

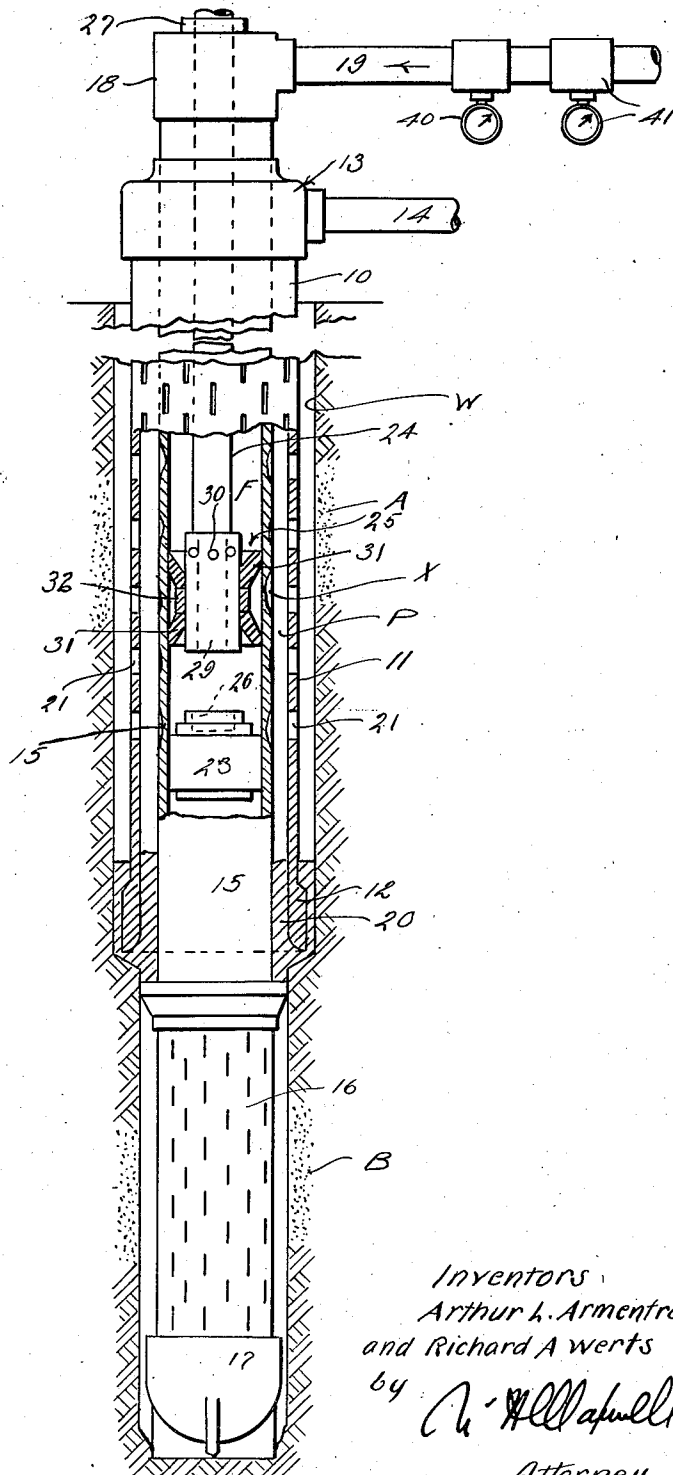
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METHOD AND APPARATUS USEFUL IN REPAIRING WELLS

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METHOD AND APPARATUS USEFUL IN
REPAIRING WELLSArthur L. Armentrout and Richard A. Werts,
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This invention relates to the art of oil wells, gas wells, etc. and relates more particularly to a method and apparatus useful in repairing tubing, casing, etc. of such wells. A general object of this invention is to provide a rapid, efficacious method and a simple, practical and inexpensive apparatus useful in repairing leaking well casing and tubing.

Leaks often develop in the casing and tubing of producing wells. For example, where a well is producing from spaced strata separated by a packer on the tubing or flow string, and the fluid from a lower stratum is independently conducted to the ground surface through an inner string of tubing, leaks frequently develop in the inner string and allow the fluids from the two strata to commingle. The fluid from the upper productive stratum flows through the liner of the outer casing with substantial velocity and impinges against the inner string and this impinging fluid usually carries solid matter which abrades the inner string and finally cuts holes in the same to permit the commingling of the fluids from the separate strata. Before such leaks can be repaired it is necessary to ascertain their depth or position with a reasonable degree of accuracy and it is difficult to accurately determine the position of such leaks. In the methods heretofore employed to locate the leaks, fluid from the earth formation was allowed or caused to flow into the well in quantities and in substantial velocities with the result that the well "sanded up" or received a large volume of solid matter which later had to be removed from the well at great cost.

Another object of this invention is to provide a method for locating leaks in well casing, tubing, etc. that does not result in the passage or entrance of solid matter into the well. In accordance with the method of the present invention clean fluid is employed and the well does not receive any solid matter but is actually flushed or cleaned as a result of the method.

Another object of this invention is to provide a method of the character mentioned in which the depth or position of the leak may be determined with great accuracy.

Another object of this invention is to provide a method for locating leaks in well casing, well tubing, etc. that may be quickly carried out without disturbing or interfering with the casing, tubing, or other permanent parts of the well installation.

Another object of this invention is to provide a method of the character referred to that

may be effectively employed to successively locate a plurality of leaks in the well tubing or string.

A further object of this invention is to provide an apparatus of the character mentioned that may be readily employed and that is wholly withdrawn from the well at the termination of the operation.

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

The figure is a vertical sectional view of a well equipped for production from two spaced strata showing the apparatus of the invention in use to locate a leak in one of the well strings.

The method and apparatus of the present invention may be used in different situations and in wells equipped in different ways. In the following detailed disclosure we will describe the invention as employed in a well equipped to simultaneously produce from a plurality of separate, distinct strata, it being understood that this is merely a typical illustrative application of the invention and is not to be construed as limiting or restricting the scope of the invention.

The well W illustrated in the drawing passes through two vertically spaced productive zones or strata A and B. The well W is provided with an outer casing 10 which may be termed a combination casing. The major upper portion of the casing 10 is imperforate, while the lower portion of the casing 10 which passes through the productive zone A is perforate, being in the form of a perforated liner 11. A shoe 12 is provided on the lower end of the casing 10 and is cemented in the well to provide a seal about the lower end of the combination casing. The casing 10 extends to the ground surface where it is provided with a head 13. The head 13 has one or more outlet conduits or pipes 14.

An inner tubing or string 15 is provided to conduct or carry away the fluid from the lower productive stratum B. The string 15 is a combination string having a perforate portion or liner 16 extending through the productive zone B, while the remaining portion of the string 15 is imperforate. The liner 16 is provided at its lower end with a shoe 17 and the liner is perforated to receive the fluid from the stratum B. The string 15 passes upwardly through the casing or string

18 with substantial clearance leaving an annular passage P for the fluid produced by the stratum A. The inner string 15 continues upwardly through the head 13 and is provided at its upper end with a head 18. One or more lateral connections or pipes 19 extend from the head 18. A seal is provided around the inner string 15 to close the lower end of the passage P and to prevent the commingling of the fluids produced from the spaced productive zones A and B. In the case illustrated the inner string 15 is cemented or sealed in the shoe 12 and lower portion of the casing 10 at 20.

It is believed that it will be understood how the fluids from the productive stratum A pass through the perforations of the liner 11 and flow up through the passage P to the head 13 to discharge from the pipe 14 and how the fluid from the stratum B enters the liner 16 and passes upwardly through the inner string 15 to flow out through the pipe 18. The fluid from the stratum A may pass through the perforations 21 of the liner 11 under substantial pressure and at a high velocity. Fluid thus produced directly from the earth formation usually carries with it a substantial proportion of sand or other solid matter, and this solid matter contained in the fluid which impinges against the inner string 15 forms pits in the string 15 and finally erodes or cuts through the inner string 15 as at X. In this connection it will be noted that the inner string 15 is spaced only a short distance inwardly from the perforations 21 which admit the fluid from the stratum A. The erosion or cutting out of the inner string 15 may occur throughout a substantial portion of the string 15 or may only occur at isolated vertically spaced points. When the inner string 15 is eroded or cut out to the extent that an opening is formed as at X the fluids from the two independent productive strata A and B are allowed or caused to commingle. In many cases this is highly undesirable and it is necessary to take immediate steps to locate the leak in the inner string and to take steps to remedy or close the leak.

The apparatus of the present invention includes a plug 23 for closing off the inner string 15, an operating string 24 adapted to be moved vertically through the string 15 and means 25 on the string 24 for slidably sealing with the interior of the tubing string.

The plug 23 is adapted to form a closure in the tubing string 15 and may be of any selected or suitable form. The plug 23 is preferably of a type that may be readily set in any selected position in the tubing or string 15 and then later withdrawn from the well. In accordance with the invention the plug 23 is set or installed in the tubing string 15 at a point below the probable or possible locations of the leaks in the tubing string. For example, as illustrated, the plug 23 is set in the tubing string 15 below the lowermost perforations 21 of the liner 11. The plug 23 is preferably of a kind that may be tightly engaged and sealed in the tubing string 15 to effectively resist the leakage or passage of fluid under substantial pressure. The plug 23 may be run into the well on a string and set at the selected point whereupon the setting string may be withdrawn from the well. In a like manner, the plug 23 may be re-engaged by a string to be withdrawn from the well thereon. We have shown a socket 26 in the upper end of the plug 23 for removably receiving the lower end of the plug setting and removing string. As plugs of the general character illustrated are common and well known in the art, we

have not illustrated or described the plug 23 in detail.

The string 24 is employed to carry the sealing means 25 and to operate or move the same during the leak locating operation. The string 24 may be a string of tubing, drill pipe, or rods and is proportioned to be received in the tubing string 15 with substantial clearance leaving an ample fluid passage F therethrough. The operating string 24 slidably passes through a gland 27 or other suitable sealing means on the head 18. In accordance with the invention the string 24 is preferably of a character that may be readily assembled and run into the well and is of such nature that its aggregate length may be easily determined and recorded during its assembling and during its movement in the well. In practice the string 24 may be the string employed to set and remove the plug 23.

The sealing means 25 is adapted to slidably seal with the interior of the tubing string 15 and is such that it may be moved through the string 15 until it assumes a position where it covers or closes the leak X. In the case illustrated the sealing means 25 includes a tubular body 29 threaded or otherwise secured to the lower end of the operating string 24. The lower end of the tubular body 29 has its passage or opening open to the interior of the tubing string 15. One or more lateral openings 30 is provided in the upper portion of the tubular body 29 to communicate with its interior for the purpose to be subsequently described.

The sealing means 25 further includes two spaced sealing rubbers or sealing members 31. The sealing members 31 are annular or tubular and are in surrounding relation to the body 29. The sealing members 31 are spaced apart by an annular spacer 32. As illustrated, the two sealing members 31 are positioned on the body 29 below the openings 30. The peripheries of the sealing members 31 slope or pitch axially outward and radially from the spacer 32 and the exposed or outer ends of the sealing members 31 are concave so that the members are expanded by fluid pressure in the string 15 to tightly seal with the internal surface of the string 15. The members 31 are preferably formed of flexible resilient material and are proportioned to slidably seal with the interior of the string 15 at spaced points or planes under all conditions. It will be seen that the passage through the tubular body 29 and the openings 30 allow fluid to readily by-pass the sealing members 31 when the sealing means 25 is moved longitudinally through the string 15. The ported tubular sealing means 25 does not have a swabbing action or piston action when moved through the tubing string 15.

The method of the invention as employed with the apparatus described above may be said to comprise the operations of setting the plug 23 to close the tubing string 15 below the probable or possible lower limit of the leaks in the same, pumping or otherwise forcing fluid downwardly through the string 15 to pass through the leak or leaks X and to flow upwardly through the outer string or casing 10 or to enter the earth formation, moving the sealing means 25 longitudinally through the tubing string 15 from one extremity to the other of the possible zone of leaks in the same until the sealing means closes the leak or leaks to restrict or stop the flow of the fluid and then recording or noting the depth at which the sealing means 25 covers or closes the leak X.

In performing the method of the invention the first step is the setting of the plug 23. Assuming that the tubing string 15 is open and clear the plug 23 is run into the string 15 and set in the usual manner well known to those skilled in the art. It is preferred to position and set the plug 23 at a point below all possible holes or leaks in the wall of the string 15. In practice the plug 23 may be set in the lower end portion of the string 15 immediately above its liner 16 so that it will be below all possible leakage openings. The string on which the plug 23 is run into the well is removed following the setting of the plug.

Following the setting of the plug 23 the sealing means 25 is secured to the lower section of string 24 and is introduced into the tubing string 15. The head 18 or its packing means 27 is assembled about the string 24 to provide a seal about the string so that fluid under pressure may be circulated through the tubing string 15 without leakage from the head. In accordance with the invention the sealing means 25 is slowly moved longitudinally through the tubing string 15 while fluid under pressure is circulated through the string. The sealing means 25 may either be moved upwardly or downwardly through the tubing string 15. In the case illustrated it may be assumed that the sealing means 25 is to be moved upwardly through the tubing string 15 to locate the points of leakage. In this instance the string 24 is assembled and run into the well to bring the sealing means 25 to its lowest position. The lengths of the stands or sections employed in making up the string 24 are determined and recorded as the string is run into the well so that the position of the sealing means 25 is known.

With the sealing means 25 in the selected initial position in the tubing string 15 either below or above the zone of possible leakage, fluid is forced under pressure through the string 15. This fluid may be water, well fluid or other selected fluid. In accordance with the invention the fluid is pumped downwardly through the string 15 to escape or pass through the leakage opening or openings X and then pass upwardly through the outer string 10 or then dissipate itself in the earth formation. Thus, in the case illustrated, the fluid is pumped or forced through the pipe 19 to pass down through the string 15, out through the leakage opening or openings X and then upwardly through the outer string 10 to discharge from the pipe 14. It is preferred to deliver the fluid under substantial pressure, say a pressure of 1000 pounds per square inch. The volume of fluid thus circulated through the strings 15 and 10, of course, depends upon the size of the leak or leaks X. The pressure on the fluid circulated may be indicated by a pressure gauge 40 and the volume or quantity of fluid being circulated may be indicated by a gauge or meter 41 associated with the pipe 19 or with the pump or other means delivering the fluid under pressure to the string 15.

With the initial position of the sealing means 25 known or determined and with the fluid being circulated through the string 15 under pressure, as above described, the string 24 is moved to slowly move the sealing means 25 longitudinally through the tubing string 15. Where the initial position of the sealing means is in the lower portion of the string 15 below the zone of possible leakage the string 24 is moved upwardly to slowly raise the sealing means through the tubing string. So long as the sealing means 25 moves through fluid tight imperforate portions of the string 15 the pressure and the volume of the fluid being

circulated remain constant. However, when the sealing means 25 reaches and covers a leak X there is a reduction in the volume of the fluid being circulated through the string 15 and an increase in the pressure on the fluid. These changes are indicated by the gauge 40 and meter 41. When the operator observes such changes in the readings of the gauge 40 and meter 41 movement of the string 24 is stopped and the position of the sealing means 25 is determined and noted. The depth or position of the sealing means 25 may be readily determined by measuring the length or amount of the string 24 that has been withdrawn or moved upwardly during the upward movement of the sealing means 25. In the drawing it will be seen how the sealing means 25 may assume a position where its sealing members 31 seal with the wall of the string 15 at points above and below a leak X. With the sealing means 25 in such a position the fluid being pumped or circulated into the string 15 cannot reach the leak X thus covered and there is, as a result, an increase in the pressure of the fluid and a reduction in the volume of the fluid circulated. The sealing means 25 may be shifted slightly to ascertain the exact position and extent of the leak X.

The gauge 40 and meter 41 will disclose whether there are any additional openings or leaks in the string 15. For example, if the pressure gauge 40 and the meter 41 indicate that there is a substantial volume of fluid in circulation when the sealing means 25 covers the known or located leak X there is in all probability an additional leak or leaks above the leak that has been located. In this situation the string 24 is again moved to slowly advance the sealing means 25 through the string 15. It will be seen that when the sealing means 25 is raised or moved from the located leak X that the fluid is free to pass through the openings 30 and tubular body 29 to by-pass the sealing means 25 and thus the fluid is free to again escape through the located leak X. The pressure and the volume of the circulated fluid is thus returned to the normal or original values. The sealing means 25 is moved slowly upward through the string 15 until it covers the second or next leak X. When this occurs the gauge 40 and meter 41 again indicate that the pressure on the fluid has increased and that the volume of fluid circulated has decreased and the operator stops movement of the string 24 and ascertains the position of the newly encountered leak X by measuring or determining the length of the string 24 that has been raised from the well. By repeating the above described operations all of several spaced leakage openings in the string 15 may be accurately located.

When the leakage opening or openings X have been located and their positions noted, as above described, the circulation of the fluid is terminated and the string 24 carrying the sealing means 25 is removed from the well. The plug 23 is released and pulled from the well. Appropriate steps are then taken to close or seal the leak or leaks X in the string 15. These repair operations are materially expedited by reason of the fact that the exact locations of the leaks have been accurately determined.

Having described only a typical preferred form and method of carrying out our invention, we do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to ourselves any variations or modifications that

may appear to those skilled in the art and fall within the scope of the following claims:

Having described our invention, we claim:

1. The method of locating a leak in a tubular well string which includes passing fluid downwardly through said string to pass through the leak, moving a sealing means through said string while the fluid is flowing therethrough until the sealing means closes the leak to reduce or terminate said flow of fluid and determining the position of the sealing means in the well string.

2. The method of locating a leak in a tubular well string which includes passing fluid downwardly through said string to pass through the leak, moving a sealing means through said string while said fluid is flowing therethrough until the sealing means closes the leak to reduce or terminate said flow of fluid, ascertaining the position of the sealing means when said flow is reduced or terminated, and then withdrawing the sealing means from the string.

3. The method of locating a leak in a tubular well string which includes closing the string below the zone of leakage, forcing fluid under pressure downwardly through said string to pass out through the leak, moving a sealing means longitudinally through said string, while the flow of said fluid is maintained, until the sealing means closes the leak to restrict or stop the flow of fluid through the string, ascertaining the position of the sealing means when it closes or restricts the leak, and then withdrawing the sealing means from the well.

4. The method of locating a leak in a tubular well string which includes setting a plug in the string below the zone of leakage, pumping fluid under pressure down the string to discharge through said leak and return upwardly in the well around said string, running a means which seals with the interior of the string longitudinally through the string while the fluid is being pumped into the string until said means closes off the leak, ascertaining the position of said means when it closes off the leak, and then withdrawing said means from the well.

5. The method of locating a leak in a tubular well string which includes closing off the tubular string below the zone of leakage by installing a plug in the tubular string, circulating fluid under pressure through the tubular string by pumping fluid down through the tubular string from its upper end to discharge from the leak therein, moving a sealing means longitudinally through the tubular string, on an operating string whose length is known, determining when the sealing means closes or restricts the leak by observing a reduction in the circulation of the fluid, determining the position of the sealing means when such reduction occurs by ascertaining the length of the operating string, and then withdrawing the sealing means, operating string and plug from the well.

6. The method of locating a leak in a tubular well string which includes closing off the tubular string below the zone of leakage by installing a plug in the tubular string, circulating fluid under pressure through the tubular string by pumping fluid down through the tubular string from its upper end to discharge from the leak therein, moving a sealing means longitudinally through the tubular string, on an operating string whose length is known, determining when the sealing means closes or restricts the leak by observing an increase in the pressure on the fluid being delivered to the tubular string, ascertaining the position of the sealing means when such increase in pressure occurs by measuring the length of the operating string, and then removing the operating means and sealing means from the well.

7. Apparatus useful in locating a leak in a tubular well string comprising, a plug for closing the well string at a point below the leak, an operating string, a body on the operating string including a sealing member for sealing with the interior of the tubular string and operable longitudinally in the tubular well string by the operating string, and means for allowing the passage of fluid past the sealing members.

8. Apparatus useful in locating a leak in a tubular well string comprising, a plug for closing the well string at a point below the leak, an operating string, a body on the operating string, and spaced sealing members on the body for slidably sealing with the interior of the tubular body, the body having a passage for communicating with the interior of the tubular string above and below the sealing members.

9. The method of locating a leak in a tubular well string which includes, closing the lower end portion of the well string, passing fluid downward through the string to escape through the leak, moving a sealing means through the string while the fluid is flowing therethrough until the sealing means closes the leak to reduce or terminate the flow of fluid, and determining the position of the sealing means in the string.

10. The method of locating a leak in a tubular well string which includes establishing circulation of fluid through the string so there is flow through the leak, observing the character of such flow, operating a member in the string operable to interfere with flow through the leak upon reaching the location of the leak, observing the variation in the character of flow occurring when said member interferes with the flow through the leak, and determining the position of the member in the string when variation in the flow occurs.

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