Sept. 23, 1952 R. H. CARR ET AL 2,611,436

APPARATUS FOR INJECTING FLUIDS INTO WELL BORES

Filed April 26, 1948 2 SHEETS—SHEET 1

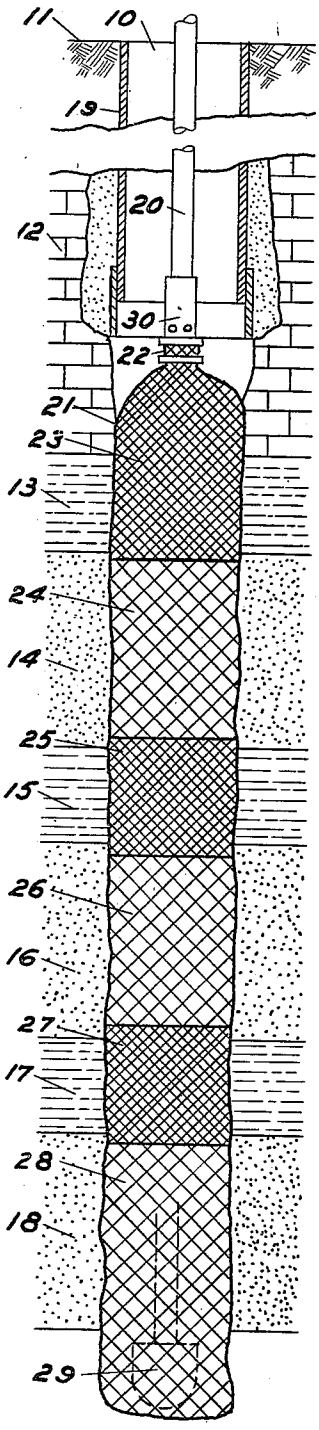


FIG. 1

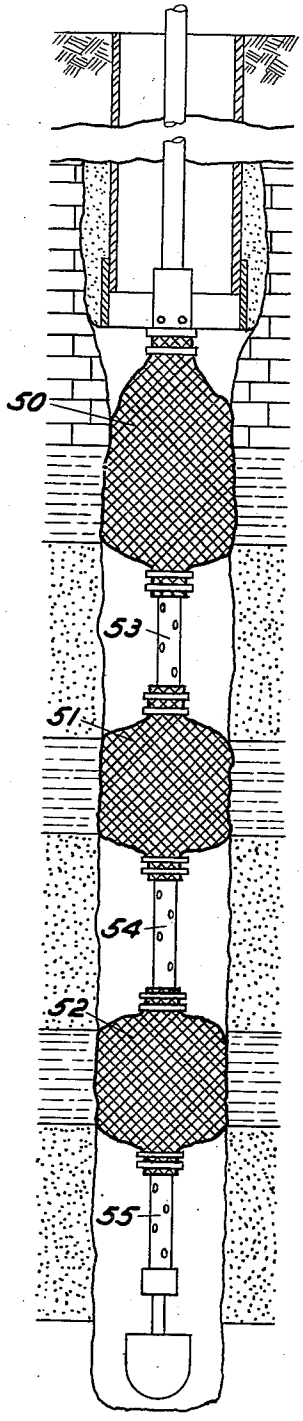


FIG. 3

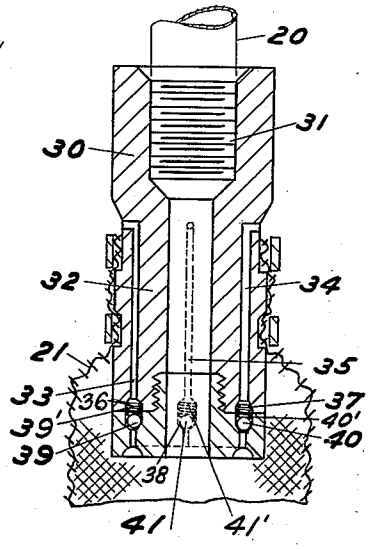


FIG. 2

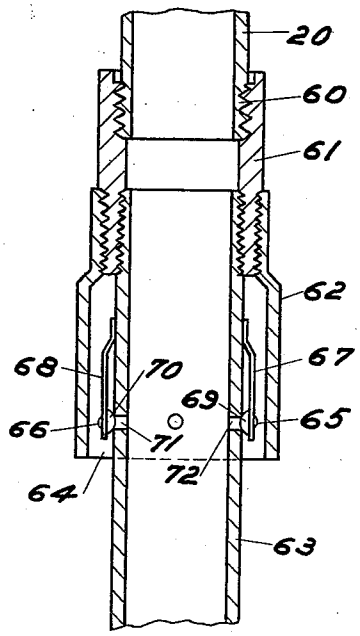


FIG. 4

INVENTORS.
RICHARD H. CARR
KENNETH A. COVELL

BY Edward H. Lang

ATTORNEY

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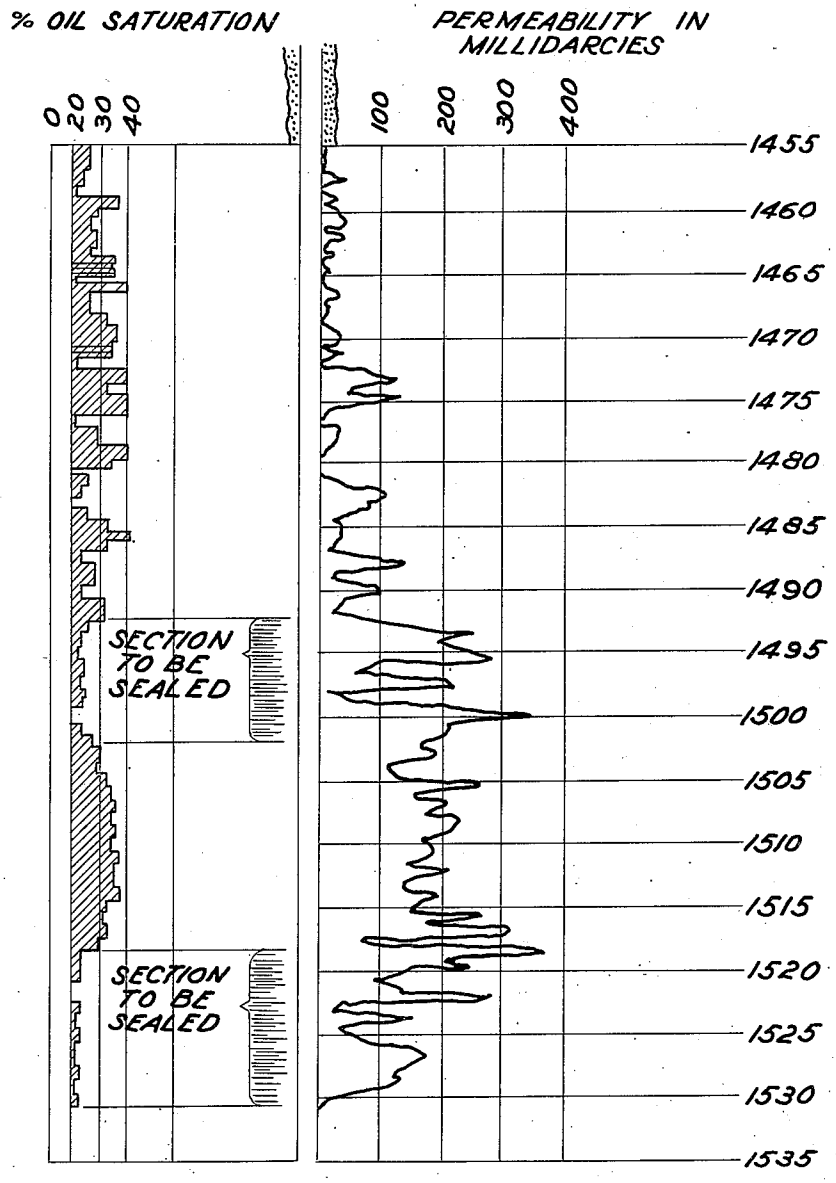


FIG. 5

INVENTORS
RICHARD H. CARR
KENNETH A. COVELL

BY Edward H Lang

ATTORNEY

Patented Sept. 23, 1952 2,611,436

UNITED STATES PATENT OFFICE

2,611,436

APPARATUS FOR INJECTING FLUIDS INTO WELL BORES

Richard H. Carr, Chicago, and Kenneth A. Covell, Winnetka, Ill., assignors to The Pure Oil Company, Chicago, Ill., a corporation of Ohio

Application April 26, 1948, Serial No. 23,338

4 Claims. (Cl. 166—1)

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This invention relates to repressuring and flooding of subterranean oil formations and is particularly concerned with a method and apparatus to make possible the selective injection of fluids into formations of low permeability.

It is common practice in flooding and repressuring operations to seal off the subterranean formations of high permeability to cause the water, gas or other fluid injected into the well bore to be forced into the formation of low permeability. Mechanical packers and chemical sealing agents have been used to accomplish the selective sealing which is necessary to make possible the selective flooding. In accordance with our invention, we use a collapsible or inflatable packer controlled by a mechanism which regulates the relative pressures within and without the packer to provide for sealing off the formations of high permeability, to avoid application of a bursting pressure to the sealer, and to permit the fluid to be injected into the formations of low permeability.

One of the objects of our invention is to provide a method for selectively repressuring our flooding subterranean oil formations.

Another object of the invention is to provide apparatus for selective sealing of different formations along an earth bore.

Still another object of the invention is to provide a differential pressure-type expansible and collapsible packer for use in earth bores.

A further object of the invention is to provide apparatus for control of the differential pressure on a collapsible and expansible packer in an earth bore.

Still another object of the invention is to provide a method and apparatus for controlling the volume and pressure of fluid injected into a well bore.

A still further object of the invention is to provide method and apparatus which will permit acidizing and sealing of selected strata along a well bore.

Other objects of the invention will in part be obvious and in part appear hereinafter.

The invention, accordingly, includes an apparatus for use in the bore hole of a well with which selected strata occurring along the length of the well can be sealed off, the apparatus including a bag made of flexible materials having degrees of permeability matched to the permeabilities of the several earth strata in the well adjacent to the bag positioned therein, and a mechanism for use with the bag, subject to operation by the fluid being injected into the well, so that an optimum pressure differential is maintained between that

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existing in the interior thereof and that in the surrounding space in the bore to cause fluid to permeate the strata it is desired to flood and to keep pressure in the bag within its bursting strength. The invention also includes the method by which the flow of fluid into the strata is controlled by having its pressure and the resistance in its path of flow matched to the permeability differences occurring along the well bore.

In the usual operation where fluid injection into sections of well bores is employed as a means for secondary recovery, it is common experience that the most permeable strata occurring in the formations through which the bore passes will take up most of the injected fluid, with the result that the effective driving force thereof is largely confined to flushing these sections, leaving the less permeable strata unaffected or only partially affected. In view of the fact that it is the less permeable strata which retain the greater amount of oil, it is of prime importance to accomplish a thorough flushing thereof in the secondary recovery operation. By use of the apparatus constituting this invention according to the method to be described, selective and substantially quantitative control of the flow of fluids into various sections of the bore holes of wells can be achieved.

It is possible that it might be desirable to avoid forcing the fluid into a given stratum in a well. In such a case, an impermeable bag or section would be placed opposite that stratum. In practice, a rubber bag has been found suitable.

Figure 1 is a diagrammatic longitudinal section on a reduced scale of an oil well bore indicating in a conventional form the location and nature of several typical strata of different porosities and showing a bag made for selective sealing set in place in accordance with our invention;

Figure 2 is a longitudinal sectional view through a differential pressure releasing valve which is used in conjunction with the apparatus to develop the desired control over the fluid flow;

Figure 3 is a longitudinal section of a well bore showing a selective sealing arrangement embodying an alternative form of our invention;

Figure 4 is a longitudinal section through an alternative form of differential pressure release valve;

Figure 5 shows a plot giving a profile of a typical well bore in terms of permeability of the several strata encountered.

In Figure 1, 10 represents a well bore passing from the surface of the earth 11 through non-

productive strata 12 into a series of strata, 13, 14, 15, 16, 17 and 18, of different permeabilities constituting the producing section of the well. In conventional style, the well bore is lined with a casing 19 within which there is tubing 20. In the producing section of the well bore, there is fitted bag 21, carried by tube 20 which enters the producing section. Bag 21 is attached to the end of tube 20 with any effective clamp and collar device 22.

For the purpose of selectively flooding the several less permeable strata during the repressuring operations, the bag 21 is made in sections of different permeabilities, 23, 24, 25, 26, 27 and 28, to match the permeabilities of the several sections occurring in the formation through which the well bore passes. Thus, at those formations of high permeability, for example those indicated as 13, 15 and 17 in the diagram, the bag consists of a material of tight, substantially fluid-impervious weave. Opposite sections of low permeability, for example, those indicated as 14, 16 and 18 in the diagram, sections of the bag are of loose-weave material and corresponding high permeability. The bottom of the bag is drawn down close to the bottom of the well by the inclusion of a weight 29 in a compartment forming its termination.

Figure 2 shows a sectional view of a pressure differential release valve which is the connecting link between the bag 21 and the end of tubing 20. The valve comprises what is essentially a bushing 30 having a threaded section 31 for engaging the tubing 20, and a section 32 of reduced diameter for connection with the bag 21. Channels 33, 34, 35, in the bushing are arranged to provide communication from inside the bag 21 to the outside. The several channels 33, 34, 35, enlarge into housings 36, 37, 38, which enclose sealing balls 39 loaded with spring 39', 40 loaded with spring 40', and 41 loaded with spring 41'. These balls coacting with the springs and channels function as check valves so that when a critical pressure differential between the inside and outside develops, they permit unidirectional flow of liquid through the differential release valve to the outside.

In Figure 3 there is shown a second arrangement of elements in which closely woven sections of material, 50, 51, and 52, are alternated with sections of perforated tubing 53, 54, 55, which are open to flow of fluid to an extent such that they replace the loose weave material described in conjunction with Figure 1.

Figure 4 shows a longitudinal cross section of an alternative form of differential pressure valve for the maintenance of an equilibrium differential pressure between the inside and the outside of a flexible bag inserted in the well. In the figure, 60 represents an end of the well tubing 20 to which there is attached a bushing 61 carrying a metal skirt 62 which enlarges to a diameter somewhat greater than the outside diameter of the tube extension 63, so that the skirt and the tube 63 define an annular space 64. The purpose of the skirt is to provide a protecting canopy over spring loaded orifice covers 65 and 66, the only two shown in the figure. The orifice covers are made up of spring steel levers 67, 68, carrying gasket buttons 69 and 70 on the respective ends thereof to cover the orifices 71 and 72. The dimensions of the spring levers 67 and 68 are matched to the orifices 71 and 72 to yield at a certain internal pressure, whereupon the buttons are forced away from the orifices to allow fluid

to flow out. When an equilibrium differential between the interior and the exterior pressures is attained, the springs will have sufficient resilience to force the buttons back into place. In this manner, the valve will maintain an equilibrium differential pressure between the interior and exterior of the packer unit.

For the most successful practice of our invention, it is desirable to have a fairly complete log of a well bore showing its profile and comparative oil saturation percentages in the several strata encountered so that selective sealing can be judiciously applied to develop maximum rates of flow from the strata it is desired to strip. Such a diagram is found in Figure 5 which shows for a typical well, percentages of oil saturation logged against depth, and a quantitative measure of the porosity of the sections throughout the well.

Having once obtained a reasonably accurate log of the well, it becomes necessary then to construct a bag which will have a weave of varying tightness along its length so that its permeability along its length is the inverse of the permeabilities encountered in the well. That is to say, the sections of the bag having the lowest permeabilities will be placed to fall opposite those sections of the well having the highest permeabilities in order to control the flow of fluid thereinto. Natural limitations on the injection of fluid into the well make most convenient the application of one pressure to all of the several sections of the well being flooded. By inserting the bag having sections of different permeabilities into the well, the changes in resistance to fluid flow into the well strata are such that a relatively smooth flow of fluid is developed.

Where no log of the well is available, the repressuring and selective sealing can be done empirically by successively blocking various strata in the bore and continuing to seal those at which a pressure is developed.

To apply the apparatus in a selective sealing and flooding operation, the bag, for example as shown in Figure 1, is connected to tube 20 by means of differential release valve 30 which provides for communication between the interior of the bag and exterior of the tube, which is the annular space between the well casing and tube. When fluid is injected through tube 20, it fills the bag and causes it to expand and press against the sides of the well bore. The different permeabilities of the several sections of the bag will alter the resistance to fluid flow at the several strata with the result that different amounts of fluid will flow into the several sections through the well. While the flow of fluid is out through the bag and into the permeable strata, balls 39 and 40 in differential pressure valve 30 will be raised to permit flow into the annular space. When the flow has continued until a head of liquid or fluid pressure is built up in the annular space between tubing and casing, the pressure difference on the two sides of the valve will reach a point such that the spring loaded balls 39 and 40 will be forced back to their positions and flow of fluid from the tube through the valves will cease. The net effect is that liquid in the tube and annulus will coact to force liquid into the strata; the first applying a pressure to the interior of the bag, the second applying a pressure to the exterior thereof, with the result that the possibility of bursting the bag is eliminated.

In this manner, it is found that an automatic development of the predetermined pressure dif-

ferential and regulation of the flow of fluid into the several strata through which a well bore passes can be achieved with a minimum of mechanical and hydraulic complications. It is merely a matter of balancing the fluid head used for forcing fluid through the bag and into adjacent strata against the head which can be tolerated in the annulus. The differential pressure release valve operates to balance the two. By maintaining a proper pressure differential between that in the bag and that on the top and bottom of the bag, danger of bursting the bag by the application of too high a pressure is eliminated.

The manner in which the differential valve shown in Figure 4 operates is substantially the same as that shown in Figure 2. Spring levers **67** and **68** operate the balance one pressure against the other.

The operation of the embodiment of the packer described in Figure 3 is fairly evident from the appearance of the drawing. Perforated lengths of tubing found between the sections of the tightly woven bag correspond to the loosely woven material of the bag described in connection with Figure 1. The remainder of the operation of the device corresponds precisely with that of the valve described in connection with Figures 1 and 2.

When it is desired to discontinue a flooding operation and remove the bag, it can be done simply by reversing the pressure differential on the bag. That is, by forcing fluid into the annulus, the pressure there is elevated and the bag collapsed.

Other variations of this flexible bag method of adjusting the permeability of subterranean strata to injection fluids include slipping the bag assembly into the well onto devices set in the formation or set in the casing and permitting the bag element to extend down into the hole to points opposite the wall of the bore hole where selected sections may be treated as indicated in the foregoing figures. Not only can the selective adjustment of the permeability of the earth strata be used for flooding the strata, but it can also be used for sealing, acidizing, or feeding plastic plugging and cementing materials into sections of wells where it is desired to have these materials come to a point opposite selected portions of the bore hole. When wells are acid treated, it is often the case that a given well is producing from more than one stratum in the bore hole, and in the conventional acid treatment, the lowermost permeable section will usually get all the benefit of the acid. As indicated here, means can be employed to direct the injection of acid into these strata which it is desired to treat and, thus, improve the efficiency of the treatment in reaching all of the sections which would be treated.

The particular qualities of the material to be used for the adjustment of the permeability are, naturally, that it should be of a material unaffected by crude oil or by the fluid it is desired to inject into the well. Various materials can be used, among which is glass fiber cloth, which material in addition to having a very high tensile strength, can be made in various degrees of permeability so that the proper adjustment of the resistance can be readily made. For further adjustment of the permeability of the material to be used, it can be coated or impregnated with various plastic paints, resins, such as the polyvinyl chlorides, asphalt and rubber base paints,

or phenol formaldehyde resins and other sealing materials which make the material used very resistant or substantially impervious to movement of fluid through its weave. Where an impermeable bag or section is desired, it can be made of rubber.

Though this apparatus and method for flooding wells has been described with a restricted number of examples, they should be taken as illustrative and not in a limiting sense.

What is claimed is:

1. An apparatus for adjusting the resistance to fluid flow of the walls of an earth bore passing through a plurality of subterranean earth strata of different permeabilities which comprises a multi-sectioned, fluid pervious, flexible envelope inflatable to a shape substantially matching the diameter of the bore and length of strata to be treated, the respective sections of said envelope being of varying permeability along its length, said permeabilities being inversely related to the permeability of the stratum contiguous to each section and the length of each section being substantially coextensive with the length of the respective stratum contiguous thereto, said permeable sections being prepared from naturally pervious, woven fabrics, a means attached adjacent to the terminal extremity of said envelope for affixing a weight thereto, a conduit communicating with the interior of said envelope for introducing fluid thereinto, and a means communicating with the interior and exterior of the envelope to provide for the maintenance of a predetermined pressure differential between the interior and exterior of said envelope sufficient to seat said envelope against the walls of the earth bore, said means being adapted to provide unidirectional fluid flow from within the said envelope.

2. An apparatus in accordance with claim 1 in which the envelope has a diameter and length slightly greater than the diameter and length of the earth bore so that upon inflation of said envelope to a predetermined pressure the outer wall of said envelope will seat itself with the walls of said earth bore in contiguous relationship thereto substantially throughout the length of said envelope.

3. An apparatus for adjusting the resistance to fluid flow of the walls of an earth bore passing through a plurality of subterranean earth strata of different permeabilities which comprises a multisectional packer, the sections of which are fluid pervious, flexible and inflatable to a shape substantially matching the diameter of the bore and length of strata to be treated, the respective sections of said packer being of different permeabilities, said permeabilities being inversely related to the permeability of the stratum contiguous to each section and the length of each section being substantially coextensive with the length of the respective stratum contiguous thereto, said permeable sections being prepared from naturally pervious, woven fabrics, a means attached adjacent to the terminal extremity of said packer for affixing a weight thereto, a conduit communicating with the interior of said sections for introducing fluid thereinto, and a means communicating with the interior and exterior of the sections to provide for the maintenance of a predetermined pressure differential between the interior and exterior thereof sufficient to seat said sections against the wall of the earth bore, said means being adapted to provide unidirectional fluid flow from within the said sections.

4. An apparatus in accordance with claim 3 in which said sections are interconnected by rigid, perforated fluid conduits.

RICHARD H. CARR.
KENNETH A. COVELL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,000,583	Cooper	Aug. 15, 1911
1,547,240	Steel	July 28, 1925
1,861,332	Waitz	May 31, 1932
2,019,418	Lang	Oct. 29, 1935
2,053,981	Villers	Sept. 8, 1936
2,107,006	Lang	Feb. 1, 1938
2,133,730	Brundred	Oct. 18, 1938
2,217,749	Hewitt	Oct. 15, 1940
2,361,194	Grebe	Oct. 24, 1944
2,365,428	Muskat	Dec. 19, 1944
2,399,125	Lehnhard, Jr.	Apr. 23, 1946