

Nov. 20, 1962

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3,064,731

CLEAVAGE BARRIERS

Filed Sept. 29, 1958

2 Sheets-Sheet 1

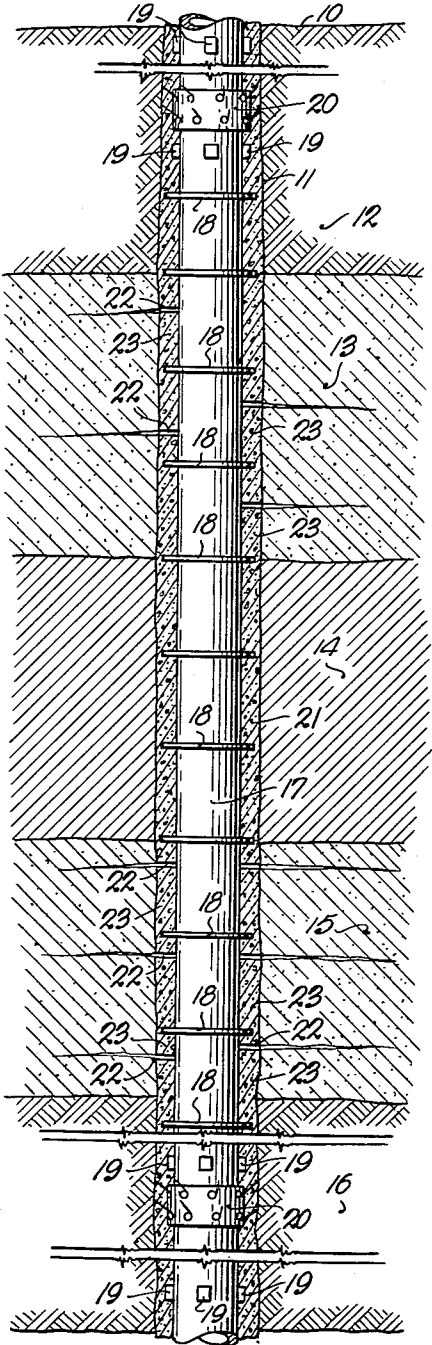


Fig. 1.

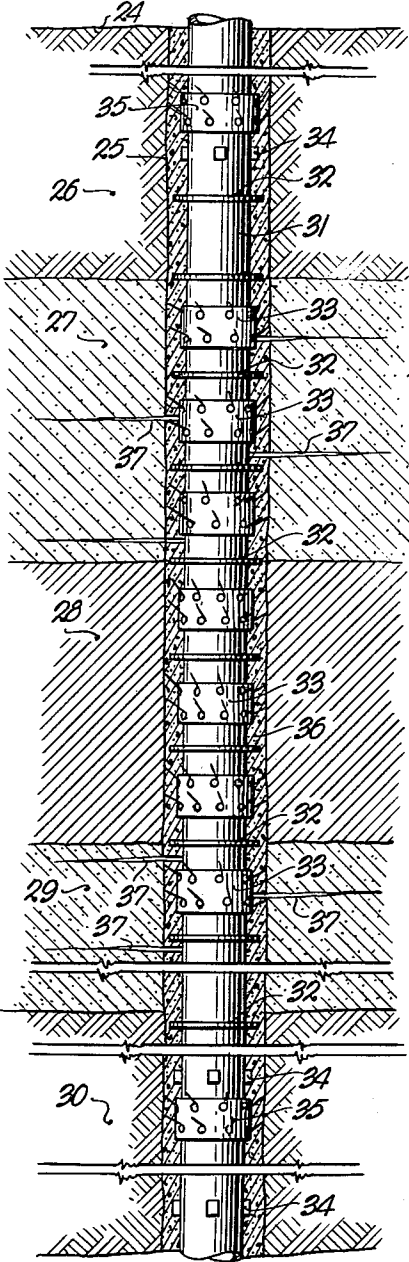


Fig. 2.

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2 Sheets-Sheet 2

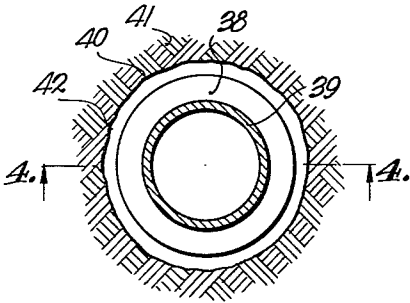


Fig. 3.

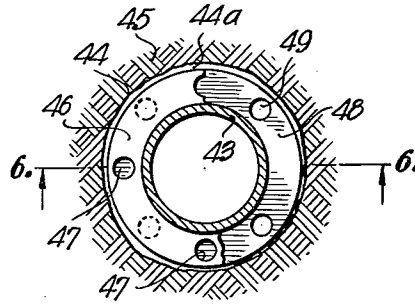


Fig. 5.

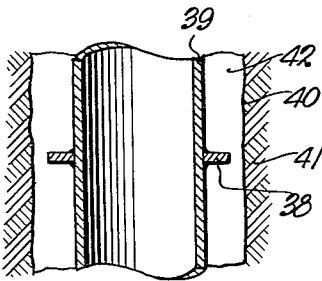


Fig. 4.

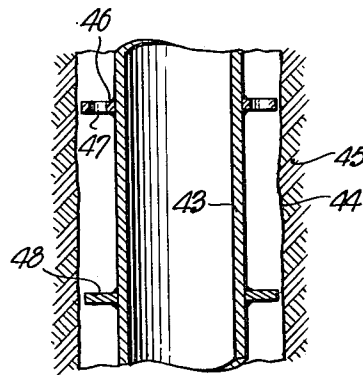


Fig. 6.

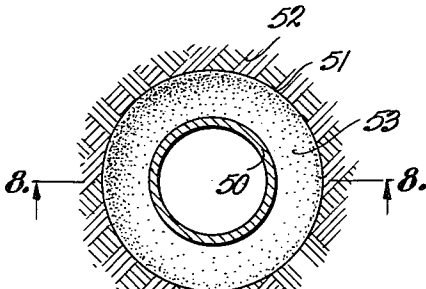


Fig. 7.

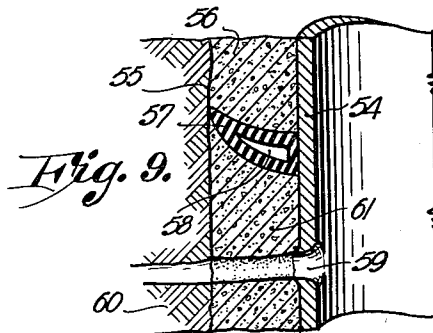


Fig. 9.

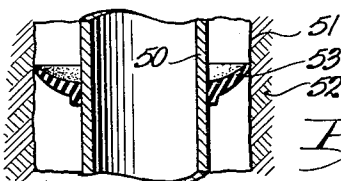


Fig. 8.

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3,064,731

CLEAVAGE BARRIERS

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5 Claims. (Cl. 166—35)

This invention relates to methods of and apparatus for protecting annular cement bonds between well pipe and well bore walls during perforation of the well pipe, as well as any application of high pressure or great force thereto and refers more particularly to methods and apparatus for closely confining any destruction of such annular cement seals by perforation or other force application to the immediate area of the well zone which is perforated, through which fracturing fluids are passed, or the like.

A usual preparation for the hydraulic fracturing of oil well formations is the perforation of the casing in the region of the producing zone. Two methods of perforation are generally employed, namely, gun perforation and jet perforation. In the former method, high velocity projectiles are fired from a special device and these, on penetration of the casing and cement, afford the necessary passageways for ejection of fracturing fluids from the casing into the formation. In the second method, shaped charges are used and the projectile effect is achieved by the jet of molten metal and superheated gas characteristic of such charges.

The perforation methods noted clearly depend on an explosive source of energy and both the casing and its surrounding annular cement seal are subjected to high to extremely high impulse loads with consequent disturbance of and damage to both the casing and the annular seal. Aside from the actual passage of the jet or projectile through the casing and surrounding annular seal, one effect of both perforation methods is to distort or inflate the casing momentarily in the vicinity of the actual perforation. This effect, coupled with the actual passage of the jet or projectile tends to crack or shatter the inelastic cement embedment of the casing. Actual experimentation both under and above ground has demonstrated unequivocally that the surrounding annular cement seal is (1) essentially pulverized at the actual perforation area, (2) shattered thoroughly immediately beyond the actual perforation area, and (3) elongate, radiating, usually longitudinal cracks extend yet further outward from the perforation area for a considerable distance. If a plurality of perforations are made simultaneously (which is conventional), this total effect is enhanced. As a result, the cement bond between the pipe and the wall of the well is effectively degraded and/or essentially destroyed. Furthermore, close control of fracturing fluids or other treatment media becomes impossible, since such media are then free to migrate from the intentional perforation area through the shattered cement zones and the radiating cement fissures which extend to the effective range of the shock waves and casing disturbances which originated at the perforation point or points. Such fissures or unwanted flow channels can extend into previously treated zones or into zones where treatment is not desirable for any of several reasons.

For treatment of relatively thin formations lying adjacent to formations which must be avoided in ensuing treatments, isolation and limitation of the destruction of the cement bond and the shock causing such destruction incidental to perforation is both desirable and necessary.

Therefore, an object of the invention is to provide methods of an apparatus for providing a periodically reinforced, annular cement bond between a casing and a well bore wall.

Another object of the invention is to provide methods of and apparatus for limiting sharply and effectively the

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area of destruction of an annular cement seal which is perforated by any existing casing and cement perforation methods and apparatus.

Another object of the invention is to provide methods of and apparatus for providing a periodically reinforced, annular cement seal between a casing and a well bore wall wherein the cement seal between the periodic reinforcements is adequately and completely bonded to both the well bore wall and the casing itself.

Another object of the invention is to provide methods of and apparatus for isolating and containing explosions, perforations and the like within a well bore whereby to better preserve the casing and its surrounding annular cement seal outside of the zones which are perforated or within which the explosions are carried out.

Another object of the invention is to provide methods of and apparatus for isolating well bore zones to protect the annular cement seal between the casing and the well bore wall without said zones against any form of penetration of the casing and annular cement seal and also during selective stimulation of the well bore wall after such penetration.

Another object of the invention is to provide such methods and apparatus for isolating well bore zones and protecting annular cement seals outside of said well bore zones which method and apparatus do not block fluid flows through the annulus between the well bore wall and the casing yet adequately contain and limit the damage to the cement seal under extreme force and pressure applied thereto within the isolated zone.

Still another object of the invention is to provide methods of and apparatus for isolating well bore zones and limiting destruction of an annular cement seal outside of said zones, said methods and apparatus both relatively cheap, relatively easy to apply and extremely simple.

Still another object of the invention is to provide methods of and apparatus for protecting cement bonds in well bores peripheral to perforation zones and the like wherein said methods and apparatus do not preclude the reciprocation of the casing in the well to provide an adequate cement seal throughout the zone to be perforated and which do not prevent the cleaning of the well bore wall and the outside of the casing during the cementing process to also aid in achieving such seal.

Other and further objects of the invention will appear in the course of the following description thereof.

In the drawings, which form a part of the instant invention and are to be read in conjunction therewith, embodiments of the invention are shown and, in the various views, like numerals are employed to indicate like parts.

FIG. 1 is a cross-sectional view through an earth formation having two formations which are desired to be perforated, a casing shown in the well bore extending through said earth formation with the inventive shock baffles shown mounted thereon.

FIG. 2 is a view similar to that of FIG. 1 but with means shown for cleaning the well bore wall and the outside surface of the pipe mounted between the shock baffles.

FIG. 3 is a cross-sectional view from above through an earth formation with a well bore extending therethrough, a casing positioned within the well bore with a first modification of the inventive shock baffle fixed thereto.

FIG. 4 is a view taken along the lines 4—4 of FIG. 3 in the direction of the arrows.

FIG. 5 is a view similar to that of FIG. 3 with a second modification of the inventive shock baffle mounted on the casing.

FIG. 6 is a view taken along the lines 6—6 of FIG. 5 in the direction of the arrows.

FIG. 7 is a view similar to that of FIG. 3 showing a

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third modification of the inventive shock baffles mounted on the casing.

FIG. 8 is a view taken along the lines 8—8 of FIG. 7 in the direction of the arrows.

FIG. 9 is a side-sectional view of a portion of a casing and well bore wall with the annular cement seal therebetween, a perforation shown with a fourth modification of the inventive shock baffle or cleavage barrier mounted on the casing.

Referring to the drawings, FIG. 1 shows a cross-sectional view through an earth formation containing two oil horizons which are desired to be perforated. The numeral 10 indicates ground level, 11 the well bore of a well extending through the two formations to be perforated, 12 the earth formations above the upper horizon to be perforated, 13 the upper horizon to be perforated, 14 the earth formations below the latter horizon, 15 the lower horizon to be perforated and 16 the earth formations below horizon 15. A casing 17 is shown extending from the surface to a level below horizon 15. A plurality of cleavage barriers or shock baffles 18 are fixed at substantially uniform intervals to the outer surface of the casing 17 and extend into the annulus in the well bore between the outside surface of casing 17 and the well bore wall 11. A plurality of conventional stops 19 are fixed to the outer surface of the casing 17 at intervals both above and below the upper and lower shock baffles 18 whereby to limit therebetween the travel of conventional scratchers 20 or other well bore wall cleaning and casing external surface cleaning devices. An annular column 21 of cement or other conventional casing sealing substance fills the annulus between the outside surface of tubing 17 and the well wall 11 from a level below horizon 15 to a level above the horizon 13. A plurality of shot holes or paths 22 extend outwardly through the casing and the casing seal out into formations 13 and 15. Radiating cracks and shattered cement areas 23 are shown surrounding these perforation points.

A typical scratcher 20 adapted to clean the external surface of the casing and the well bore face 11 during reciprocation of the casing is shown in application Serial No. 539,446, filed October 10, 1955, "Abrading Scratchers," Hall, John A. and Hall, Elmer D.

In the showing of FIG. 1, the inventive process comprises running the casing 17 (with shock baffles 18 positioned thereon at regular intervals) into the well bore and so positioning it that the baffles 18 are spaced opposite the formation or formations to be perforated. If the formation is to be perforated only at a limited area or a specific point or level, the baffles 18 need only be spaced around the particular area or point. However, if an entire formation is to be perforated, as in FIG. 1 relative formations 13 and 15, the baffles are preferably spaced at regular intervals across the entire formation with baffles at the extremities of the formation and preferably extending at least slightly therebeyond. The width of the baffles must be such that they do not prevent the casing being run into the well bore, yet substantially fill the annulus between the casing and well bore. Thus baffles 18 are formed to provide an intermediate width between the average distance between the casing and the well bore wall, in any given size well bore.

When the perforating jets or projectiles are fired through the casing and its surrounding annular cement seal into the surrounding formation, baffles 18 cannot and do not prevent the shattering or destruction of the cement around the casing at the specific perforation point or some ballooning or expansion of the casing. However, shattering and cracking is markedly limited and contained by the baffles and, particularly, the production of long radiating crack due to the severe shock of the explosion is substantially eliminated and thus the cement seal is maintained intact and with full integrity a relatively short distance from the perforation points. These statements

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have been fully proved by actual tests employing conventional casing and perforating means.

While it is preferable to space the perforations above and below the specific and individual baffles, I have discovered that conventional perforation methods will readily penetrate baffles 18 formed of steel to reach the formation so it is not at all critical or necessary to perforate between the baffles to get the desired penetration. The particular baffle which is perforated is lost at the perforation point in a limited area and loses its effectiveness in that area as a shock baffle and breakage limiter. However, the remainder of a perforated baffle remains as a functioning unit relative shots above and below it. The spacing of the baffles depends upon the depth of the formation area to be shot, the number and pattern of perforations contemplated, etc. Spacing any given perforation between at least two baffles will materially aid in controlling the damage to the annular cement seal, but a plurality of baffles on each side of each perforation is most effective. If a large cross-sectional area within a formation is to be very completely shot out, no baffles may be spaced within that area but a plurality of baffles both above and below the particular area of concentration of perforations. In such case, the seal of the casing in that area will be completely destroyed, but the radiation of effect therefrom will be limited and controlled. However, the arrangement of FIG. 1, with a plurality of baffles spanning the zone to be perforated and the placement of perforations among or between the various baffles is preferred.

The casing is conventionally run into the well bore before cement is flowed into the well bore annulus to seal the casing to the wall. Reciprocation of the casing in the well bore as the cement is being run is conventionally preferred to provide a more uniform seal. Reciprocation of the casing is possible with the shock baffles mounted on the casing, the baffles acting as somewhat of a block to the flow of cement, but permitting sufficient cement to pass thereabove during reciprocation to completely and adequately surround and seal the casing. The baffles may be perforated, as will be later described relative FIGS. 5 and 6, to aid in passage of the cement.

FIG. 2 shows a modification of the apparatus and method wherein means are provided between the shock baffles to aid in cleaning the well bore wall and the outside surface of the casing during the casing cementing process whereby to achieve a better cement bond between the casing and the well bore wall and, also, incidentally, aid in the shock baffling and cleavage barrier process. Referring to FIG. 2, 24 designates ground level, 25 a well bore, 26 the earth formation above the second horizon 29 to be perforated which overlies earth formation 30. Casing 31 is run in the well bore 25 and has a plurality of shock baffles or cleavage barriers 32 fixed to the external surface of the casing at periodic intervals therealong. A plurality of scratchers 33 are mounted on the external surface of the casing so as to slide back and forth therealong as the casing is reciprocated in the well bore. Said scratchers are preferably of the type previously described relative application Serial No. 539,446, supra. Above and below the portion of casing 31 to which are fixed the baffles 32 are fixed a plurality of conventional stops 34, between which are fixed more scratchers 35, preferably of the type described.

While the spacing of the barriers 32 shown is like that of FIG. 1 (completely across the horizons shot), it should be understood that the barriers 32 may be spaced merely above and below the horizons to be perforated, around or through specific isolated perforation areas, or the like. In earth formations like those of FIGS. 1 and 2, where formations 13 and 15 and 27 and 29 are relatively close together, it is preferred to space the baffles as shown so that, after perforating, the baffles between the perforated zones would avoid destruction or cracking of the annular seal between the per-

forated horizons and thus maintain them isolated from one another.

An annular cement seal 26 is shown between the outside surface of the casing 31 and the well bore wall 25 extending from a level below the bottom horizon 29 to be shot to a level above the top horizon 27 to be shot. The purpose of scratchers 33 is to insure that both the well bore wall and the outside surface of the casing 31 between the baffles 32 are well cleaned during the cementing process. Cement is flowed into the well bore through the casing 31 up around the outside thereof, while the casing is being reciprocated. Baffles 32 are preferably in both FIGS. 1 and 2, spaced as close together as is conveniently possible, but in FIG. 2 preferably at least a distance apart at least twice the width of the scratchers. For example, if the scratchers had a width of 6 inches, the baffles 32 would be spaced one foot apart; if the scratchers had a width of 9 inches, the baffles would be spaced one and one-half feet apart. A one to three foot spacing of baffles 18 or 32 in the type of completion shown in FIGS. 1 and 2 is typical, but not intended to be limiting. The closer the control desired over the perforated area and the shattering of the cement annular seal, the closer together the baffles must be spaced. In FIG. 2, a plurality of perforation holes or paths 37 are shown extending through the casing, the surrounding annular seal 36 and into the formations 27 and 29. As previously described relative FIG. 1, occasionally the perforations will fire through the baffles themselves. In a FIG. 2 type completion, it is far more likely that they will go through scratchers 33, but I have found that this is no problem and the perforations easily penetrate the scratchers which are set in the cement. The scratchers themselves aid in the control of the destruction of the annular cement seal around the perforation points, first, in their actual extension out beyond the surface of the casing and, second, in the wire scrapers which bridge between the casing and the well bore wall. Thus, the combination of scratchers and cleavage barriers or shock baffles shown in FIG. 2 is more efficient in reducing the extension of the perforation damage than the FIG. 1 showing alone. Indeed, scratchers as disclosed, centralizers as shown in the J. E. Hall Patent No. 2,731,816, issued January 24, 1956, Hall Patent No. 2,727,576, issued December 20, 1955, or well tools such as a cement basket as in Hall Patent No. 2,392,145, issued January 1, 1946, if spaced sufficiently close together and in a proper pattern on a casing relative a shot zone, can operate with greater or lesser success as cleavage barriers alone. Such well tools, if employed alone as cleavage barriers, must be spaced on each side of a perforation point or zone or throughout the zone as disclosed in FIGS. 1 and 2. In all applications of the invention, if it is desired to limit the extent of the shock damage in one direction only, the cleavage barriers may be placed only on one side of the perforation point. The arrangement of FIG. 2 is preferred because of the ability of such arrangement to provide an adequate seal between the casing and the well bore wall throughout the entire cleavage barrier and perforation zone. Additionally, the use of the circumferential bands around the casing also is preferred as the bands then can offer substantial resistance to inflation or expansion of the casing at the instant of the casing at the instant of perforation with the great pressures applied to the casing. The conventional well tools heretofore mentioned, unless they employ heavy collars, do not offer this advantage. Likewise, pluralities of centralizers, cement baskets or like tools sufficiently closely spaced on the casing to practice the invention tend to block the flow of cement into the well bore annulus in the casing cementing process to an objectionable degree.

Referring now to FIGS. 3 and 4, therein are shown two views of one modification of a cleavage barrier which comprises a circumferential preferably metal (steel,

brass, etc.) flange or band 38 fixedly mounted to the outside surface of a casing 39 by welding or other conventional means of attachment. The casing and cleavage barrier are shown in a well bore 40 in an earth formation 41. The clearance between the outside periphery of the cleavage barrier 38 and the well bore wall must be sufficient to permit running of the casing into the well bore with the cleavage barriers mounted thereon and also provide cement circulation therearound, yet the extension of the cleavage barrier 38 into the annulus 42 must be sufficient to give substantial blockage to the passage of the shock waves and radiating cracks encountered in perforation.

FIGS. 5 and 6 show another casing 43 positioned within a well bore 44 in earth formation 45 with cleavage barrier 46 circumferentially attached by welding or other conventional means to the external surface of the casing 43. Cleavage barrier 46 has perforations or openings 47 extending therethrough. The provision of these openings 47 permit a greater extension of the cleavage barrier 46 into the annulus 48 to better block the shock waves and radiating cracks because the perforations 47 permit the passage of cement in the sealing process. A second cleavage barrier 48 is shown mounted below the first cleavage barrier 46 having openings 49 therein staggered relative the openings in the above cleavage barrier. This arrangement permits full blockage of the shock waves and cement breakage yet permits a ready passage of cement in the cementing and sealing process.

FIGS. 7 and 8 show a third modification of the inventive shock baffle wherein a resilient baffle is employed of rubber or other resilient tough material which is able to completely fill the annulus between the casing and the well bore wall. Casing 50 is positioned within well bore 51 in earth formation 52 and has baffle 53 circumferentially mounted on the casing and of such width as to contact the well bore wall continuously around its periphery when the casing is centered in the well bore. The resilience of the baffle 53 permits the cement under pressure to by-pass it in the sealing and cementing process and permits the baffle to reverse itself as the casing 50 is reciprocated in the cementing process. It is also contemplated that the baffle 53 be perforated, if desired, for easier passage of the cement and the perforations staggered, if desired, as in the FIGS. 5 and 6 modification. The resilience of the baffle, when set in the cement, offers some advantages as to dampening shock waves and lessening the transmission of shock through the hardened cement in the perforation process. However, certain disadvantages in the use of this construction, particularly in the maintenance of its position on casing during the reciprocation process and cementing represent drawbacks not found in the preferably metallic variations of FIGS. 3-6.

FIG. 9 shows a variation of the modification of FIG. 6 wherein a resilient baffle is provided with an air space therein. Casing 54 is positioned within a well bore 55 the annulus of which is filled with cement 56 or other sealing substance. Baffle 57 is circumferentially mounted on the casing 54 and has air space or cavity 58 circumferentially positioned therein. When the casing 54 is perforated as at 59, the perforation penetrating the formation 60, the shock waves and destruction 61 pass to the baffle 57, the collapse of which into itself because of air pocket 58 serves to aid in dampening the shock and lessening the transmission of shock due to this collapsibility in addition to the resilience of the baffle itself. The metallic modifications of FIGS. 3-6 may be thickened and hollowed out if desired. Likewise, the lesser width forms of FIGS. 3-6 may be of resilient material.

The method thus comprises fixing a plurality of vertically spaced shock baffles to the outer surface of a well bore casing to be cemented and perforated before running the casing in the well, running the casing into the well bore with the baffles thereon, cementing the casing

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in the earth formation with the shock baffles positioned opposite the well bore zone to be perforated, and perforating the casing and its surrounding annular cement seal at least at one point between the upper and lowermost shock baffles. Stated otherwise the process comprises periodic reinforcement of the annular seal in the vicinity of a zone to be perforated. The casing and surrounding annular seal may be perforated at the plurality of points between the uppermost and lowermost baffles. The casing and its surrounding annular seal are preferably perforated only between baffles but, without seriously hampering the method, may be perforated through the baffles. The best results are obtained when a plurality of baffles are positioned on each side of each perforation point or zone. However, good results are obtained with only one baffle. The baffles preferably extend continuously around the casing, but may be discontinuous. The gaps due to discontinuity may be compensated for by staggering of discontinuities in adjacent baffles. Perforations in the baffles preferably are compensated for by staggering of perforations in adjacent baffles. The baffles may be resilient and in such case may have a greater outer diameter than the internal diameter of the well bore in which the casing is inserted. The baffles may be at least partially hollow, whether resilient or not. Well wall cleaning and casing cleaning devices may be advantageously used with the shock baffles, positioned therebetween, and may themselves contribute to the shock baffling and cleavage barrier function. The baffles themselves, if metallic, and if rigidly fixed to the casing, and of sufficient width and thickness, may also aid in the maintaining of the shape of the casing under the explosive of the perforations, thus minimizing the shattering and cracking of the cement in the perforation process.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all material hereinabove set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. A method of controlling the vertical extension of fracturing and destruction in an annular cement seal surrounding a casing in a well bore in an earth formation in a process of perforating the casing and its surrounding annular seal in at least one vertically defined production zone in the said earth formation, wherein it is desired

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to limit the said fracturing and destruction of the annular seal as closely as possible to said production zone whereby to minimize communication between said production zone and the surrounding nonproducing formations after perforation comprising the steps of fixing a first shock baffle and a second shock baffle vertically spaced from one another to the outer surface of the portion of the casing to be cemented and perforated before running the casing in the well, running the casing into the well bore and cementing it therein with the said baffles positioned within the vertical limits of the well bore production zone to be perforated, and perforating the casing and its surrounding annular seal at a point vertically spaced between the said first and second baffles and within the vertical limits of said production zone.

2. A method as in claim 1 including fixing at least one other shock baffle closely above and one other closely below the said first and second baffles, whereby to limit and control perforation damage within and relative to said production zone.

3. A method as in claim 2 wherein the said other baffles are each so vertically disposed on the casing as to be positioned opposite said production zone when the casing is cemented and perforated.

4. A process of controlling damage to an annular seal between a casing and the well bore wall in a process of perforating the casing, its annular seal and the well bore wall of a production zone comprising applying a plurality of reinforcements to the casing which interpenetrate the annular seal throughout the production zone to be perforated and are vertically spaced from one another and perforating the casing and seal within the vertical limits of said production zone only between said reinforcements.

5. A process of controlling damage to an annular seal between a casing and the well bore wall of a production zone in a well in a process of perforating the casing, its annular seal and the well bore wall of said production zone comprising applying a plurality of reinforcements to the casing which are vertically spaced from one another and interpenetrate the annular seal throughout the production zone to be perforated and closely thereabove and therebelow, said reinforcements adapted to limit and confine perforation damage to the annular seal within and relative to the production zone to be perforated, and perforating the casing and seal only within the vertical limits of said production zone and between reinforcements in the production zone.

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