Aug. 20, 1940. R. M. RIDLEY 2,212,044

METHOD AND APPARATUS FOR PERFORATING WELL CASINGS

Filed July 24, 1939

Fig. 1.

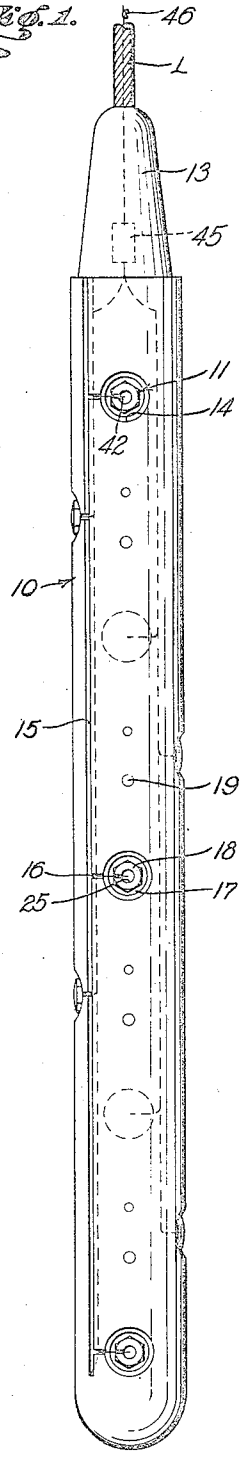


Fig. 2.

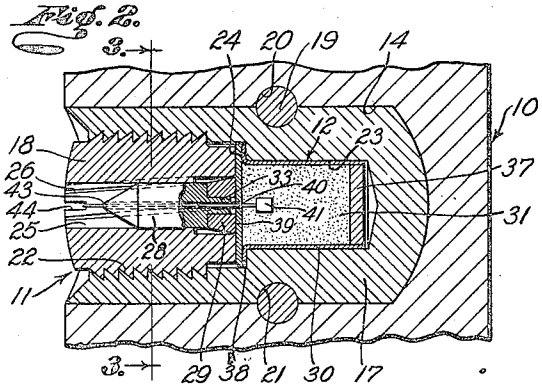


Fig. 3.

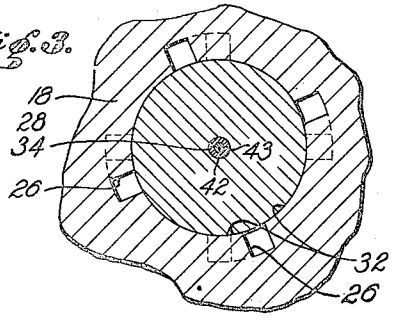


Fig. 6.

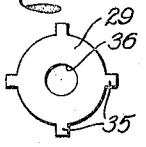


Fig. 4.

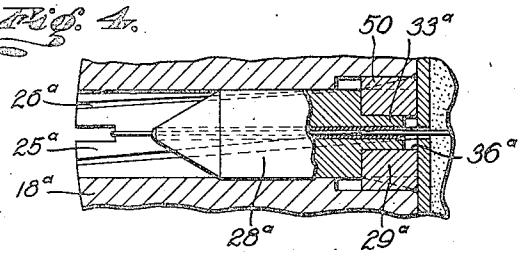


Fig. 5.

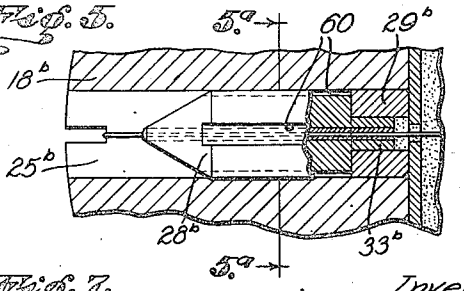


Fig. 5a.

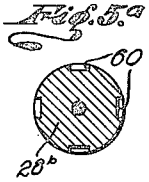
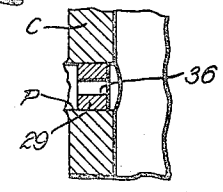


Fig. 7.



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Patented Aug. 20, 1940 2,212,044

UNITED STATES PATENT OFFICE

2,212,044

METHOD AND APPARATUS FOR PERFORATING WELL CASINGS

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Application July 24, 1939, Serial No. 286,194

18 Claims. (Cl. 164—0.5)

This invention relates to well tools and well production methods, and relates more particularly to a tool and method for perforating well casing. A general object of this invention is to provide a practical, effective, gun perforator and novel projectiles for the same, and a rapid, efficient method for perforating well casing.

It is often necessary to perforate a well casing at a productive zone of the well following the setting and cementing of the casing. Tools have been developed that fire projectiles through the wall of a set casing to perforate the same. These so-called gun perforators are successful and effective but their use is restricted to wells that are more or less free of sand. The projectiles fired by the gun perforators make large holes or perforations in the casing and where the oil or other produced fluid carries a large amount of sand, excessive quantities of sand are admitted by the large perforations and the well soon becomes sanded up.

Another object of this invention is to provide a gun perforator that is useful and effective in the perforation of casing installed in wells where the produced fluid is accompanied by large percentages of sand and other solid matter.

Another object of this invention is to provide a gun perforator that forms or provides perforations in the casing that are reduced or limited in fluid capacity to restrict the entrance of sand and other solid matter into the casing.

Another object of this invention is to provide a gun perforator that automatically beans, lines, or bushes the perforations in the casing to reduce their size and fluid capacity, and to assure uniformity in the capacity and shape of the several perforations.

Another object of this invention is to provide a gun perforator of the character mentioned that inserts the beans or bushings in the perforations in such a manner that they are securely and dependably fixed in the perforations to form reducers and wear resistant linings for the perforations.

Another object of this invention is to provide a gun perforator that may handle and install perforation beans or bushings of hard material that are very resistant to wear to prevent or reduce the enlargement of the fluid admitting openings by the abrasive action of the solid matter in the produced fluid.

Another object of this invention is to provide a novel projectile for casing perforators that embodies a trailing part that lodges in the perforation when the projectile pierces the well casing, and that forms a reducer, bean or bushing in the perforation.

Another object of this invention is to provide a projectile of the character mentioned in which the perforation bushing serves to resist or to assist in resisting the pressure developed by the explosive charge until such pressure becomes sufficiently high to assure the full piercing of the casing by the projectile.

Another object of this invention is to provide a cartridge for a gun perforator that embodies the projectile, the above-mentioned perforation bushing, the charge container and the squib associated as a single fluid-tight unit that is easily handled and quickly loaded in the gun unit of the perforator.

A further object of the invention is to provide a method for perforating well casing in which the casing is perforated after being set in the well and the resultant perforations are provided with linings or bushings for reducing the fluid capacity.

The various objects and features of my invention will be fully understood from the following detailed description of typical preferred forms and applications of the apparatus and manner of carrying out the method of my invention, throughout which description reference is made to the accompanying drawing, in which:

Fig. 1 is a side elevation of a gun perforator embodying the present invention. Fig. 2 is an enlarged, vertical, detailed, sectional view of the perforator illustrating one of the gun units and its cartridge. Fig. 3 is an enlarged transverse detailed sectional view taken as indicated by line 3—3 on Fig. 2. Fig. 4 is an enlarged fragmentary, sectional view of a portion of a gun unit illustrating another form of projectile of the invention. Fig. 5 is a view similar to Fig. 4 illustrating still another type of projectile. Fig. 5ª is a transverse, sectional view taken on line 5ª—5ª of Fig. 5. Fig. 6 is an end view of one of the trailers or bushings after it has left the gun unit, and Fig. 7 is a fragmentary, longitudinal, sectional view of a well casing, illustrating a lining or bushing set in a perforation in the casing.

The perforator of the present invention illustrated in Figs. 1, 2 and 3 may be said to comprise, generally, a body 10, a plurality of gun units 11 carried by the body 10, and improved cartridges 12 for the gun units.

The body 10 forms the carrier for the gun units 11 and the other parts of the tool and is adapted to be run into and out of the well. In practice the body 10 may be an elongate member

of generally cylindrical shape provided with a suitably rounded lower end. A rope socket 13 is provided on the upper end of the body for securing the tool to a line L for running the tool into and out of the well. One or more openings or sockets 14 are provided in the body 10 to receive the gun units 11. In the case illustrated there is a plurality of longitudinally and circumferentially spaced sockets 14. The sockets 14 may be arranged in longitudinal rows with the sockets of the adjacent rows in vertically offset relation. The sockets 14 are cylindrical bores open at the exterior of the body 10 and fully closed at their inner ends. Longitudinal external grooves 15 are provided in the body 10 to be adjacent the mouths of the sockets 14. Transverse notches 16 may connect the grooves 15 with the mouths of the sockets 14. The grooves 15 extend upwardly to the rope socket 13.

The gun units 11 are arranged in the sockets 14 to receive the cartridges 12. The gun units 11 are preferably alike and each includes a body or block 17 and a barrel 18. The blocks 17 are cylindrical elements proportioned to fit the sockets 14. Pins or wedges 19 are passed through transverse openings 20 in the body 10 and cooperate with notches 21 in the blocks 17 to removably secure the blocks in the sockets. Central longitudinal openings 22 enter the blocks 17 from forward ends of the blocks. The inner portions of the openings 22 are reduced in diameter to form chambers 23 and to provide forwardly facing annular shoulders 24. The chambers 23 are fully closed at their inner ends.

The barrels 18 are tubular parts removably secured in the openings 22 of the blocks 17. In the preferred construction the barrels 18 are threaded in the outer portions of the openings 22. The barrels 18 and the walls of the openings 22 have coarse, heavy threads. The walls of the openings 22 and the inner portions of the barrels 18 are preferably unthreaded or plain. The outer portions of the barrels 18 are polygonal for engagement by wrenches and the outer ends of the blocks 17 are recessed to render the polygonal parts of the barrels accessible. The barrels 18 are provided with central longitudinal bores 25. The bores 25 are cylindrical except at their inner end portions where they are tapered or flaring. In accordance with the invention the bores 25 are rifled, being provided with longitudinal grooves 26. The grooves 26 are circumferentially spaced and are of like size and shape. The grooves 26 may either be straight or spiralled. In the form of the invention described the grooves 26 are pitched or spiralled. The grooves 26 extend inwardly from the mouths of the bores 25 to the tapered inner parts of the bores where they die out.

A cartridge 12 is loaded in each gun unit 11 and each cartridge includes a projectile 28, a perforation lining member or bushing 29 on the projectile 28, and a container 30 holding a charge 31 for firing the projectile. The projectiles 28 are arranged in the bores 25 and are designed to pierce or perforate the well casing. Fig. 7 of the drawing illustrates a portion of well casing C having a perforation P formed by a projectile 28. The projectiles 28 are generally cylindrical elements proportioned to bear on or fit the lands 32 of the bores 25, which lands occur between the grooves 26. The forward ends of the projectiles 28 are pointed or otherwise shaped to pierce the casing C. The rear ends of the projectiles 28 are flat and provided with rearwardly projecting stems 33 of reduced diameter. In the form of the invention being described, central longitudinal openings 34 extend through the projectiles 28. The openings 34 extend from the forward ends of the projectiles to the rear ends of the stems 33. The projectiles 28 may be formed of any selected material, for example, they may be constructed of hardened steel.

The perforation lining members or bushings 29 are important features of the invention. The bushings 29 are carried by the projectiles 28 and are designed to lodge in the perforations P formed in the casing C by the projectiles. The lining members or bushings 29 are ring-like or spool-like elements arranged on the stems 33 of the projectiles 28. The bushings 29 are secured to the projectiles 28 in such a manner that they are fired together with the projectiles and become detached from the projectiles as the projectiles pass through the casing C. In practice the bushings 29 may be press-fitted on the stems 33 in such a manner that they travel with the projectiles until they enter the perforations P. The perforation lining members or bushings 29 are adapted to fit the tapered inner portions of the bores 25, being provided with tapered peripheries.

In the form of the invention being described the bushings 29 are made of a formable or malleable material such as brass, copper, bronze, or alloys of such materials so that the force developed by the charges 31 shapes them into conformity to the rifled bores 25. This provides the bushings 29 with pluralities of circumferentially spaced lugs 35. Fig. 6 of the drawing illustrates a bushing 29 after it has left a barrel bore 25. It is to be understood that the perforation lining members or bushings 29 are initially formed without the lugs 35 and that the high pressure developed by the charges 31 drives the bushings 29 through the rifled bores 25 so that the bores act as dies. The rifles or grooves 26 of the bores 25 receive the metal of the bushings 29 as the bushings are forced out through the bores and serve to shape the spaced lugs 35. The explosive pressure behind the bushings 29 has no tendency to detach the bushings from the stems 33 and the bushings leave the bores 25 with the projectiles. The projectiles 28 of course form perforations P whose diameter is substantially equal to the diameter of the projectiles, and when the members or bushings 29, carried by the projectiles, encounter the perforations P their lugs 35 bind or stick in the perforations. The lugs 35 may be flattened down through their contact with the walls of the perforations P or may remain as ears or projections on the bushings.

The wedging or lodging of the lugs 35 in the perforations P stops the bushings so that the bushings become detached from the projectiles and remain in the perforations P while the projectiles continue outwardly to perforate the surrounding cement where the same is present. Thus the bushings 29 remain in the perforations P as reducers, beans, or linings. In this connection it is to be noted that the size of the openings 36 in the bushings 29 depends upon the diameter of the projectile stems 33 and that the stems 33 may be formed to provide fluid admitting openings 36 in the casing C of any selected diameter. The openings 36 are, of course, considerably smaller than the perforations P and the bushings 29 serve to prevent or limit the

entrance of gravel, sand particles, etc. into the well.

The containers 30 occupy the chambers 23 and are connected with the bushings 29 and the projectiles 28. The containers 30 are tubular cylindrical elements closed at their rear ends by plugs 37. The plugs 37 are inserted following the loading of the powder charges 31. Outwardly projecting annular flanges 38 are provided on the forward ends of the containers 30 and are adapted to bear against the shoulders 24. A carrier plate or element 39 is arranged across the mouth or outer end of each container 30. The elements 39 are secured and sealed to the flanges 38 by welding, brazing, sweating, or the like. The elements 39 are perforate or annular having central openings 40 in alignment with the projectile openings 34. The elements 39 serve to connect the projectile assemblies with the containers 30. The rear ends of the bushings 29 are secured to the elements 39 by sweating, or the like. The forward faces of the elements 39 are engaged by the rear ends of the barrels 18 and when the barrels are threaded in and tightened down the elements 39 and the flanges 38 are clamped between the barrels 18 and the shoulders 24. This provides effective fluid-tight and pressure-tight seals at the forwards ends of the charge containers 31. It will be observed that the cartridges 12 are complete assemblies that may be easily and quickly loaded in the gun units 11.

The means for firing or igniting the powder charges 31 include igniters or squibs 41 in the containers 30. Wires 42 are connected with the squibs 41 and pass outwardly through the openings 40 and 34 to the mouths of the bores 25. Seals 43 are provided in the outer portions of the openings 34 to seal about the wires 42 and prevent the leakage of fluid through the openings. The wires 42 are trained through notches 44 in the outer parts of the barrels 18 and through the notches 16. The wires 42 continue upwardly through the grooves 15 to suitable means for controlling the ignition of the squibs 41. The present invention is not primarily concerned with the means or method of controlling the ignition of the squibs 41. As indicated in Fig. 1 of the drawing, the ignition wires 42 may enter the rope socket 13 and may connect with a controlling device or distributor 45 governed by a control wire 46 associated with the line L.

In the operation of the perforator described above, and in carrying out the method of the invention, the gun units 11 are loaded with the cartridges 12 and the body 10 carrying the units 11 is lowered into the well on the line L. When the perforator is in the portion of the casing to be perforated the device or distributor 45 is operated to ignite the squibs 41. It is usually preferred to ignite the squibs 41 in succession so that the projectiles 28 are successively fired. When a powder charge 31 is fired by its squib 41 the charge builds up a high pressure. The element 39 resists the immediate discharge of this pressure and the tapered bushing 29 fitting the tapered part of the bore 25 offers substantial resistance to the pressure. When a very high pressure has built up, the element 39 fails and the pressure acting on the bushing 29 shapes the bushing to the rifled bore 25 and drives the bushing and its projectile 28 from the barrel 18. The heat generated by the powder charge 31 may assist in the forming of the bushing 29. The bushing 29 forced through the rifled bore 25 has spaced peripheral lugs 35 when it leaves the bore 25. The projectile 28 pierces the casing C to provide a perforation P and the bushing 29 traveling with the projectile encounters or enters the perforation. The lugs 35 on the bushing lodge in the perforation P and this stops the bushing. The lugs 35 are very tightly driven into the perforation P and the bushing 29 is securely fixed in the perforation. The bushing 29 thus remains as a permanent reducing element or screen element of the casing C. The opening 36 of the bushing 29 may be of a predetermined or selected diameter depending upon the character and condition of the well. When the several gun units 11 have been fired the casing C is provided with a multiplicity of spaced perforations P each lined by a bushing 29. Following the above operations the tool is withdrawn from the well on the line L.

In Figs. 4, 5 and 5a of the drawing I have illustrated somewhat modified forms of gun units 11 and cartridges 12.

The construction shown in Fig. 4 of the drawing includes a barrel 18a having a rifled bore 25a whose inner portion may be flared or tapered in the same manner as the bore 25. The projectile 28a employed in the bore 25a may be the same as the projectile 28 and fits the bore. A perforation lining or bushing 29a is arranged on the stem 33a of the projectile 28a. The bushing 29a is press-fitted on the stem 33a or is otherwise detachably connected with the projectile 28a. The bushing 29a is formed of steel, or the like, so that an electrolytic action will not be set up between the bushing and the steel casing when the bushing is lodged in the perforation. The body of the bushing 29a is of substantially the same diameter as the bore 28a to pass through the bore and lugs 50 are provided on the periphery of the bushing. The lugs 50 are arranged and proportioned to pass through the grooves 26a of the rifled bores 25a and are intended to catch or lodge in the perforation formed in the casing by the projectile 28a. The rear end of the bushing 29a is welded or otherwise secured to the carrier element 39. The various other parts of the assembly may be the same as described above. When the projectile 28a is fired from the barrel 18a the bushing 29a travels with the projectile. The lugs 50 pass out through the grooves 26a. As the projectile 28a passes through the wall of the casing C the lugs 50 strike the wall of the perforation formed by the projectile and thus stop the bushing 29a. The bushing 29a is thus detached from the projectile 28a and the projectile continues outwardly. The lugs 50 securely fix the bushing 29a in the perforation. Where the bushing 29a is formed of steel and of less diameter than the projectile 28a, the lugs 50 may retain their general shape when they lodge in the perforation and the bushing may act as a screen having a central opening 36a and having spaces or openings at its periphery between the spaced lugs 50.

The barrel 18b of the structure illustrated in Figs. 5 and 5a has a plain unrifled bore 25b receiving a projectile 28b. The projectile 28b has a suitably pointed forward end and its inner end has a reduced stem 33b. In this form of the invention spaced longitudinal grooves 60 are provided in the projectile 28b. The grooves 60 are continuous and extend from the inner end of the projectile 28b to the pointed forward end where they die out. When the projectile 28b is fired to pierce the casing, the grooves 60 form or leave lugs on the wall of the perforation. A perforation liner or bushing 29b is detachably arranged on the stem 33a to line the perforation formed by

the projectile 28b. The bushing 29b is plain or ungrooved and suitably fits the bore 25b. When the projectile 28b is fired the bushing 29b travels with the projectile and lodges in the perforation formed in the casing by the projectile. The bushing 29b encounters the lugs formed on the wall of the perforation by the grooves 60 and is stopped by the lugs, while the projectile continues on through the casing, cement and earth formation. The lugs on the wall of the perforation stop and hold the bushing so that the bushing is retained in the perforation to act as a reducer or liner for the perforation. Instead of forming grooves in the projectile as shown in Figs. 5 and 5a the projectile may be made slightly smaller in diameter than the bore 25b and the bushing 29b so that the bushing will lodge in the perforation formed in the casing by the smaller projectile.

Having described only typical preferred forms of apparatus and of the manner of carrying out the method of my invention, I do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may appear to those skilled in the art or fall within the scope of the following claims:

Having described my invention, I claim:

1. A well tool for perforating well casing comprising a body, a gun unit carried by the body, a projectile in the gun unit, a charge for firing the projectile, and a perforate trailer associated with the projectile to be fired therewith and formed to lodge in the perforation formed in the casing by the projectile.

2. A well tool for perforating well casing comprising a body, a gun unit carried by the body, a projectile in the gun unit, a charge for firing the projectile, and a tubular bushing behind the projectile adapted to be fired with the projectile to lodge in the opening formed in the casing by the projectile.

3. A well tool for perforating well casing comprising a body, a gun unit carried by the body, a projectile in the gun unit, a charge for firing the projectile so that the projectile forms a perforation in the casing, and a bushing for the perforation carried by the projectile to line the perforation.

4. A well tool for perforating well casing comprising a body, a gun unit carried by the body, a projectile in the gun unit, a charge for firing the projectile, a stem on the rear end of the projectile, and a tubular member detachably carried on the stem and designed to remain in the perforation as a liner therefor as the projectile pierces the casing wall.

5. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore and grooves in the wall of the bore, a projectile to be fired from the bore to form a perforation in the casing, means for firing the projectile, and a bushing for the perforation associated with the projectile to be fired therewith and designed to have parts that pass through the grooves and lodge in the perforation to stop the bushing in the perforation.

6. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore and grooves in the wall of the bore, the inner portion of the bore being enlarged, a projectile to be fired from the bore to form a perforation in the casing, a charge for firing the projectile, and a formable member in the enlarged portion of the bore and associated with the projectile to be fired therewith and to be formed through cooperation with the bore and grooves to have parts which retain it in the perforation.

7. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore and a groove in the wall of the bore, the inner portion of the bore being flared, a projectile to be fired from the bore, means for firing the projectile, and a tapered member in the flared portion of the bore associated with the projectile to be fired therewith and cooperating with the flared portion of the bore to resist the pressure developed by said means until the member is formed to pass through the bore and its groove and thus have a lug for retaining the member in the perforation.

8. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore and a groove in the wall of the bore, the inner portion of the bore being enlarged, a projectile to be fired from the bore, means for firing the projectile, a member detachably connected with the projectile to be fired therewith, and a lug on the member adapted to pass through the groove and to cooperate with the perforation to retain the member in the perforation.

9. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore, the inner portion of the bore being enlarged, a projectile in the bore having a longitudinal opening, a powder charge in the gun unit for firing the projectile, means for firing the charge including an ignition wire extending through the opening to the charge, and a liner for the perforation in the enlarged portion of the bore adapted to be fired with the projectile to lodge in the perforation.

10. A well tool for perforating well casing comprising a body, a gun unit carried by the body, a projectile in the gun unit, a charge for firing the projectile, a reduced stem on the rear end of the projectile, the projectile having a longitudinal opening which extends through the stem, a bushing removably arranged on the stem to be fired with the projectile and adapted to lodge in the perforation formed in the casing by the projectile, and means for firing the charge including an ignition wire extending through the opening.

11. A tool for perforating well casing comprising a body to be run into the casing, a gun unit carried by the body and including a barrel having a bore, the inner portion of the bore being enlarged, and a cartridge in the gun unit including a projectile in the bore, a bushing member in the enlarged portion of the bore associated with the projectile to be fired therewith and designed to remain in the perforation in the casing, a carrier element connected to the member, and a charge container secured to and sealed with the carrier element.

12. In a casing perforator for perforating a well casing in a well, a projectile for piercing the casing, and a bushing detachably arranged on the projectile to lodge in the perforation in the casing.

13. In a perforator for perforating well casing, a projectile for piercing the casing, and a tubular bushing element detachably connected with the rear end of the projectile to lodge in the perforation in the casing.

14. In a casing perforator to be lowered into a

well casing, a projectile for piercing the casing, and a tapered bushing member of formable material detachably associated with the projectile to lodge in the perforation in the casing.

15. In a casing perforator for perforating a casing in a well, a projectile for piercing the casing, and a bushing element detachably arranged on the projectile to lodge in the perforation in the casing, the said element having projecting lugs.

16. In a casing perforator for perforating a casing in a well, a projectile for piercing the casing, the projectile having a longitudinal groove, and a bushing element detachably arranged on the projectile to lodge in the opening formed by the projectile.

17. The method of perforating a casing set in a well comprising firing a projectile through the wall of the casing to form a perforation therein, and lodging a bushing in the perforation.

18. The method of perforating a casing set in a well comprising firing a projectile through the wall of the casing to form a perforation therein, and firing a perforate element to lodge in the perforation to form a lining therefor.

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