

Feb. 24, 1959

J. E. LANDERS ET AL

2,875,142

METHOD AND APPARATUS FOR CATHODIC PROTECTION OF WELLS

Filed June 2, 1955

2 Sheets-Sheet 1

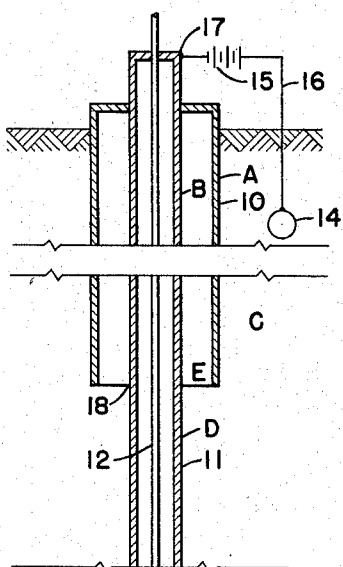


FIG. 1

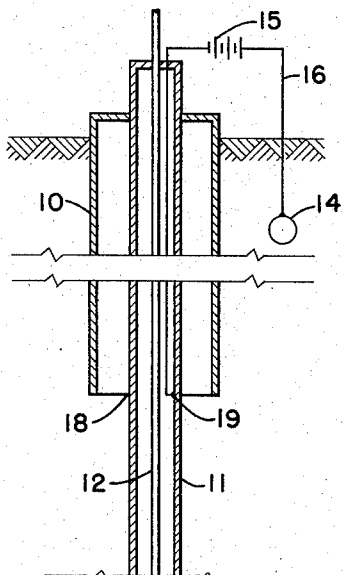


FIG. 3

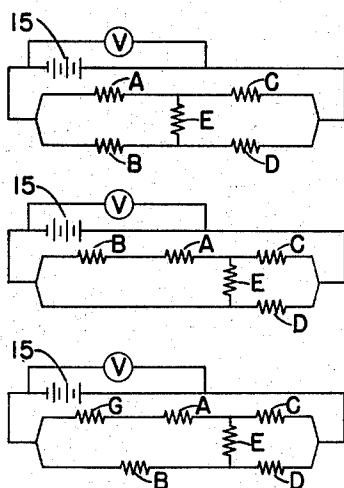


FIG. 2

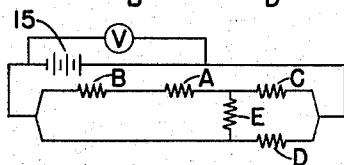


FIG. 4

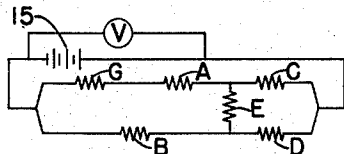


FIG. 6

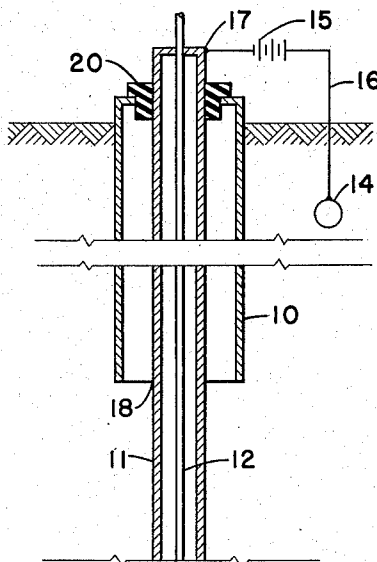


FIG. 5

INVENTORS.
JAMES E. LANDERS
JOHN D. SUDBURY
BY

Floyd Trimble
ATTORNEY

Feb. 24, 1959

J. E. LANDERS ET AL

2,875,142

METHOD AND APPARATUS FOR CATHODIC PROTECTION OF WELLS

Filed June 2, 1955

2 Sheets-Sheet 2

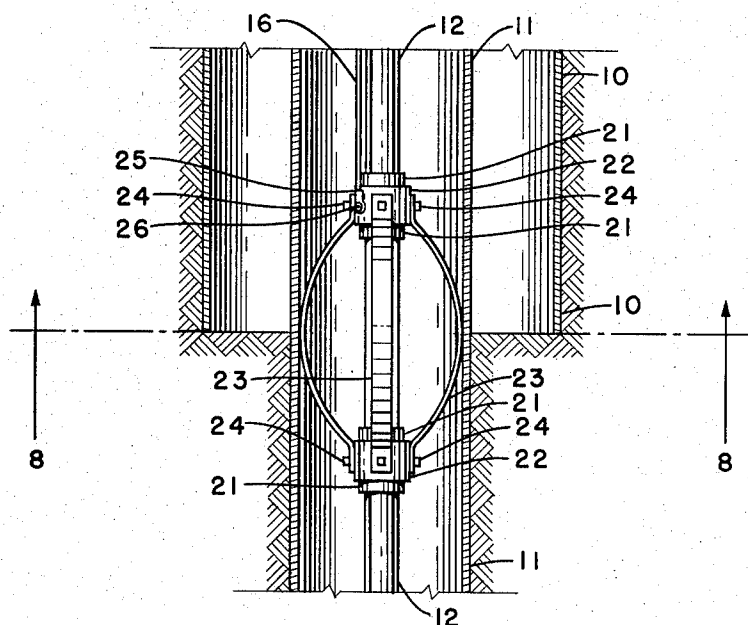


FIG. 7

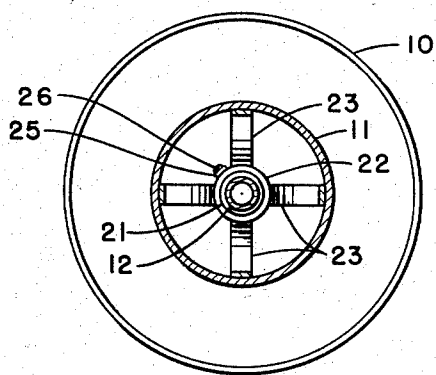


FIG. 8

INVENTORS.
JAMES E. LANDERS
JOHN D. SUDBURY
BY
Floyd Trimble
ATTORNEY

1

2,875,142

METHOD AND APPARATUS FOR CATHODIC PROTECTION OF WELLS

James E. Landers, El Paso, Tex., and John D. Sudbury, Ponca City, Okla., assignors to Continental Oil Company, Ponca City, Okla., a corporation of Delaware

Application June 2, 1955, Serial No. 512,741

5 Claims. (Cl. 204—147)

This invention relates to method and apparatus for use in connection with the cathodic protection against electrochemical corrosion of oil well structures and is more specifically directed to prevention of accelerated corrosion of an oil well casing in localized areas adjacent to the lower extremity or base of the enveloping surface pipe.

Throughout the following specification and claims the term "tubing" is to be understood to mean the pipe string of 2-2½-inch diameter which traverses the length of the well and through which fluids are produced. The term "casing" is the 5-7-inch pipe set to the bottom of the well for the purpose of protecting the hole from waters and loose earth. The term "surface pipe" is to be understood to mean the 9-12-inch diameter pipe which extends part way down into the well outside of the tubing and is cemented to the earth formations around the well. The term "current" is used to denote the flow of electrons from an area of negative charge to an area of positive charge.

When a well casing traverses two formations, each containing water of a different salt concentration, an electrical potential difference is developed between the two sections of casing in contact with the two formations. Electrons enter one of these sections which, in combination with the surrounding formation and the interface, is referred to herein as the anode area. The electrons then traverse the casing and flow from the second section which, in combination with the surrounding formation and interface, is referred to herein as the cathode area. The electrons then complete the circuit by returning to the anode area through the formation. As the electrons flow through the casing an electrochemical process causes hydrogen atoms to form in the cathode area and iron from the casing to dissolve in the anode area. The iron is dissolved by the formation of iron ions. The hydrogen formed in the cathode area, if not removed, would eventually insulate the casing from the cathode area sufficiently to prevent the flow of electrons. Hydrogen is usually removed, however, either by reaction with oxygen to form water, or by the action of hydrogen consuming bacteria.

If the electron flow is permitted indefinitely, enough iron will be removed from the casing in the anode area to corrode the casing and develop leaks.

This electrochemical corrosion of the casing in the anode area may be prevented by connecting the negative terminal of a direct current source to the casing and connecting the positive terminal of the source to an anode buried in the earth adjacent to the well. This direct current source must be of sufficient magnitude that the casing at all points along its length is cathodic with respect to the anode buried in the adjacent earth. If such is the case, electrons will flow from the casing through the earth to the buried anode. Of greater importance is the fact that no electrons will flow to any point of the casing, and, consequently, no electrochemical corrosion will result.

2

The difficulty encountered with this method of electrical protection of the casing is that, when the negative terminal of the current source is applied to the casing, the current divides, part of it flowing down the casing and part of it flowing down the surface pipe.

As will be described in more detail later in this specification, electrons in most wells flow from the base of the surface pipe to the casing, causing as described above, corrosion of the casing at that point.

It is, therefore, the principal object of our invention to provide a method and apparatus for preventing electrochemical corrosion of the casing adjacent to the base of the surface pipe.

It is a more particular object of our invention to provide a method and apparatus for maintaining an electric current between a well casing and an anode buried in the ground while maintaining the lower part of the surface pipe substantially anodic with respect to the portion of the casing adjacent thereto.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, said invention, then, comprises the features herein-after fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings:

Figure 1 illustrates the conventional method for cathodically protecting encased wells;

Figure 2 is a diagram of the electric circuit associated with the method illustrated in Figure 1;

Figure 3 illustrates the preferred form of the method of our invention for cathodically protecting an encased well;

Figure 4 is a diagram of the electric circuit associated with the method illustrated in Figure 3;

Figure 5 illustrates an alternative method of our invention for cathodically protecting an encased well;

Figure 6 is a diagram of the electric circuit associated with the method illustrated in Figure 5;

Figure 7 is an elevational view partially in cross-section of the part of a well surrounding the bottom of the casing wherein is shown the apparatus of our invention for practicing the preferred method of our invention; and,

Figure 8 is a horizontal cross-sectional view of the apparatus of Figure 7 taken along the plane and in the direction substantially indicated by the line and the arrows at 8—8.

Broadly stated, our invention appertains to oil well cathodic protection methods in which the well structure is maintained cathodic with respect to a protective anode buried in the ground and which are intended to eliminate all electrochemical corrosion in the well structure. It comprises maintaining the potential of the casing in the area of the base of the surface pipe at least as great as the potential at the base of the surface pipe. In brief, the casing is maintained cathodic with respect to the base of the surface pipe, thereby eliminating the flow of electrons from the pipe to the casing and the consequent accelerated corrosion in that area.

With reference now to Figure 1 wherein is illustrated the conventional method for cathodically protecting an encased well, 10 designates the surface pipe of the well and 11 designates the casing therein. Inside the casing 11 is the conventional tubing 12 through which production flows. The casing 11 and the surface pipe 10 are made of metal and are electrically connected at the top of the

3

well. An anode 14 is embedded in the earth adjacent to the well, and a source of direct current 15 is connected by a cable 16 between the anode 14 and a point 17 on the top of the casing 11 as indicated.

With reference now to Figure 2 wherein is shown a diagram of the electric circuit of this combination, A represents the resistance of the surface pipe 10 from the point where it joins casing 11 to its bottom. B represents the resistance of the casing 11 from the point where it joins the surface pipe 10 to a point 18 on it adjacent to the bottom of the surface pipe 10. C represents the resistance of the earth to the flow of current from the surface pipe 10 to the anode 14. D represents the resistance of the casing 11 and the earth to current flow down the casing 11 and through the earth to the anode 14 from the point 18, and E represents the resistance of the well fluids to current flow between the point 18 and the bottom of the surface pipe 10. V represents the electromotive force of the current source 15.

In this circuit, when

$$\frac{A}{V(A+C)} = \frac{B}{V(B+D)}$$

or in simpler form

$$\frac{A}{C} = \frac{B}{D}$$

the potentials at the point 18 and the bottom of the surface pipe 10 are equal because the potential drop across A equals the potential drop across B. When these potentials are equal, no current will flow through E, and hence neither the surface pipe 10 nor the casing 11 will be corroded. When

$$\frac{A}{V(A+C)}$$

is less than

$$\frac{B}{V(B+D)}$$

or in simpler form when

$$\frac{A}{C}$$

is less than

$$\frac{B}{D}$$

the potential drop across A will be less than the potential drop across B and current will flow through E into the casing 11 causing corrosion of the casing 11 in the neighborhood of the point 18. When

$$\frac{A}{V(A+C)}$$

is greater than

$$\frac{B}{V(B+D)}$$

or in simpler form, when

$$\frac{A}{C}$$

is greater than

$$\frac{B}{D}$$

the potential drop across A will be greater than the potential drop across B, and hence current will flow through E onto the surface pipe 10 causing corrosion of the bottom of the surface pipe 10.

In most wells, the values of the resistances A, B, C, and D are such that

$$\frac{A}{C}$$

is less than

$$\frac{B}{D}$$

4

and the casing 11 is corroded in the neighborhood of the point 18. This situation could be altered in any one of several ways. As A or D is increased or as B or C is reduced, the values of the ratios will approach each other until

$$\frac{A}{C} = \frac{B}{D}$$

when no current will flow between the point 18 and the bottom of the surface pipe 10. As A or C is increased further or as B or D is reduced further,

$$\frac{A}{C}$$

will become greater than

$$\frac{B}{D}$$

and current will flow from the point 18 to the bottom of the surface pipe 11 corroding the latter.

Increasing A while reducing B

As the point of contact 17, where the negative terminal of the current source 15 is connected to the casing, is moved down the casing, where the resistance of the casing between the point 17 and the point where it joins the surface pipe is F, the potential drop between the point 17 and the bottom of the surface pipe is

$$\frac{A+F}{V(A+F+C)}$$

and the potential drop between the points 17 and 18 is

$$\frac{B-F}{V(B-F+D)}$$

Current will continue to flow from the bottom of the surface pipe 10 to the point 18 until the point 17 is moved far enough down the casing 11 so that

$$\frac{A+F}{V(A+F+C)} = \frac{B-F}{V(B-F+D)}$$

or reducing this until

$$\frac{A+F}{C} = \frac{B-F}{D}$$

This would be the ideal point to connect the negative terminal of the current source 15 to the casing, but since the values of the resistances A, B, C, D, and F are too difficult to determine, it is more convenient to move the point 17 further down the casing to a point where it is certain that

$$\frac{A+F}{C}$$

will be greater than or equal to

$$\frac{B-F}{D}$$

The depth at which the bottom end of the surface pipe 10 is located is ascertainable from the records made when the well was encased and is also ascertainable by any one of a number of other ways. When the point 17 is moved down the casing 11 to a point 19 adjacent to the bottom of the surface pipe 10, as illustrated in Figure 3, the potential difference between the point where the negative terminal of the current source 15 is connected to the casing 11 and the point 18 becomes

$$\frac{B-B}{V(B-B+C)} = 0$$

and the potential difference between the point where the negative terminal of the current source 15 contacts the casing 11 and the bottom of the surface pipe becomes

$$\frac{A+B}{V(A+B+C)}$$

5

as illustrated in Figure 4. In this case, where the negative terminal of the current source 15 is connected to the point 19 on the casing, current will flow from the points 18 and 19, which coincide and describe a circumferential line on the casing 11, to the bottom of the surface pipe 10. This current will cause electrochemical corrosion of the bottom of the surface pipe 10, but such corrosion is permissible since it does not hinder production of the well.

Increasing A without reducing B

With reference now to Figure 5, the well equipment here illustrated is identical to that illustrated in Figure 1 except that here the top of the surface pipe 10 is separated from the casing 11 by an insulating collar 20. When the resistance of the collar 20 is designated as G, the potential at the point 18 on the casing 11 is

$$\frac{B}{V(B+D)}$$

and the potential of the bottom of the surface pipe 10 is

$$\frac{A+G}{V(A+G+C)}$$

as illustrated in Figure 6. No current will flow between the point 18 and the bottom of the surface pipe when these potentials are equal, that is, when

$$\frac{A+G}{V(A+G+C)} = \frac{B}{V(B+D)}$$

or reducing this, when

$$\frac{A+G}{C} = \frac{B}{D}$$

In an ideal situation, the resistance of G would be carefully chosen so that this relationship would exist; but since the values of A, B, C, and D are difficult to determine, it is convenient to select a value of G for which

$$\frac{A+G}{C}$$

is certain to be greater than or equal to

$$\frac{B}{D}$$

When this is the case, current will again flow from the casing 11 to the surface pipe 10 corroding the latter; but as mentioned above, this corrosion is permissible.

Reducing C

If the anode 14 is moved closer to the surface pipe 10 than it was in the situation described in connection with Figure 1, the value of C is reduced and the value of the ratio

$$\frac{A}{C}$$

is increased. When the value of the resistance C is reduced to a point where

$$\frac{A}{C} = \frac{B}{D}$$

no current will flow between the point 18 and the bottom of the surface pipe. This procedure is not desirable because, since it eliminates current flow through the resistance E in Figure 1 by increasing the current through C relative to the current through D, this procedure necessitates the use of current source 15, the electromotive force of which is impractically large if a sufficient current to effect adequate cathodic protection is to be driven through the casing. Furthermore it is known that greater variations in potential, along the length of the surface pipe, occur as the anode is brought closer to

6

the pipe. The objects of my invention cannot, therefore, be achieved by controlling the distance between the anode and the surface pipe.

Increasing D

If a resistance is maintained between two adjacent sections of the casing 11 below the point 18, the value of D is increased, and hence the value of

$$\frac{B}{D}$$

is reduced. If this resistance is of sufficient magnitude so that

$$\frac{A}{C} = \frac{B}{D}$$

no current will flow between the point 18 and the bottom of the surface pipe, but this procedure is less desirable for the same reason as is the procedure of reducing the value of the resistance C.

With reference now to Figure 7 wherein is shown a form of apparatus of our invention for the practice of the method of our invention illustrated in Figure 3, 10 designates the lower part of the surface pipe; 11 designates a section of the casing adjacent thereto; and 12 designates a section of the tubing referred to above. Mounted on the tubing 12 and secured thereto by any suitable means are two insulating collars 21. Secured to the outside of the collars 21 by any suitable means such as shrink fitting are two metal collars 22. Four convex springs 23 are secured between the collars 22 by bolts 24. The natural contour of the springs 23 is sufficiently convex that they firmly contact the inner wall of the casing 11. The insulated cable 16 referred to above extends down into the well from the current source 15, and a terminal 25 on the end of the cable 16 is connected to the upper collar 22 by a bolt 26. When current is applied to the cable 16, it is conveyed to the casing 11 at a point adjacent to the bottom of the surface pipe 10 through the terminal 25, the collars 22 and the convex springs 23. The collars 22 are insulated from the tubing 12 because, if current were permitted to flow down the tubing 12, currents might flow through the well fluids, when present, between tubing 12 and the casing 11. Such currents, if they were permitted to exist, would cause corrosion of the tubing 12 or the inner surface of the casing 11 deeper in the well.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We, therefore, particularly point out and distinctly claim as our invention:

1. In the process of cathodically protecting the casing in an encased well in which the surface pipe extends downwardly for only a portion of the depth of the well and in which the casing is maintained cathodic with respect to a protective anode buried in the ground and spaced from the well structure, the step comprising connecting a direct current source between said anode and a point on the casing adjacent to the bottom of the surface pipe.

2. In the process of cathodically protecting the casing in an encased well in which the surface pipe extends downwardly for only a portion of the depth of the well and in which the casing is maintained cathodic with respect to a protective anode buried in the ground and spaced from the well structure, the step comprising maintaining an electrical insulator between the top of said surface pipe and the casing.

3. In the process of cathodically protecting the casing in an encased well in which the surface pipe extends downwardly for only a portion of the depth of the well

7

and in which the casing is maintained cathodic with respect to a protective anode buried in the ground and spaced from the well structure by a direct current source the negative terminal of which is connected to the casing and the positive terminal of which is connected to an anode buried in the earth adjacent to the well, the step of maintaining an insulator between two adjacent sections of the casing below the level of the bottom of the surface pipe, the magnitude of the resistance of the surface pipe between the point where it joins the casing and its bottom divided by the resistance of the earth structures surrounding the surface pipe between the surface pipe and the anode, being at least as great as the ratio, of the resistance of the casing between the point where the surface pipe is connected thereto and the part of the casing adjacent to the bottom of the surface pipe divided by the resistance of the casing, said insulator, and the earth structures surrounding the well between said part of the casing and said anode.

4. The apparatus for preventing electrochemical corrosion of the casing of encased wells which comprises in combination an anode buried in the earth adjacent to said encased well, means electrically contacting the casing of said well adjacent to the lower end of the surface pipe of said well, and a source of direct electric current connected between said means and said anode.

5. In a process for cathodically protecting oil well

8

casing in which a current is applied to the casing from an external power source to maintain a flow of electrons from the casing to an anode buried in the earth out of contact with said casing and in which said oil well casing is enveloped for a portion of its depth by a surface pipe, the improvement which comprises maintaining the potential of the casing in the area adjacent to the base of the surface pipe at least as great as the potential of the base of the surface pipe so that no electrons flow from the base of the surface pipe to the adjacent area of the casing.

References Cited in the file of this patent

UNITED STATES PATENTS

2,149,617	Menaul	Mar. 7, 1939
2,244,322	Zoller et al.	June 3, 1941
2,310,757	Waener	Feb. 9, 1943
2,359,239	Newton	Sept. 26, 1944

OTHER REFERENCES

Ewing: Soil Corrosion and Pipe Line Protection, Pub. by Am. Gas Assoc., 1938, pp. 224-259 (pages 227 and 228 relied on).

Blum et al.: Principles of Electroplating and Electroforming, McGraw, Hill, N. Y., 1949, 3rd edition, pages 44, 45.