

June 15, 1965

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3,189,094

FIRING APPARATUS FOR GUN PERFORATORS

Filed Jan. 3, 1963

3 Sheets-Sheet 1

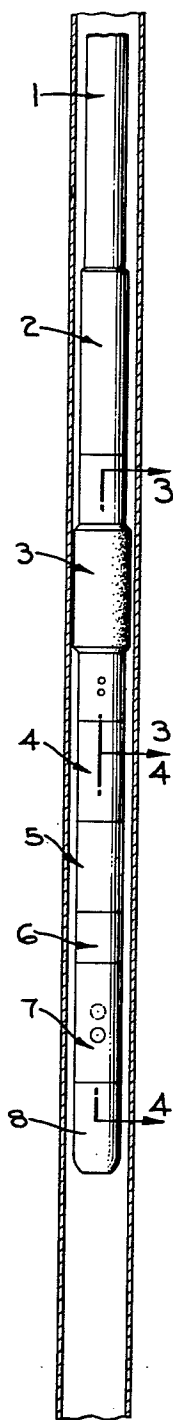


FIG. 1.

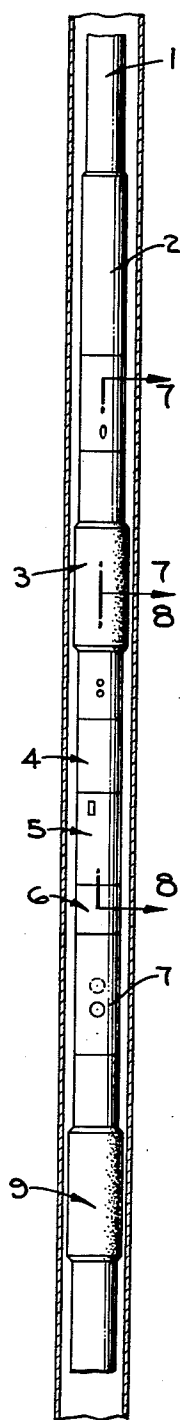


FIG. 2.

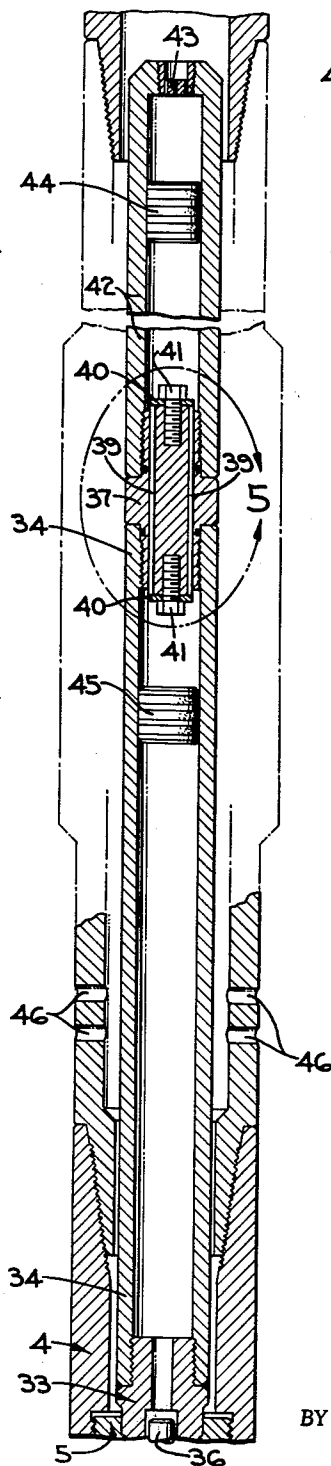


FIG. 3.

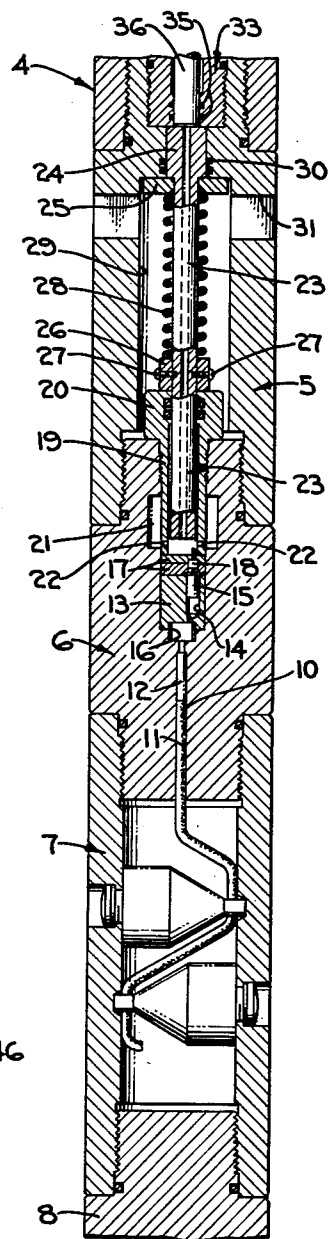


FIG. 4.

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3 Sheets-Sheet 2

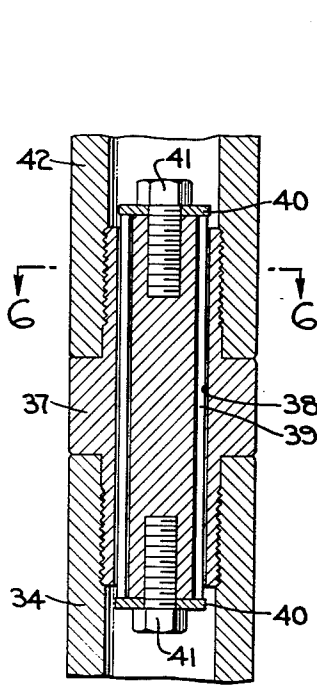


FIG. 5.

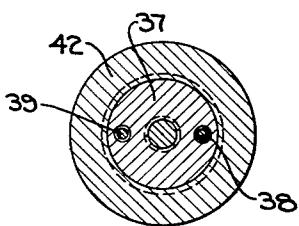


FIG. 6.

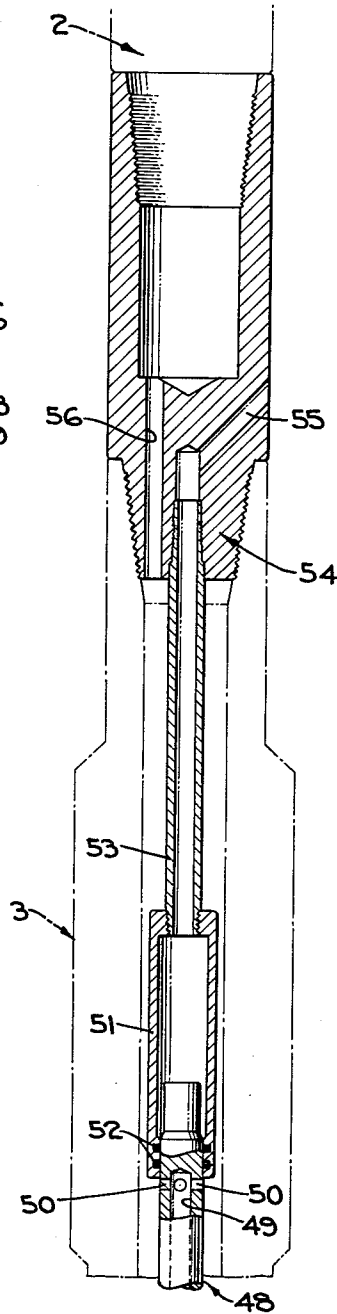


FIG. 7.

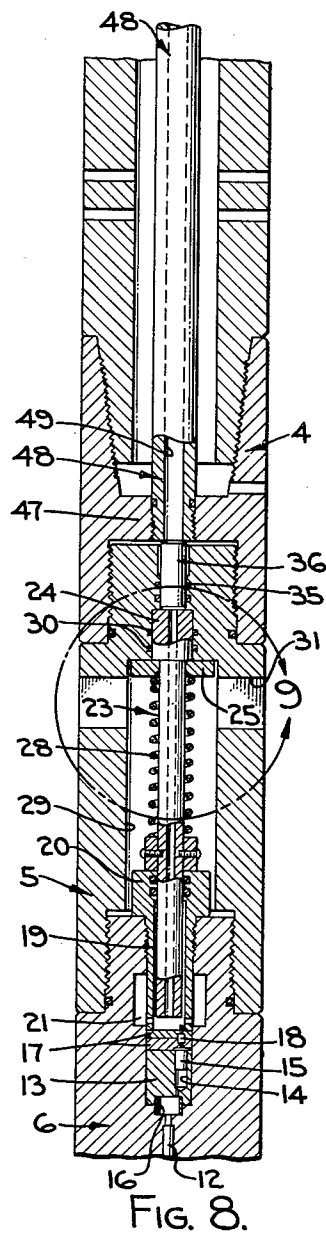


FIG. 8.

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3 Sheets-Sheet 3

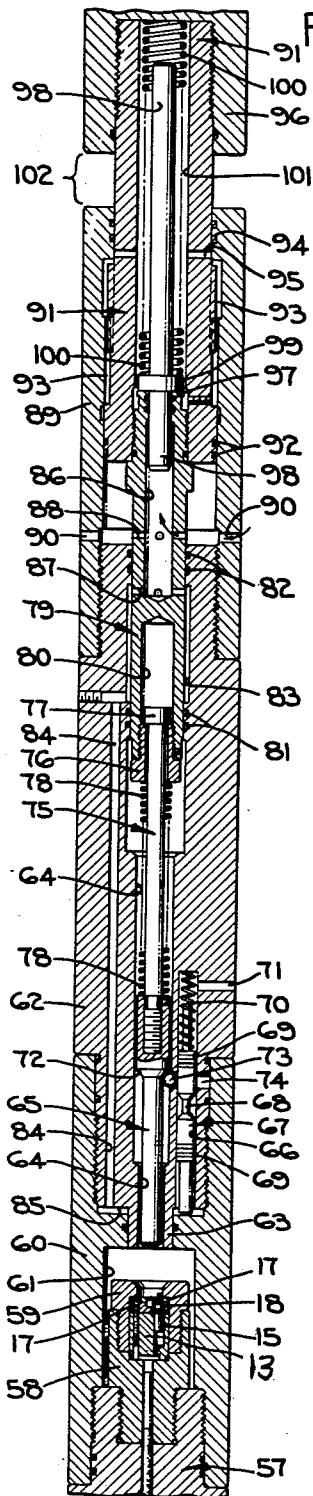


FIG. 11.

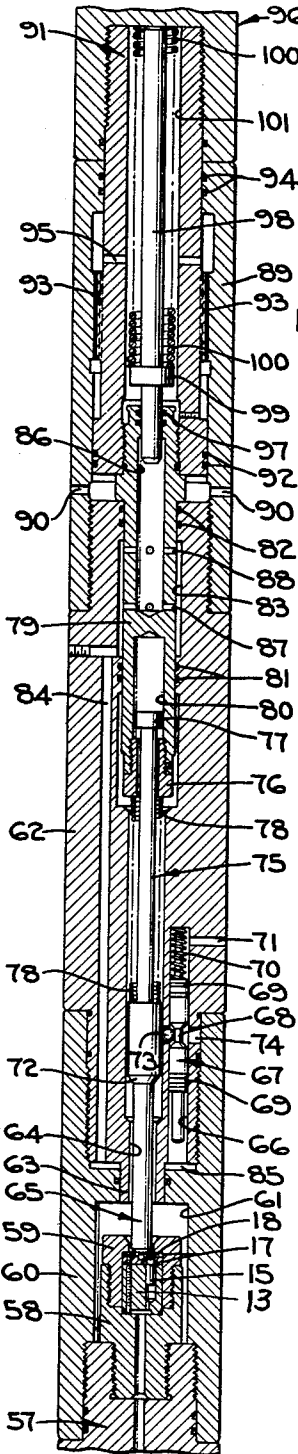


FIG. 12.

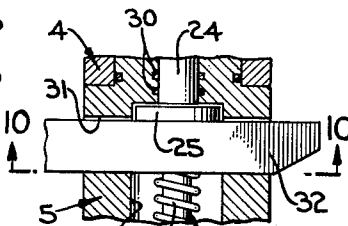


FIG. 9.

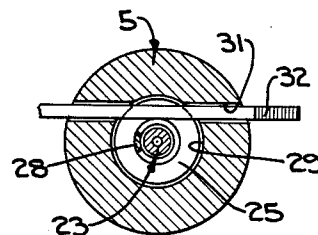


FIG. 10.

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3,189,094

FIRING APPARATUS FOR GUN PERFORATORS
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Company, Duncan, Okla., a corporation of Delaware
Filed Jan. 3, 1963, Ser. No. 249,229
14 Claims. (Cl. 166—55.1)

This invention relates to firing apparatus for gun perforators, more particularly, to firing apparatus for gun perforators which are suspended from a tubing string below a single well packer or between a pair of well packers for purposes of formation testing.

An object of this invention is to provide a firing apparatus which is armed or prepared for operation by utilizing the submergence pressure exerted by the surrounding well fluid in which the gun perforator is lowered, and subsequently operates after the accompanying packer or packers are set and have established a relatively low pressure zone in the region to be gun perforated.

A still further object is to providing a firing apparatus of this type which is particularly adapted for formation testing operations, and is so arranged that it cannot be operated until the formation tester packers have been set and the formation tester valve has been opened.

A further object of this invention is to provide a firing apparatus which, by reason of the requirement that hydrostatic pressure be utilized to arm the apparatus, is particularly safe against accidental operation to discharge the gun perforator prior to lowering the gun perforator into a well.

A still further object is to provide a firing apparatus of this type, which should it fail to function as intended, is self-disarming as the hydrostatic head diminishes during withdrawal, and which, on being exposed at the mouth of the well, may be manually locked in a disarmed condition before raising the gun perforator from the well casing.

With above and other objects in view as may appear hereinafter, reference is directed to the accompanying drawings, in which:

FIGURE 1 is a substantially diagrammatic view showing the assembly of a tubing string, formation tester valve, packer and a gun perforator in conjunction with the firing apparatus and indicating in section and fragmentarily the surrounding casing.

FIGURE 2 is a similar diagrammatic view in which the gun perforator and firing apparatus are shown disposed between a pair of packers.

FIGURE 3 is an enlarged fragmentary longitudinal sectional view taken through 3—3 of FIGURE 1 with the packer indicated in broken outline.

FIGURE 4 is an enlarged fragmentary longitudinal sectional view continuing from FIGURE 3 and taken from 4—4 of FIGURE 1.

FIGURE 5 is an enlarged sectional view taken within circle 5 of FIGURE 3.

FIGURE 6 is a transverse sectional view taken through 6—6 of FIGURE 5.

FIGURE 7 is an enlarged fragmentary longitudinal sectional view taken in and through 7—7 of FIGURE 2, showing a modified form of the firing apparatus with the packer shown in broken lines.

FIGURE 8 is an enlarged fragmentary longitudinal sectional view continuing from FIGURE 7 taken from 8—8 of FIGURE 2.

FIGURE 9 is a fragmentary sectional view taken within circle 9 of FIGURE 8.

FIGURE 10 is a transverse sectional view taken through 10—10 of FIGURE 9.

FIGURE 11 is a fragmentary longitudinal sectional view showing a further modified form of the firing appa-

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ratus, the firing apparatus being shown in its disarmed position.

FIGURE 12 is a similar fragmentary longitudinal sectional view showing the modified firing apparatus after causing operation of the gun perforator.

Reference is first directed to FIGURES 1 and 2. The assembly with which the firing apparatus is employed includes a tubing string 1. Attached to the lower end of the tubing string is a housing 2 which contains a conventional formation tester valve. A packer 3 which is also conventional, is secured to the lower end of the housing 2. Below the packer are series connected upper and lower firing apparatus housings 4 and 5. Below the housing 5 is a firing assembly block 6 attached to a gun perforator 7, the lower end of which is shown in FIGURE 1, and terminates in a nose piece 8.

In FIGURE 2, the gun perforator is attached to a second or lower packer 9. The packer or packers may be of the type to engage a surrounding casing, or may be open-hole packers which engage the surrounding formation.

In conducting a formation test, the assembly is lowered into a cased or uncased well bore which contains a fluid, such as well drilling mud so that, externally, all parts of the assembly are subjected to the submergence pressure exerted by the fluid in the well. The formation tester valve, however, is initially closed so that the pressure within the empty tubing string is essentially at atmospheric pressures.

When the packer or packers are set, the zone opposite the gun perforator is isolated from the region above the packer, if a single packer is used; or, above the uppermost packer if two packers are used. Thereafter, when the formation tester valve is opened, the zone opposite the gun perforator is exposed essentially to atmospheric pressure, or at least to a pressure which is greatly lower than the submergence pressure or hydrostatic pressure of the fluid in the well.

When this condition has been established, the gun perforator is fired to penetrate the wall casing or the surrounding formation so that the surrounding formation fluids flow into the tubing string to complete the formation testing operation. The present invention is directed to a unique firing apparatus for the gun perforator. Attention is first directed to the embodiment of the firing apparatus shown in FIGURES 3, 4, 5 and 6.

The firing assembly block 6 is externally screw-threaded at opposite ends for connection to the gun perforator 7 and the lower housing 5. The firing assembly block is provided with a central bore 10, the lower end of which receives a detonating cord 11 utilized in a conventional manner to fire the charges contained in the gun perforator. It should be noted that the gun perforator may be of the jet or shaped charge type or may be of the bullet firing type. In addition to the detonating cord, the bore 10 contains a detonating cap 12. The upper end of the bore 10 is enlarged to receive a cartridge plug 13 having an offset bore 14 containing a cartridge 15. In order to connect the offset bore 14 with the bore 10 and to seal the lower end of the cartridge plug, there is provided a short tubular liner 16.

Above the cartridge plug 13 there is fitted a pair of retainer disks 17 which support a firing pin 18 in alignment with the cartridge 15 in such a manner that the firing pin has limited axial movement for firing the cartridge. The cartridge may be a conventional blank cartridge such as used in firearms.

The cartridge plug and retainer disks are held in place by a sleeve 19 which is screw-threaded into the upper end of the firing assembly block. The sleeve includes an enlarged head 20 which sealingly engages the upper end of the firing assembly block. Intermediate the ends of

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the sleeve 19 the bore of the firing assembly block is laterally enlarged to form an annular cavity 21 communicating with the interior of the sleeve 19 through ports 22.

Slidably mounted within the sleeve 19 is a tubular firing hammer 23 which initially clears the firing pin 18 but is capable of being moved downwardly to engage the firing pin. The tubular firing hammer projects above the head 20 of the sleeve 19 and seal rings are provided in the head 20. The upper end of the firing hammer is increased in diameter to form a head 24 under which is secured an annular disk 25. Immediately above the head 20 of the sleeve 19 the firing hammer is provided with a collar 26 attached thereto by shear pins 27. A spring 28 extends between the collar 26 and the disk 25. The collar 26 functions initially to hold the firing hammer in its initial or upper position, clear of the firing pin 18. After the pins 27 are sheared, the spring 28 continues to hold the firing hammer in its upper position clear of the firing pin.

The lower housing 5 is provided with a relatively large bore 29. The bore 29 is dimensioned to receive the head 20 of the sleeve 19 and the disk 25. The upper end of the bore 29 is reduced in diameter to forming a sliding fit with the head 24 of the firing hammer 23 and is provided with seal rings 30. Immediately below the disk 25 the housing 5 is provided with a cross slot 31 which receives a cross bar 32 for the purpose of locking the disk 25 in its upper position and thereby lock the firing apparatus in its disarmed condition. The bar 32 is used before the gun perforator is lowered into the well bore and is reinserted when the gun perforator is removed from the well bore.

The upper housing 4 is tubular and the upper end of the lower housing 5 is externally screw-threaded to fit therein. The upper end of the housing 5 is provided with a screw-threaded socket which receives a tubular end piece 33 welded to an upwardly extending tube 34. The lower end of the end piece is provided with seal rings 35 and slidably receives a piston 36 of uniform diameter. The piston 36 rests on the upper surface of the head 24 of the tubular firing hammer 23.

The upper end of the tube 34 is internally screw-threaded and connected to a meter valve body 37. The meter valve body has one or more meter bores 38 extending therethrough in each of which is positioned a flow-restricting pin 39. Retainer rings 40 at the axial extremities of the meter valve body hold the pins in place and are in turn held in place by end screws 41.

A second or upper tube 42 is connected by screw threads to the meter valve body 37. The upper end of the tube 42 is provided with a strainer plug 43. Slidably mounted within the upper and lower tubes 42 and 34 are floating pistons 44 and 45 respectively. A viscous fluid completely fills the space between the floating pistons.

The tubes 34 and 42 extend upwardly within the bore of the conventional packer 3 and the upper end of the tube 42 is in communication with the surrounding well fluid or oil well mud through side ports 46.

Operation of the firing apparatus as shown in FIGURES 3, 4, 5 and 6 is as follows:

The region below the lower piston 45 initially contains air at atmospheric pressure. As the assembly including the firing apparatus is lowered into the well bore the submergence pressure gradually increases so that a gradually increasing pressure is applied to the top of the upper floating piston 44. The viscous fluid between the pistons flows slowly through the meter valve body 37 causing the lower piston 45 to move downwardly and compress the air in the lower portion of the tube 42. The pressure thus created is applied to the top of the piston 36.

Simultaneously the submergence pressure increases within the bore 29 due to the presence of the cross slot 31 so that an upward force is exerted on the head 24 of the firing hammer 23. The cross sectional areas of the piston 36 and the head 24 are so related that there is a

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net upward force maintaining the firing hammer in its upper position in addition to the spring 28.

When the assembly has been lowered to the desired position within the well bore, the packer or packers are set and the formation tester valve is open. When this occurs, the back pressure in the bore 29 is eliminated, at least to the extent that the fluid pressure on the top of the piston 36 may function to drive the piston 36 downward with sufficient force to shear the pins 27 and cause the lower end of the firing hammer to engage the firing pin 18. When this occurs the cartridge 15 ignites the detonating cap 12 which, in turn, detonates the cord 11 and causes the perforating elements of the gun perforator to function.

The metering valve formed by the bore 38 and pins 39 prevents the fluid pressure from escaping from the lower tube 34 before this pressure has had opportunity to force the piston 36 downward. The fluid pressure does, however, dissipate after a predetermined time so that in the event the gun perforator should fail to fire, downward force on the firing hammer is soon dissipated. If the shearing pins have sheared, the spring 28 alone functions to raise the firing hammer. If the shearing pins have not sheared, any force which would cause these pins to shear is relieved.

When the formation testing operation is completed and the packer is unseated, the submergence pressure is again applied to the underside of the head 24 of the firing hammer to insure that there is no force available to cause malfunctioning of the firing apparatus. When the firing apparatus has been raised to the mouth of the well to expose the cross slot 31 the bar 32 may be inserted before the gun perforator itself is withdrawn.

Reference is now directed to FIGURES 7 and 8. The firing structure here illustrated is the same as the first described structure. However, in place of the end piece 33 and tubes 34 and 42, other means are provided for subjecting the piston 36 to submergence pressure. In the modified construction, the upper end of the lower housing 5 receives the piston 36 directly. The upper housing 4 is provided with an internal constriction 47 which receives a lower stem 48 having a bore 49 extending to a point near its upper end at which point it is intercepted by cross port 50. The upper end of the lower stem 48 is slidably received within a sleeve 51 having seal rings 52. The upper end of the sleeve 51 is, in turn, joined to an upper stem 53 which is tubular throughout its length. The upper end of the stem 53 is joined to an adapter fitting 54 interposed between the packer 3 and the formation tester valve housing 2. The adapter fitting is provided with a side port 55 communicating with the surrounding oil well fluid at a point above the packer 3. The adapter fitting is also provided with an axial port 56 communicating between the interior of the packer and the interior of the tubing string below the tester valve.

Operation of the modified firing apparatus shown particularly in FIGURES 7 and 8, is as follows:

During the lowering of the tubing string and formation testing assembly into the well bore, the packer is in its extended position so that the cross ports 50 are located immediately below the sleeve 51 and are in communication with the well fluid outside the formation tester assembly. Consequently, as the assembly is lowered into the well bore the submergence pressure gradually accumulates and urges the piston 36 downward. As in the first described structure, this force is counterbalanced by the force exerted upwardly on the head 24 of the firing hammer due to the fact that the bore 29 is also exposed to submergence pressure.

When the packer is set, it is necessary that it be shortened lengthwise, causing the upper end of the lower stem 48 to enter the sleeve 51. In doing so the submergence pressure is maintained on the upper end of the piston 36 due to the fact that there is a continuous passage from the lower end of the lower stem 48 through

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the tubular stem 53 and side port 55. When the packer sets and the tester valve 2 is opened, the pressure on the underside of the packer in the region of the cross slot 31 and the bore 29 is relieved so that there is a net force sufficient to drive the piston 36 downwardly so as to cause the gun perforator to fire.

It should be noted that in both constructions, should fluid pressure exist in the region between the piston 36 and the head 24 of the firing hammer, this pressure will also exist at the lower end of the firing hammer and in the cavity 21. Normally the bore of the tubular firing hammer 23 and the cavity 21 is maintained at atmospheric pressure and is free of liquid so that the firing hammer is free to move. Should this region become liquid-filled, the firing hammer is rendered inoperative as it cannot move down with sufficient force to cause the firing pin to fire the cartridge.

Reference is now directed to FIGURES 11 and 12. In this construction, a modified firing assembly block 57 is illustrated. The modified block differs in that the firing assembly is mounted on top of the block rather than set within a bore within the block. A screw-threaded socket is provided in the upper end of the block 57 which receives an externally screw-threaded lower end of an adapter fitting 58 which, in turn, is internally screw-threaded at its upper end to receive a plug 59. The plug 59 is provided with a bore which receives the plug 13, cartridge 15, retainer disks 17 and firing pin 18 of the first described structure. The modified assembly block 57 screw-threads into the lower end of a lower housing 60 having a socket 61 dimensioned to receive the adapter fitting 58 and plug 59. The upper end of the lower housing 60 is internally screw-threaded to receive an intermediate housing 62. The lower extremity of the intermediate housing is provided with a short stem 63 which extends through and is sealingly received in an internal constriction provided in the mid-portion of the lower housing 60.

The intermediate housing 62 is provided with a central bore 64 which receives a firing hammer 65 the lower end of which is adapted to enter the socket 61 and engage the exposed upper end of the firing pin 18. The intermediate housing is provided with an offset bore 66 parallel to the bore 64 which receives a latch plunger 67 having a neck portion 68 intermediate its ends and seal rings 69 adjacent each end. A spring 70 urges the latch plunger 67 downward. A side port 71 is connected with the upper end of the bore so that fluid pressure also forces the latch plunger 67 downward. The upper portion of the firing hammer 65 is enlarged to form a shoulder 72 which is initially engaged by a locking ball 73 located in a cross bore 74 joining the bore 64 and offset bore 66.

Screw-threaded into the upper end of the firing hammer 65 is a connecting rod 75 which extends through a collar 76 and terminates in a head 77. A spring 78 is interposed between the firing hammer 65 and the collar 76.

The collar 76 screw-threads into the lower end of a slide valve mandrel 79. The lower end of the mandrel 79 is provided with a clearance socket 80 to receive the head 77 of the connecting rod and the upper portion of the bore 64 which extends through the intermediate housing 62 is provided with spaced sets of seal rings 81 and 82 which sealingly engage the mandrel 79 and form therebetween an annular cavity 83 surrounding the mandrel. The cavity 83 is connected by a passageway 84 extending downwardly of the intermediate housing 62 and intersects a cavity 85 formed at the lower end thereof to which the lower end of the offset bore 66 is exposed.

The upper end of the mandrel 79 is provided with a socket 86 having lower and upper side ports 87 and 88 which for one position of the mandrel are located below and above, respectively, of the upper set of seal rings 82.

The intermediate housing 62 screw-threads into an upper housing 89 which is essentially cylindrical. Im-

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mediately above the intermediate housing 62 the upper housing is provided with side ports 90. In the initial condition of the firing apparatus the side ports 90 communicate with the upper side ports 88, socket 86, lower side ports 87 and cavity 83 so that submergence pressure is applied through the passageway 84 and cavity 85 to the underside of the offset bore 66 to counterbalance submergence pressure applied through the side port 71.

The upper end of the mandrel 79 screw-threads into a tubular stem 91 the lower end of which is provided with seal rings 92 to form a piston cooperating with the cylindrical upper housing 89. Near the upper end of the upper housing 89 the housing and stem are provided with cooperating splines 93 so that torque may be applied through the stem to the housing. The upper end of the housing is provided with seal rings 94 for sealing engagement with the stem 91 so that the region between the seal rings 92 and 94 is isolated. This region is connected by cross ports 95 with the interior of the tubular stem 91. The upper end of the tubular stem is screw-threaded into a fitting 96 which in turn is connected to the packer 3 having ports 46 as indicated in FIGURE 3.

The socket 86 formed in the upper end of the mandrel 79 is provided at its entrance end with seal rings 97 and is adapted to receive a plunger 98 which projects upwardly into the tubular stem 91. The plunger is provided with a flange 99 to limit its movement into the socket 86 and a heavy spring 100 is then interposed between the flange 99 and the fitting 96. The tubular bore of the stem 91 above the mandrel 79 forms an atmospheric pressure chamber 101.

Operation of the firing apparatus shown in FIGURES 11 and 12 is as follows:

This embodiment of the invention is particularly adapted for formation testers utilizing two packers or a single packer of the type which is set by engagement by the lower end of the tubing string assembly with the bottom of the well, or with a bridging plug, or the firing apparatus may be interposed between the packer and conventional setting slips. This is necessitated by the fact that upon setting of the packer the gap designated 102 between the fitting 96 and the upper housing 98 shown in FIGURE 11, must be closed as shown in FIGURE 12.

During descent of the formation testing apparatus into the well bore, submergence pressure is applied to both ends of the latch plunger 67; that is, the submergence pressure is applied through the side port 71 and is also applied through side port 90, socket 86, passageway 84 and cavity 85. The only force acting on the latch plunger 67 is the spring 70 which holds the latch plunger in its lower position so that the locking ball 73 is retained under the shoulder 72 and holds the firing hammer 65 in its raised position.

Submergence pressure is also applied to the side port 90 and upper socket 86 against the plunger 98 to compress the spring 100. The spring 100 is a stiff spring so that when compressed into the limit determined by the upper end of the plunger 98 it exerts a force of several hundred pounds. While the formation testing apparatus is being lowered into the well bore the submergence pressure existing in the space between the lower end of the stem 91 and the upper end of the intermediate housing 62 maintains the firing apparatus in a lower position spaced from the fitting 96 by the gap 102 as shown in FIGURE 11.

When the packer is set, the firing apparatus is mechanically forced in a direction to close the gap 102 which causes the mandrel 79 to move downward in the intermediate housing 62 isolating the upper socket 86 from the external well fluids. When the formation tester valve is open exposing the region under the packer to essentially atmospheric pressure, the pressure on the upper end of the latch plunger 67 is relieved. The spring 100 tends to force the plunger 98 downward. By reason of the

fact that the upper socket 86, annular cavity 83, passage-way 84 and cavity 85 are completely liquid-filled, downward movement of the plunger 98 causes an upward force to be exerted on the latch plunger 67 lifting the latch plunger to the position shown in FIGURE 12 so as to release the locking ball 73 and allow the firing hammer 65 to be forced downward by the spring 78. The lower end of the firing hammer engages the firing pin so as to fire the gun perforator.

Should the firing apparatus malfunction and the gun perforator fail to fire, the firing apparatus is disarmed as soon as the packer is unseated and the tubing spring is raised for the reason that the gap 102 is restored, causing the mandrel 79 to engage the head 77 and raise the firing hammer clear of the firing pin. Also, submergence pressure is again applied to the underside of the latch plunger 67 so that if the locking ball has failed to release the firing hammer there is no danger that the hammer will be released while the formation testing apparatus is being withdrawn.

Before insertion of the firing apparatus into the well bore and upon withdrawal of the firing apparatus a yoke (not shown) is manually inserted in the gap 102 to lock the apparatus in its disarmed condition.

It will be observed that all of the embodiments of the firing apparatus herein shown and described utilize the submergence pressure to arm the firing apparatus during descent of the formation testing assembly and then utilize the low pressure condition created when the packer has been set and the formation testing valve open to cause operation of the firing apparatus.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspect and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. The combination with a formation tester including a tubing string, packer means for isolating the zone to be tested from the submergence pressure of well fluid, a formation tester valve operable to connect said zone with the interior of said tubing string, thereby to subject said zone to the reduced pressure present in the tubing string, and a gun perforator for perforating said zone for flow of formation fluids into said tubing string, of a firing apparatus for said gun perforator, comprising: a firing pin and cartridge means for said gun perforator; mechanism including a hammer responsive to submergence pressures for engaging said firing pin; means also responsive to submergence pressures, for restraining said mechanism during movement of the formation tester to the zone to be tested; said means being exposed to said reduced pressure on setting of said packer means and opening of said formation tester valve, thereby to release said mechanism to cause firing of said gun perforator.

2. A firing apparatus as set forth in claim 1, wherein: said mechanism also includes means defining a compressible fluid chamber and a flow restricting means between said chamber and surrounding well fluid, whereby, on slow descent of said firing apparatus, the pressure in said chamber tends to equal the submergence pressure and whereby, on sudden exposure of said restraining means to reduced pressure, the pressure of fluid in said chamber is operable to drive said hammer.

3. A firing apparatus as set forth in claim 1, wherein: said mechanism defines passage means in communication with surrounding well fluid above said packer, for exposure to submergence pressure after exposure of said restraining means to reduced pressure thereby to actuate said hammer.

4. A firing apparatus as set forth in claim 1, wherein: said restraining means includes a latch plunger for restraining said hammer, said latch plunger having opposed

surfaces initially exposed to submergence pressures, one of said surfaces being exposed to reduced pressure on setting of said packer to cause said latch plunger to release said hammer.

5. The combination with a formation tester including a tubing string, packer means for isolating the zone to be tested from the submergence pressure of well fluid, a formation tester valve operable to connect said zone with the interior of said tubing string, thereby to subject said zone to the reduced pressure present in the tubing string, and a gun perforator for perforating said zone for flow of formation fluids into said tubing string, of a firing apparatus for said gun perforator, comprising: a firing hammer operable to fire said gun perforator; restraining means responsive to submergence pressure to maintain said firing hammer inoperative; and a release means responsive to reduction in pressure, on setting of said packer for releasing said restraining means, thereby to permit operation of said firing hammer and firing of said gun perforator.

6. A firing mechanism as set forth in claim 5, wherein: a plunger subject to submergence pressure engages said hammer to urge operation thereof; said restraining means defines a pressure area also subject to submergence and opposing said plunger; and said release means exposes said pressure area to reduced pressure, on setting of said packer and opening of said formation tester valve, thereby to permit said plunger to cause operation of said hammer.

7. A firing mechanism as set forth in claim 6, wherein: means defining a compressible fluid chamber subject to submergence pressure is exposed to one side of said plunger; and flow restriction means is interposed between said chamber and well fluid externally of said chamber, to delay reduction in pressure within said chamber on exposure to reduced external pressure, thereby to cause operation of said plunger and firing hammer on operation of said release means.

8. A firing mechanism as set forth in claim 6, wherein: telescoping tube means communicating between said plunger and the surrounding well fluids at a point above said packer to maintain said plunger exposed to submergence pressure after setting of said packer.

9. A firing mechanism as set forth in claim 5, wherein: said restraining means is a latch assembly engageable with said firing hammer including a latch plunger having opposite ends exposed to said submergence pressure; and said release means is a passage defining means, exposing one end of said latch plunger to reduced pressure, on setting of said packer and operation of said tester valve, thereby to cause said latch plunger to release said firing hammer.

10. The combination with a formation tester including a tubing string, packer means for isolating the zone to be tested from the submergence pressure of well fluid, a formation tester valve operable to connect said zone with the interior of said tubing string, thereby to subject said zone to the reduced pressure present in the tubing string, and a gun perforator for perforating said zone for flow of formation fluids into said tubing string, of a firing apparatus for said gun perforator, comprising: an ignition cartridge disposed in the upper end of said gun perforator; a firing pin above said cartridge having a hammer engageable upper end; a firing hammer; a housing structure interposed between said packer and gun perforator for supporting and guiding said firing hammer; a firing hammer control means within said housing structure defining opposing surfaces exposed to submergence pressure for initially restraining said firing hammer; and triggering means operable, on setting of said packer and opening of said formation tester valve, to isolate one of said surfaces from submergence pressures thereby to cause operation of said firing hammer.

11. A firing apparatus as set forth in claim 10, wherein: said firing hammer control means includes an enlarged

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head at the upper end of said hammer adapted, when exposed to submergence pressure, to exert an upper force on said firing hammer, and a plunger above said firing hammer tending, when exposed to submergence pressure, to cause operation of said firing hammer; said triggering means includes a ported chamber communicating with the surrounding well fluids at a point below said packer, thereby to expose said enlarged head to reduced pressures on setting of said packer; and means is provided to maintain said plunger subject to submergence pressures after setting of said packer and until firing of said gun perforator.

12. A firing apparatus as set forth in claim 10, wherein: said firing hammer control means includes an enlarged head at the upper end of said hammer adapted, when exposed to submergence pressure, to exert an upper force on said firing hammer, and a plunger above said firing hammer tending, when exposed to submergence pressure, to cause operation of said firing hammer; said triggering means includes a ported chamber communicating with the surrounding well fluids at a point below said packer, thereby to expose said enlarged head to reduced pressures on setting of said packer; means, including an end of said plunger, forming a compressible fluid chamber; and means exposing said chamber to submergence pressures, including a flow restricting orifice, whereby, on sudden relief of submergence pressure, pressure is momentarily maintained on said plunger to operate said firing hammer.

13. A firing apparatus as set forth in claim 10, wherein: said firing hammer control means includes an enlarged

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head at the upper end of said hammer adapted, when exposed to submergence pressure, to exert an upper force on said firing hammer, and a plunger above said firing hammer tending, when exposed to submergence pressure, to cause operation of said firing hammer; said triggering means includes a ported chamber communicating with the surrounding well fluids at a point below said packer, thereby to expose said enlarged head to reduced pressures on setting of said packer; and means including telescoping tubes communicating between said plunger and a point above said packer to maintain said plunger exposed to submergence pressure after setting of said packer.

14. A firing apparatus as set forth in claim 10, wherein: said firing hammer control means includes a latch plunger disposed at one side of said firing hammer and having opposed ends forming said opposed surfaces, and a locking element initially restrained by said latch plunger in position to secure said firing hammer.

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