March 12, 1957 J. E. WALSTROM 2,784,786

FORMATION TESTING APPARATUS

Filed June 26, 1953 2 Sheets-Sheet 1

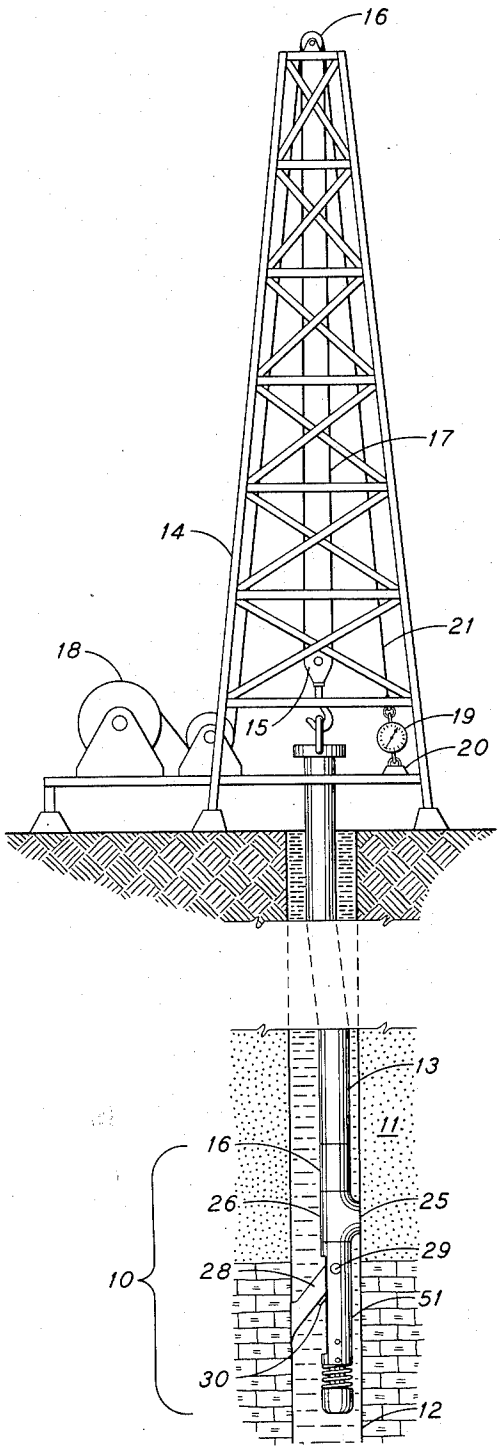


FIG. 1

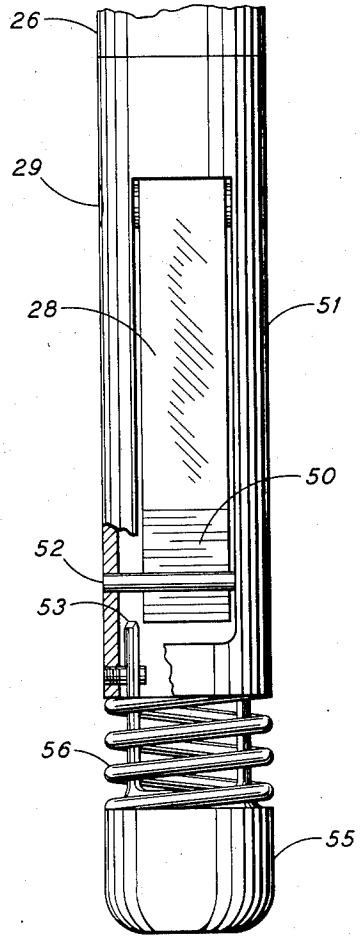


FIG. 3

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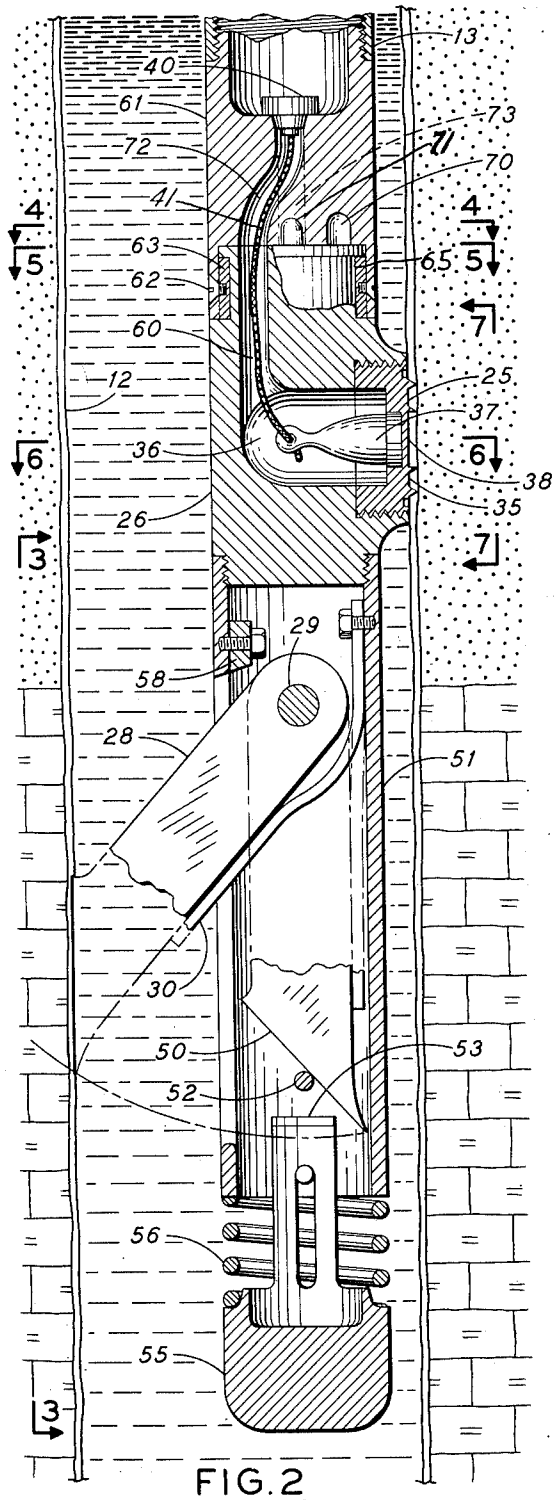


FIG. 2

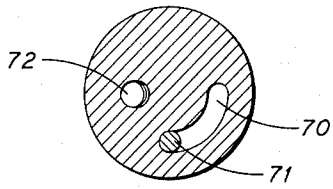


FIG. 4

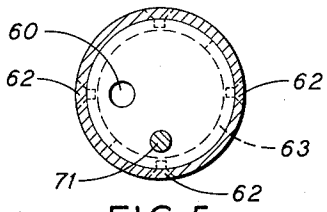


FIG. 5

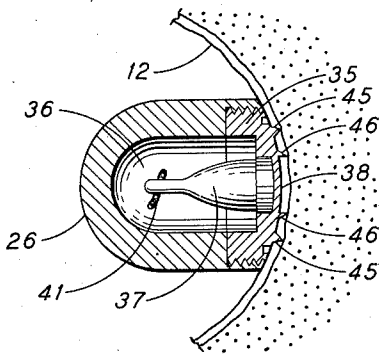


FIG. 6

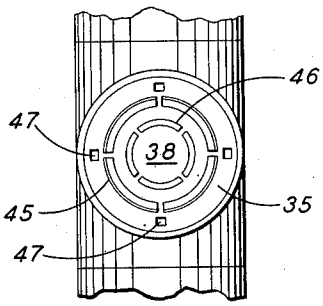


FIG. 7

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FORMATION TESTING APPARATUS

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4 Claims. (Cl. 166—3)

The present invention relates to apparatus for withdrawing fluid samples from earth formations traversed by a bore hole, more particularly to apparatus for sampling fluid content of a formation through the side wall of the bore hole traversing said formation, and has for an object the provision of an improved apparatus for open-hole sampling in situ of the fluids contained in earth formations by rupturing or piercing the formation while controlling the lateral thrust of a body member of a sampling device against the formation to be tested to maintain a seal therebetween, both before and during sample withdrawal, said lateral thrust being controlled by adjustment of the weight of the drill pipe supported between the body and a thrust-exerting, formation-engaging leg member mounted on said body.

In the drilling of exploratory wells for oil, gas, and the like, it is often desired to be able to test fluid content of formations traversed by the well bore which lie at a considerable distance above the bottom of the bore hole. Heretofore, such off-bottom testing for fluid content has only been possible under somewhat limited circumstances.

One of the methods commonly used includes the use of a pair of full-hole packers positioned above and below the formation to be tested. The difficulty with this type of testing, also known as straddle-packer testing, lies in a small clearance available between the packers and the walls of the bore hole due to the limited expandability of the packers. In commercial practice, it has been found that packers can only be expanded in diameter about one inch, where the diameter of the hole is in the range of seven to nine inches. Where the formation to be tested lies at a depth of several thousand feet, such small clearance introduces a very serious hazard of sticking the drill pipe in the hole.

Another serious limitation in the use of full-hole, straddle packers lies in the fact that such straddle packers can only be set relatively near the bottom of the hole.

Where a formation of interest lies more than a very few hundred feet off bottom, it is generally necessary to land a plug in the well bore below the formation to be tested upon which the drill pipe may be seated in order to expand a single full-hole packer above the test formation. In practice, it has been found that a testing tool upon which a packer is run into the hole may slip off such a plug or the plug may be pushed down the hole, and in some instances the plug may leak. Additionally, it is not desirable to plug the hole if total depth has not been reached in the drilling of the well. In some instances delayed testing until total depth has been reached may render the formation subject to severe damage by mud, or the formation may be damaged by caving or sloughing, while the drilling is continued. Thus, a potentially-productive formation may be lost entirely if the formation is not tested until a subsequent date.

Alternative to the foregoing methods of testing a formation is the so-called drill stem test in which at predetermined intervals the drilling tool is withdrawn and a reduced diameter, or rat-hole, drilling tool introduced. By so drilling, a seal-off between the main portion of the bore hole and the rat hole may be obtained by using the shoulder between the rat hole and the full hole as a seat for a conical packer, or the reduced diameter hole used with a side-wall packer of corresponding diameter. This reduced diameter permits the side-wall packer to be run in and out of the hole without additional danger of sticking the drill pipe. However, this type of testing operation is extremely costly due to the necessity of stopping the normal drilling operation at regular depth intervals to drill a reduced diameter hole. Subsequent reaming of the hole is required to reach full-hole size. Furthermore, the predetermined depth interval may often prevent testing of a particular part of the interval, without setting of bottom plugs.

The third alternative available heretofore in commercial practice, and by far the most expensive, involves the setting of casing in the well bore with subsequent piercing of the casing, as in normal oil-well completion practice. This method is so expensive that it is normally followed only when the indications of a producing formation are extremely good. On what is considered a marginal show of oil or gas in the well, the setting of casing and completion of the well to test the "show" is often considered so unattractive that it is not employed. However, should the "show" have been improperly evaluated as being marginal, a valuable well or field may be abandoned.

In accordance with the present invention there is provided an apparatus for open-hole formation testing for fluid content which may be used at any time after the drilling of a well by conventional drilling procedures. Further, the formation fluid content may be sampled in adequate volume to obtain a true representation of the fluid in accordance with the invention by supporting the testing apparatus adjacent the formation on drill pipe. In a preferred form of apparatus, the body member is provided with means for forcing a portion of the body into engagement with the side of the bore hole, which includes a pivotally-mounted leg member adapted to engage the opposite side of the bore hole and so pivoted with respect to the body that the lateral thrust of the body member against the formation may be controllably adjusted by regulating the weight of that portion of the drill pipe which is supported between the leg member and the portion of the body member in contact with the formation. Means for piercing the portion of the body member in engagement with the formation, as well as the formation, is provided within the body of the testing tool, and flow passages between the formation and the drill pipe are provided to permit formation fluids to rise within the drill pipe after the formation has been pierced or ruptured. Further, in accordance with the invention, valve means may be provided between the bottom of the drill pipe and the body member to provide a shut-off to prevent accumulation of fluid in the drill pipe from being lost into the bore hole through the fluid passages in the body member during withdrawal of the tool and the drill pipe upon which it is supported.

Further objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings which form an integral part of the present specification.

In the drawings, Fig. 1 is a diagrammatic representation of a preferred form of the present invention illustrating the manner in which the testing tool is supported in the well bore and controllably brought into contact with the formation whose fluid content is to be tested.

Fig. 2 is an enlarged cross-sectional view of the lower end of the testing tool illustrated in Fig. 1.

Fig. 3 is a side view of the testing tool taken in the direction of arrows 3—3 in Fig. 2.

Fig. 4 is a cross-sectional plan view in the direction of arrows 4—4 in Fig. 2 illustrating a portion of the valve mechanism between the drill pipe and the testing tool.

Fig. 5 is a cross-sectional plan view in the direction of arrows 5—5 in Fig. 2 showing another portion of the valve mechanism.

Fig. 6 is a cross-sectional plan view taken in the direction of arrows 6—6 in Fig. 2 particularly illustrating the formation-engaging face portion of the testing tool and the means for piercing said face and the adjacent formation.

Fig. 7 is a side elevation view in the direction of arrows 7—7 in Fig. 2 particularly illustrating a preferred form of the face-engaging portion of the testing tool.

With reference to the drawings, and in particular Fig. 1, there is illustrated a preferred form of apparatus for carrying out the present invention, in which a fluid sampling tool **10** for sampling the fluid content of a formation **11** traversed by bore hole **12** is adapted to be supported in the bore hole by a stand of drill pipe indicated generally as **13**, which, in turn, is supported by drilling derrick **14** including traveling block **15** and crown block **16** through cable **17**. As will be understood by those skilled in the art, drill pipe **13** may be raised and lowered in the bore hole by cable **17** operating through traveling block **15** and crown block **16** by reeling and unreeling the cable on drum **18**. The weight of the drill pipe **13** is arranged to be recorded or indicated by dead weight indicator **19**, which is interposed between the anchor means **20** and the dead wire line **21**, which forms an extension of the end of cable **17** passing downwardly from crown block **16**.

In accordance with the present invention, during rupture of the formation and withdrawal of fluid therefrom the weight indicating means **19** and the pipe supporting means, including derrick **14** and cable **17**, provides a means for controlling the lateral thrust of the face or formation-engaging portion **25** of the body **26** of the fluid sampling tool **10** against the wall of the bore hole. The lateral thrust of face portion **25** against formation **11** is provided by a combination of the vertical weight of drill pipe **13** and laterally-extending leg member **28**. In the present arrangement, leg **28** is pivoted at **29** and brought into engagement with the wall of bore hole **12** by spring member **30**. The function of wedging leg **28**, when the weight on testing tool **10** is increased by decreasing the tension on pipe **13** and cable **17**, is to exert a lateral thrust of predeterminable value between face **25** and the side wall of bore hole **12** opposite the formation which is to be tested.

As more fully illustrated in Figs. 2, 6 and 7, the face portion **25** for engaging the formation whose fluid content is to be tested may comprise a plug member **35** threadably engaging the body member **26**, which is provided with a chamber **36** for positioning an explosive for piercing the formation, such as shaped charge **37**, in a portion **38** of plug **35** which is ruptured or pierced by explosive detonation of charge **37**. In the preferred embodiment of the invention, portion **38** forms a hold-back plate to permit shaped charge **37** to increase its piercing depth into formation **11** when detonated by the dropping of a go-devil through pipe **13** to contact blasting cap **40**. Prima cord **41**, extending through passageways **72** and **60**, is exploded by cap **40** to detonate, in turn, shaped charge **37**.

As particularly illustrated in Fig. 7, plug **35** may be provided with a pair of ring-like cutting edges **45** and **46**, which may be brought into firm contact with the formation wall by piercing through the mud cake, as shown in Fig. 6, which normally surrounds the periphery of bore hole **12**. To assist in the ready removal and insertion of plug **35** into body member **26**, plug **35** may be provided with a plurality of spanner-wrench-engaging holes **47**. As mentioned hereinabove, tool **10**, and the face portion thereof, is brought into engagement with the side wall of bore hole **12** with a controllable thrust by the vertical action of the weight of drill pipe **13** acting through wedging leg **28** and pivot **29** by which leg **28** is connected to extension **51** of body member **26**.

Since it is desirable to maintain as small as possible the total diameter of the drill pipe **13** and the testing tool run into hole **12**, provision is made for maintaining the wedging leg **28** in a restrained position against the action of spring **30**, as partially illustrated in Fig. 2 and more fully shown in side elevation, Fig. 3. As illustrated in these figures, leg **28**, including the side wall engaging portion **50**, is held by a transverse pin **52** within the housing **51**, which forms a lower extension of body member **26**. Pin **52** is of the shear type which may be severed by knife edges **53** being moved upwardly by bull-nose plug **55** being raised against biasing spring **56** when the weight of the drill pipe in body member **26** is brought to bear thereon by lowering the entire tool to the bottom of the drill hole. Upon severance of the shear pin **52**, wedging leg **28** is forced outwardly into the position shown in Fig. 1 and partially illustrated in Fig. 2 by biasing spring **30**. A stop member **58** may be provided above wedging arm **28** to prevent arm **28** from pivoting above the horizontal in the event that a cavernous formation is encountered during the withdrawal of the tool from the well bore. It will be apparent that the length of wedging leg **28** may be made such that the tool may be employed even where cavernous formations are encountered by extending the length of the leg.

After completion of the test, provision is made for shutting off the communication between the formation and drill pipe **13** through fluid passageways **60** and **72** which formed the ignition path between cap **40** and charge **37**. Such shut-off is made by rotation of collar member **61** which forms an upward extension of testing tool **10** adapted to engage the lower end of drill pipe **13**. As particularly illustrated in Fig. 2 rotatable collar **61** is secured through screw **62** to a ring member **63** fitted within an upwardly-extending and flanged portion **65** of the body portion **26**. Collar member **61** is preferably provided with recessed portion **70** of arc-like configuration adapted to engage a pin member **71**, best seen in Fig. 4, mounted upon the upper end of extended portion **65** of body **26**. By rotation of drill pipe **13** and collar member **61** fluid flow passageway **72** in collar **61** may be rotated into the dotted line position, designated as **73**, before the tool is lifted to withdraw the face of the testing tool away from the sampled formation.

In operation of the present invention, particularly the form thereof illustrated in the drawings, the testing tool **10** is assembled, as illustrated in Fig. 2, and run into the hole with the pipe **13** maintained substantially dry. The tool is then lowered until the bottom of the well bore is reached, at which time the weight of the drill pipe supported by derrick **14** is decreased as indicated on weight indicator **19**, thereby to shear holding pin **52** to permit wedging leg **28** to rotate outwardly into engagement with the wall of well bore **12**. The pipe and testing tool are then raised in the well until the tool is opposite the formation whose fluid content is to be tested, such as formation **11**. At that time the combined weight of the tool and drill pipe supported by derrick **14** and cable **17** is again decreased to a predetermined degree as measured by weight indicator **19**. This action causes the lateral thrust between face **25** and formation **11** to be increased to a degree adequate to assure a firm sealing between the face of the formation and the face of the testing tool. A go-devil is then dropped through drill pipe **13** to detonate blasting cap **40**, prima cord **41**, and charge **37**. Upon detonation of these explosives the formation face is ruptured and the fluid flow path through chamber **36**, passageway **60** and **72** cleared for the upward flow of fluid from within formation **11** into pipe **13**.

After the passage of adequate time for fluid content to rise through body **26** into drill pipe **13**, the drill pipe may be rotated in a clockwise direction as seen in Figs. 4 and 5, to close communication between passageways **72**

and passageway 60 and the tool lifted to release the lateral thrust between the face of the formation and the portion of the body member in engagement therewith and the entire assembly withdrawn from the well for removal of the fluid sample.

From the foregoing detailed description, it will be apparent that in accordance with the present invention there is provided a fluid sampling apparatus for testing the content of a formation traversed by a bore hole, in which the contact between the body member and the formation may be maintained through the application of a controllable amount of lateral thrust introduced by the vertical weight of the drill pipe acting through a side wall engaging leg both before, during, and after the piercing or rupturing of the formation and the withdrawal of fluid sample from the formation.

Various modifications and changes in the foregoing apparatus will occur to those skilled in the art without departing from the scope of the present invention. In particular, the face-engaging portion of plug 35 may be adapted to provide other forms of sealing faces particularly adapted to the type of formation whose fluid is to be sampled. It will also be apparent that a plurality of face-engaging similar to the single one illustrated in the drawings may be brought into contact with the face of the wall simultaneously and fluid withdrawn through each of the face portions. While a shaped charge for piercing the formation has been illustrated and described, other forms of gun perforating apparatus may be employed which may be detonated by concussion or electrical energy.

Other modifications and changes may be made without departing from the scope of the appended claims, and all such modifications falling within the terms of said claims are intended to be included therein.

I claim:

1. Open-hole fluid sampling apparatus adapted to be lowered into an open bore hole on a length of drill pipe comprising a body member connected to said drill pipe and movable relative thereto, said body member having a laterally disposed face adapted to engage the side wall of an open bore hole, a wedging leg pivotally connected to said body member below said laterally disposed face, said leg including biasing means for forcing the opposite end of said leg extending below said pivot point into engagement with the side wall of said bore hole opposite a formation whose liquid content is to be sampled, means for applying at least a portion of the weight of said drill pipe to said leg to wedge said opposite end of said leg into engagement with said bore hole wall to pivot said body member about the point of engagement of said leg with said bore hole wall for forcing said face into firm engagement with said bore hole wall, a sample-receiving chamber in said drill pipe, rupturing means for rupturing said face and said formation, and cooperating fluid passage means in said body member and in said drill pipe for establishing fluid communcation to said sample chamber from said ruptured face to permit flow from said formation through said ruptured face to said sample chamber, said communicating passage means being adapted to be closed in response to relative movement between said body member and said drill pipe upon completion of the sampling to trap said formation fluid in said sample chamber.

2. Open-hole fluid sampling apparatus adapted to be lowered into an open bore hole on a length of drill pipe comprising a body member connected to said drill pipe and movable relative thereto, said body member having a laterally disposed face adapted to engage the side wall of an open bore hole, a wedging leg pivotally connected to said body member below said laterally disposed face, said leg including biasing means for forcing the opposite end of said leg extending below said pivot point into engagement with the side wall of said bore hole opposite a formation whose fluid content is to be sampled, means for applying at least a portion of the weight of said drill pipe to said leg to wedge said opposite end of said leg into engagement with said bore hole wall to pivot said body about the point of engagement of said leg with said bore hole wall for focusing said face into firm engagement with said bore hole wall, a sampling-receiving chamber in said drill pipe, explosively-actuated rupturing means within said body member and adjacent said face for rupturing said face and said formation, cooperating fluid passage means in said body member and in said drill pipe for establishing fluid communication to said sample chamber from said ruptured face to permit fluid flow from said formation through said ruptured face to said sample chamber, explosive cap means in the lower portion of said sample-receiving chamber of said drill pipe, and explosive cord means extending through said cooperating fluid passage means for connecting said cap means to said rupturing means, said communicating passage means being adapted to be closed in response to relative movement between said body member and said drill string upon completion of the sampling to trap said formation fluid in said sample chamber.

3. Open-hole fluid sampling apparatus adapted to be lowered into an open bore hole on a length of drill pipe comprising a body member connected to said drill pipe and having at least a portion thereof rotatable relative to said drill pipe, said rotatable portion of said body member having a laterally disposed face adapted to engage the side wall of an open bore hole, a wedging leg pivotally connected to said rotatable portion of said body member below said laterally disposed face, said leg including biasing means for forcing the opposite end of said leg extending below said pivot point into engagement with the side wall of said bore hole opposite a formation whose fluid content is to be sampled, means for applying at least a portion of the weight of said drill pipe to said leg to wedge said opposite end of said leg into engagement with said bore hole wall to pivot said body member about the point of engagement of said leg with said bore hole wall for forcing said face into firm engagement with said bore hole wall, a sample-receiving chamber in said drill pipe, explosively-actuated rupturing means within said body member and adjacent said face for rupturing said face and said formation, and cooperating fluid passage means in said rotatable portion of said body member and in said drill pipe for establishing fluid communication to said sample chamber from said ruptured face to permit fluid flow from said formation through said ruptured face to said sample chamber, said communicating passage means being adapted to be closed by rotation of said drill pipe while said rotatable portion of said body member is in contact with said bore hole wall and upon completion of the sampling to trap said formation fluid in said sample chamber.

4. Open-hole fluid sampling apparatus in accordance with claim 3 including explosive cord means for igniting said explosively-actuated rupturing means extending from said sampling-receiving chamber in said drill pipe to said rupturing means through said cooperating fluid passage means, said cord means resisting rotation of said rotatable portion of said body member with respect to said drill pipe and preventing rupture of said face by said rupturing means if said cord means has been severed by closure of said cooperating passage means by rotation between said body member and said drill pipe, and means for igniting said explosive cord means in said sample-receiving chamber of said drill pipe.

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