its bottom is less than formation pressure. The sample is taken at the pressures in the well at the sampling point. The consequent release of pressure in such test results in a separation of gas from the oil and in fact the production test is incapable of giving information as to the gas-oil ratio. The bottom hole sampler is of no value in determining the productive capacity of a formation about to be drilled, or which has not yet been produced.

It will be observed that by my apparatus the formation is sampled at the pressure of the formation, while the hole is full of drilling fluid, and before the well produces oil into the well bore from the formation sampled. The fluids being withdrawn from the formation into a sealed chamber assures that the sample is taken before any phase separation occurs, so that the true sample of all of the formation fluids, gas, oil and water, is taken. The sample will contain all these components in the ratio in which they are present in the formation.

Because of the simplicity of my test method and the rapidity with which the test can be made, I can repeat my test as frequently as desired as the coring or drilling proceeds.

It is a further object of my invention to withdraw a sample of the formation fluid from a formation into a chamber sealed in the formation to be tested. The pressure on the fluid thus removed into the chamber is allowed to come to

equilibrium with the pressure of the fluid in the formation.

It is another object of my invention to seal this chamber in the formation by driving a punch into the formation, which punch is connected by a conduit to the sample receiving chamber.

It is a further object of my invention to drive the punch by the weight of the drill string and to hold such punch in the formation by such weight.

It is a further object of my invention to employ a sampling device which may be introduced into the drill string and withdrawn therethrough.

It is a further object of my invention to employ a sampling tool which permits of the withdrawal of samples into a chamber in which a piston is moved to introduce the sample by means of a line passing through the drill string.

It is a further object of my invention to determine the formation pressure of a formation by withdrawing a given volume of sample of formation at the pressure of the formation and without separation of any components thereof, and then measuring the pressure of said sample when maintained at said volume and at the temperature at which said sample is withdrawn from the formation.

It is a further object of my invention to determine the physical or chemical characteristics of fluids present in a formation by taking a sample of the fluids in such formation without permitting separation of the components of said fluid at their end in said formation and determining the characteristics thereof.

Further objects of my invention will be made clear by further description of my invention, taken together with figures illustrating the apparatus, of which:

Fig. 1 is an assembly shown partly in section of my test apparatus positioned in a drill string.

Fig. 2 is a vertical section of the lower portion of the apparatus of Fig. 1 showing the position of the several parts prior to the withdrawal of the sample.

Fig. 3 is a vertical section of the lower portion of the drill string showing my apparatus in position and showing the initial stage of the withdrawal of the sample.

Fig. 4 is the same section showing the position of the various parts of my apparatus upon the complete withdrawal of the sample.

Fig. 5 is a section taken along 5—5 of Fig. 2.

Fig. 6 is a section taken along 6—6 of Fig. 2.

Fig. 7 is an elevation of the tester as withdrawn from the drill string, showing the position of the wedge in the broken away portion.

The tester consists of a barrel 7 into the end of which is screwed a latch assembly 8, provided with a bore 9 through which is passed a piston rod 21. The latch assembly is screwed into the barrel 7 at the reduced screw threaded portion 10. This portion is provided with a shoulder 11. The conical wedge 12 is positioned within the latch assembly 8 at the lower end thereof. It is provided with a central bore through which the piston rod passes. Attached to the conical wedge 12 is a freely suspended spring 13 surrounding the piston rod 21. Between the walls 14 of the latch assembly 8 are positioned two latches 15 mounted upon the pins 16 carried by the walls 14. These latches are swingably mounted upon these pins. Between said walls 14 are also mounted two pins 17 to which are connected springs 18. These springs are also connected to the latches 15 at suitable cut out portions as shown. The springs tend to hold the tops of the latches 15 outwardly in the positions shown in Fig. 1 and Fig. 2.

Connected to the piston rod 21 is a piston 19 positioned within the barrel 7. The piston rod is connected at 20 to the piston. The connection 20 carries a shoulder of such dimensions as to engage the spring 13 as will be described later. Attached to the bottom of the barrel 7 is a valve assembly 24, carrying a port 25 communicating with the barrel 7. Within this assembly is positioned a check valve 27 acting against a spring 26. The valve assembly carries a valve seat 28 provided with a suitable seat for the valve 27 shown at 30. This may be made of fiber or any other suitable material. A bore 29 communicates with the valve chamber 24. Into this valve assembly is screwed the punch 31. This punch carries a longitudinal bore 33 and horizontal bore passages 34. The punch ends in a head 32 which may be in the form of a cone or may be a cutter head or any other form of head which would permit of the punching of the formation. The barrel of the punch is made conical in section at 33*a* to provide a wedge action to seal the tool in the formation as will be described later. The barrel is provided with a recessed portion shown at 35 which may be wound with wire so as to provide the ports 34 with a screen portion to prevent introduction of fractured portions of the formation into the bore and thus to prevent clogging.

This device may conveniently be used in combination with a core head 3 of the kind commonly employed with wire line coring outfits. Such core heads are provided with a cutter head 4 carrying a shoulder 4*a* at the bottom of the inner barrel. Such core heads may also be provided with an enlarged section 5 into which a sub 2 is screwed. Sub 2 is connected to the drill string 1. The lower end of the sub 2 provides a shoulder against which the latches are seated, as will be described below.

As will be understood, the drill pipe is positioned in a rotary table and in a derrick as is conventional in oil well drilling operations.

When the sampling is desired, the core head 4 is raised off bottom by means of elevators 40 attached to the "kelly" or drill stem which is in turn attached to the drill pipe 1. The tester with the piston positioned upon the valve assembly 24, in the position shown in Fig. 2 and Fig. 1, is dropped into the drill pipe. It will be understood that the wire line 39 shown in Fig. 1 to be attached to the head 22 by means of the overshot 38 is not so attached. The device is allowed to descend by gravity, or may be circulated down by drilling fluid which is pumped at the same time. When this procedure is to be employed the mud swivel is attached to the drill stem after the tester is inserted, and mud is pumped down on top of the tester.

The drill string and the bore hole are full of drilling fluid so as to prevent the entrance of formation fluid into the bore hole. As the tester passes down through the drill pipe 1 and through the drilling fluid therein, the top of latches 15 will be urged outwardly by springs 18 and the latches will ride over the inner wall of the bore of the pipe 1. The cutter head 4 is off bottom a distance of at least equal to the length of the punch 31. When the unit has descended sufficiently far so that the latches 15 clear the shoulder of the sub 2, the latches will enter the enlarged portion 5 and the springs will push the

latches outwardly until the stops 15*a* are in contact with the wall of 8 in the position shown in Figs. 1 and 2. The top shoulder of the latch will be below the bottom shoulder of the sub 2. The lower end of the valve assembly 23 will rest on the ledge 4*a*.

The assembly is now ready to pierce the formation by being driven into the formation. This is done by lowering the string of drill pipe 1. The full weight of this string of pipe which may amount to several thousand pounds, settles upon the shoulders of the latches 15 and the punch 32 is driven into the formation in the position shown in Figs. 1 and 2. The punch will be driven into the formation for a distance equal to that required for setting the core head 4 on the bottom of the bore hole.

It will be observed that the punch barrel 31 is sealed from the well bore by the formation into which it is punched. There is imposed upon the upper face of the piston 19 the hydrostatic head of the drilling fluid in the drill string. On the under face of the check valve we have the formation pressure.

An overshot is lowered at the end of a wire line into the drill pipe and descends until it engages the head 22. A load indicator 60 is positioned on the wire line. Such load indicators are well known in drilling operation and will measure the pull which is imposed upon the wire line 39. The piston rod is now withdrawn slowly. It is therefore necessary to impose upon the wire line 39 a pull equal to the difference between this hydrostatic head and the formation pressure. Since the hydrostatic head of the formation fluid is a constant, by maintaining a constant pull at a constant load value the barrel underneath the piston will be filled with fluid and there will be maintained on the underneath side of the piston a pressure equal to the formation pressure existing upon the face of the formation into which the punch has been pushed. This pressure will lift the valve 27 against the compression of the spring 26 and the fluid will flow into the barrel underneath the piston 19. It is desirable to withdraw the piston in small stages of withdrawal with rest periods between each stage of withdrawal. This allows the pressure in the barrel to come to equilibrium with the formation pressure and assures that the fluid pressure in the barrel is maintained at the formation pressure.

There is an advantage to this stage withdrawal of the fluid, since it permits of pressure equalization and does not permit of large fluctuations of pressure in the barrel. This prevents separation of dissolved gas and assures that sampling will occur without any substantial separation of the component parts. If the piston were suddenly raised a large distance so as to cause an evacuation of the barrel, this would permit the formation pressure to rush into a space at low pressure. Substantial phase separation and gas release would occur. While the pressure would rise to reestablish pressure equilibrium between the formation and the barrel, it will be found that the gas will not redissolve into the oil to re-establish the original composition of the oil. This could only be approached by vigorous mixing of the gas and oil at that pressure. This sudden rush of oil into a region of very low pressure would also give a false sample in that if there is free gas along with the oil the gas will be preferentially withdrawn so that the sample will show a much greater proportion of gas to oil than is present in the formation.

It is therefore desirable to limit the piston withdrawals so that only moderate adjustments of pressure are made, and ideally it is withdrawn at the same rate as the formation fluid flows out of the formation into the sampler. This insures that the formation is sampled at the pressures of the formation.

The spring should be sufficient to seat the valve, but not such as to cause any material difference in pressures across said valve. It will be observed that the sample is taken by pulling up on the wire line while holding down by the weight of the drill pipe. There are therefore two forces operating in opposite directions, one a holding down force which holds the barrel of the tester in place, and an opposite force which withdraws the piston and permits of the taking of the sample.

The piston is withdrawn until the top of the piston is brought against the lower end of the spring 13. The continued upward movement of the piston 19 will raise the spring and the conical wedge 12 against the lower end of the latches 15 as shown in Fig. 3. The further upward movement of the piston 19 will compress this spring between the piston and the wedge, and the piston will move until it reaches the lower end of the reduced portion 10. The arrival of this piston at this point will be evidenced by an increasing load as indicated at the indicator 60, since any further pull will constitute a lifting of the whole string of drill pipe 1.

When the piston is at the extreme of its upward movement the pressure in the barrel 7 is in equilibrium with the formation pressure. The spring 26 will seat the valve 27 on its seat 30. There is therefore trapped inside the barrel 7 between the underneath side of the piston and the valve seat 30 a sample of formation fluid at the pressure of the formation. This space is therefore full of fluid and the sampler is ready for removal.

It will be found that in testing even the deepest wells, the hydrostatic pressure on the upper face of the piston 19 will not be so great, even though no fluid is present in the formation to be tested, as to require a pull on the wire line such as to cause a parting of the line. However, a precaution against this may be provided by means of a shear pin 20*a*. When the pull is so great the pin 20*a* will part before either the wire line or the piston rod parts. The coupling will be moved upward to unlatch the latch assembly as previously described.

When the signal of the arrival of the piston at the top of the stroke is received, i. e. when the load as indicated by 60 suddenly rises, tension is maintained in the wire line 39 to hold the piston at its upward extreme position, and the elevators are lifted to pull the drill string 1 and the core barrel 3 and the cutter 4 off bottom, as shown in Fig. 4. The weight has now been taken off the top of the latches 15 and the compressed spring 13 moves the wedge 12 upward, moving the top of the latches 15 inwardly as shown in Fig. 4. The lifting of the string of pipe will cause an engagement of the shoulder of the valve seat 23 with the shoulder 4*a* and as the drill string is lifted the punch is withdrawn from the formation.

The tester is now withdrawn by lifting the wire line. The drill string may remain in place in the bore hole and the tester withdrawn through the drill pipe to the center.

Coring and drilling may now be resumed to

a desired depth and the test repeated when the new core is withdrawn. Since we may employ the same core head as is used with wire line core barrels, it is merely necessary to withdraw the wire line core barrel with its core and introduce the sampler in its place. Such a procedure permits of taking the sample with substantially no interruption in the coring procedure.

It will be observed that in carrying out the method according to the description given above, there will be trapped, along with the formation fluid, some portion of the drilling fluid. Thus, in introducing the tester into the drill string with the piston in the position shown in Figs. 1 and 2, some drilling fluid which is present in the drill string, will enter through the ports 34 and will pass up through the bore 33 and will unseat the valve 27 due to the hydrostatic head of the fluid, and will enter underneath the piston.

Since the hydrostatic head underneath the piston and on top of the piston will be the same, the piston will not be moved upwardly, and when this balance is attained the spring 24 will shut the valve by seating the ball 27 on its seat 30. When a sample is taken the withdrawal of the piston upwardly causes the movement of fluid from the formation into the barrel 7, and there will be trapped in this barrel along with the formation fluid, that portion of the drilling fluid which has entered the bore 33.

It is however possible, if it is desired, to avoid this contamination. This may be carried out in the following manner. Prior to the screwing of the valve chamber 23 into the barrel 7, the valve chamber is filled with mercury through port 34 until it fills the valve chamber. The barrel is then screwed onto the valve chamber 23, keeping the chamber in upright position. The punch 31 is then filled with mercury. Mercury is poured into the bore 33 through a funnel of suitable character until the mercury starts running out of the ports 34. A piece of frangible adhesive tape such as Cellophane tape adhesively coated, is then pasted over the ports 34. With the punch in upright position, the whole sampler assembly is screwed onto the punch which is held in upright position during this operation.

The head of the piston may be so designed that the free space underneath the piston is of negligible volume. The volume of the port 29 may be held to a minimum so as to be negligible. When the tester is dropped through the drilling fluid in the drill pipe, the hydrostatic pressure exerted against the tape on ports 34 is greater than the pressure existing in the mercury column in 33 and if this pressure is sufficient to rupture the tape there will be an entrance of a small amount of formation fluid through the ports 34 to lift the mercury sufficient to fill the volume of the port 29 and the volume underneath the piston 19. This will be done by lifting the valve 27 from its seat by the hydrostatic pressure which was thus greater at the ports 34 than underneath the piston 19 and on top of the mercury in the valve chamber of valve assembly 26. When this vavle has been lifted in this manner, the pressure on top of the piston, underneath the piston, in the valve chamber, and in the bore 33 will be in equilibrium, and the spring 26 will seat the valve 27 on seat 30. When the punch is driven into the formation the tape will be torn away and the ports 34 will be exposed to the formation fluid. When the sample is taken the mercury will collect in the barrel 7, together with that insignificant amount of drilling fluid which has also been trapped with the mercury. It will be observed by proper design of the piston head and the valve seat that even this contamination by the drilling fluid may be minimized or completely avoided.

The oil may also be analyzed to determine the cut of the oil, i. e. how much water is present along with the oil in the formation. Such methods of analysis are well known. If the sample in the barrel 7 has been contaminated by drilling fluid the degree of contamination may be determined by analyzing the salinity of the water cut taken from the oil. Since fresh water low in salinity is used in making up a drilling fluid, and at any rate the salinity of the drilling fluid is known, any variation in salinity must be proportional to the water cut due to the connate water present along with the oil. Analogous methods for determining the degree of contamination of oil by drilling fluid is used in making core analyses for determination of connate water present with oil in a core, and will be understood by those skilled in this art.

Other tests may be made upon this oil to obtain different types of information. This all may be done because a sufficient sample is taken at the pressure and temperature of the formation so that all the fluids in the formation are sampled in the proportion in which they are present in the formation and at the pressure thereof. The sample is withdrawn, sealed at this pressure, and is taken to a laboratory where various analyses are thus made possible.

The foregoing description and accompanying drawings are illustrative of one embodiment of my invention. Various changes and modifications may be made therein within the scope of the appended claims.

I claim:

1. In combination, a drill string, a core head at one end of the drill string, a sub connecting said core head to said drill string, an enlarged section in said core head, a sampling device adapted to be lowered into said core head, said sampling device comprising a barrel, a piston in said barrel, a latch assembly at one end of said barrel, said latch assembly comprising a swingable latch adapted to engage said enlarged section whereby the weight of said drill string may be placed on said latch to hold said device in place in said core head, a piston rod passing through said latch assembly, a wedge surrounding said piston rod, and freely movable in a vertical direction to engage said latch, a spring freely suspended from said wedge whereby said spring is compressed between the piston and said wedge when said wedge is moved into engagement with said latch by said spring on compression by said piston, whereby said wedge will retract said latch when the weight of the drill string is taken off said latch and said piston is moved upward to compress said spring, a check valve at the other end of said barrel, a punch connected to said barrel, a conduit in said punch connected to said valve and said barrel whereby said punch is driven into said formation when the weight of said drill string is placed on said latch, means passing through the drill string from the surface and engaging said piston rod, whereby said piston rod may be raised to withdraw a sample from said formation and to compress said spring and lift the wedge into engagement with said latch and whereby the wedge will unlatch the said barrel when the weight of the drill string is raised off

said latch to permit the withdrawal of said sampling device.

2. A sampling device adapted to be lowered into a drill string carrying a core head at the bottom of said drill string, said sampling device comprising a barrel, a piston in said barrel, a latch assembly at one end of said barrel, said latch assembly comprising a swingable latch adapted to engage said drill string whereby the weight of said drill string may be placed on said latch to hold said device in place in said core head, a piston rod passing through said latch assembly, a wedge surrounding said piston rod, and freely movable in a vertical direction to engage said latch, a spring freely suspended from said wedge whereby said spring is compressed between the piston and said wedge when said wedge is moved into engagement with said latch by said spring on compression by said piston, whereby said wedge will retract said latch when the weight of the drill string is taken off said latch and said piston is moved upward to compress said spring, a check valve in said barrel, a punch connected to said barrel, a conduit in said punch connected to said valve and said barrel whereby said punch is driven into the formation to be sampled by said sampling device when the weight of said drill string is placed on said latch, means passing through the drill string from the surface and engaging said piston rod, whereby said piston rod may be raised to withdraw a sample from said formation and to compress said spring and lift the wedge into engagement with said latch and whereby the wedge will unlatch the said barrel when the weight of the drill string is raised off said latch to permit the withdrawal of said sampling device.

3. In combination, a drill string, a core head at one end of the drill string, a sub connecting said core head to said drill string, an enlarged section in said core head, a sampling device adapted to be lowered into said core head, said sampling device comprising a barrel, a piston in said barrel, a latch assembly at one end of said barrel, said latch assembly comprising a swingable latch adapted to engage said enlarged section whereby the weight of said drill string may be placed on said latch to hold said device in place in said core head, a piston rod passing through said latch assembly, a wedge surrounding said piston rod and freely movable in a vertical direction to engage said latch, a spring freely suspended from said wedge whereby said spring is compressed between the piston and said wedge when said wedge is moved into engagement with said latch by said spring on compression by said piston, whereby said wedge will retract said latch when the weight of the drill string is taken off said latch and said piston is moved upward to compress said spring, a check valve at the other end of said barrel, a conduit connected to said valve and said barrel whereby said conduit is pushed into said formation when the weight of said drill string is placed on said latch, said conduit carrying means for sealing said conduit in said formation, means passing through the drill string from the surface and engaging said piston rod, whereby said piston rod may be raised to withdraw a sample from said formation and to compress said spring and lift the wedge into engagement with said latch and whereby the wedge will unlatch the said barrel when the weight of the drill string is raised off said latch to permit the withdrawal of said sampling device.

4. A sampling device adapted to be lowered into a drill string carrying a core head at the bottom of said drill string, said sampling device comprising a barrel, a piston in said barrel, a latch assembly at one end of said barrel, said latch assembly comprising a swingable latch adapted to engage said drill string whereby the weight of said drill string may be placed on said latch to hold said device in place in said core head, a piston rod passing through said latch assembly, a wedge surrounding said piston rod, and freely movable in a vertical direction to engage said latch, a spring freely suspended from said wedge whereby said spring is compressed between the piston and said wedge when said wedge is moved into engagement with said latch by said spring on compression by said piston, whereby said wedge will retract said latch when the weight of the drill string is taken off said latch and said piston is moved upward to compress said spring, a check valve in said barrel, a punch connected to said barrel, a conduit connected to said valve and said barrel, packer on said conduit whereby said conduit is pushed into the formation to be sampled by said sampling device when the weight of said drill string is placed on said latch, means passing through the drill string from the surface and engaging said piston rod, whereby said piston rod may be raised to withdraw a sample from said formation and to compress said spring and lift the wedge into engagement with said latch and whereby the wedge will unlatch the said barrel when the weight of the drill string is raised off said latch to permit the withdrawal of said sampling device.

5. A sampling device adapted to be lowered into a drill string carrying a core head at the bottom of said drill string, said sampling device comprising a barrel, a piston in said barrel, a latch assembly at one end of said barrel, said latch assembly comprising a swingable latch adapted to engage said drill string whereby the weight of said drill string may be placed on said latch to hold said device in place in said core head, a piston rod passing through said latch assembly, a wedge surrounding said piston rod, and freely movable in a vertical direction to engage said latch, a spring freely suspended from said wedge whereby said spring is compressed between the piston and said wedge when said wedge is moved into engagement with said latch by said spring on compression by said piston, whereby said wedge will retract said latch when the weight of the drill string is taken off said latch and said piston is moved upward to compress said spring, a check valve in said barrel, a conduit connected to said valve and said barrel, whereby said conduit is pushed into the formation to be sampled by said sampling device when the weight of said drill string is placed on said latch, means passing through the drill string from the surface and engaging said piston rod, whereby said piston rod may be raised to withdraw a sample from said formation and to compress said spring and lift the wedge into engagement with said latch and whereby the wedge will unlatch the said barrel when the weight of the drill string is raised off said latch to permit the withdrawal of said sampling device.

LAWRENCE S. CHAMBERS.

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