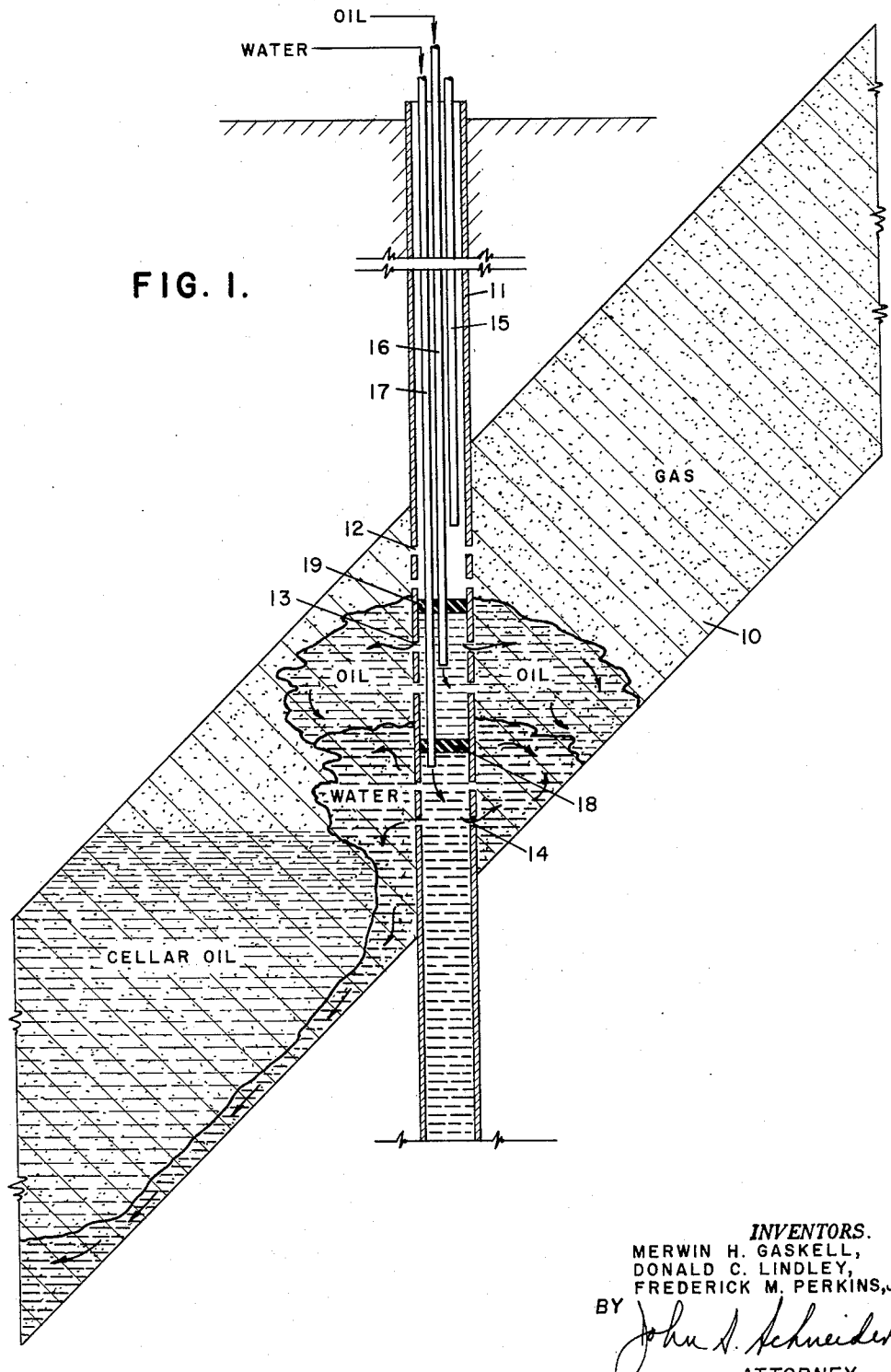
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CELLAR OIL RECOVERY BY WATER DISPLACEMENT

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FIG. 1.



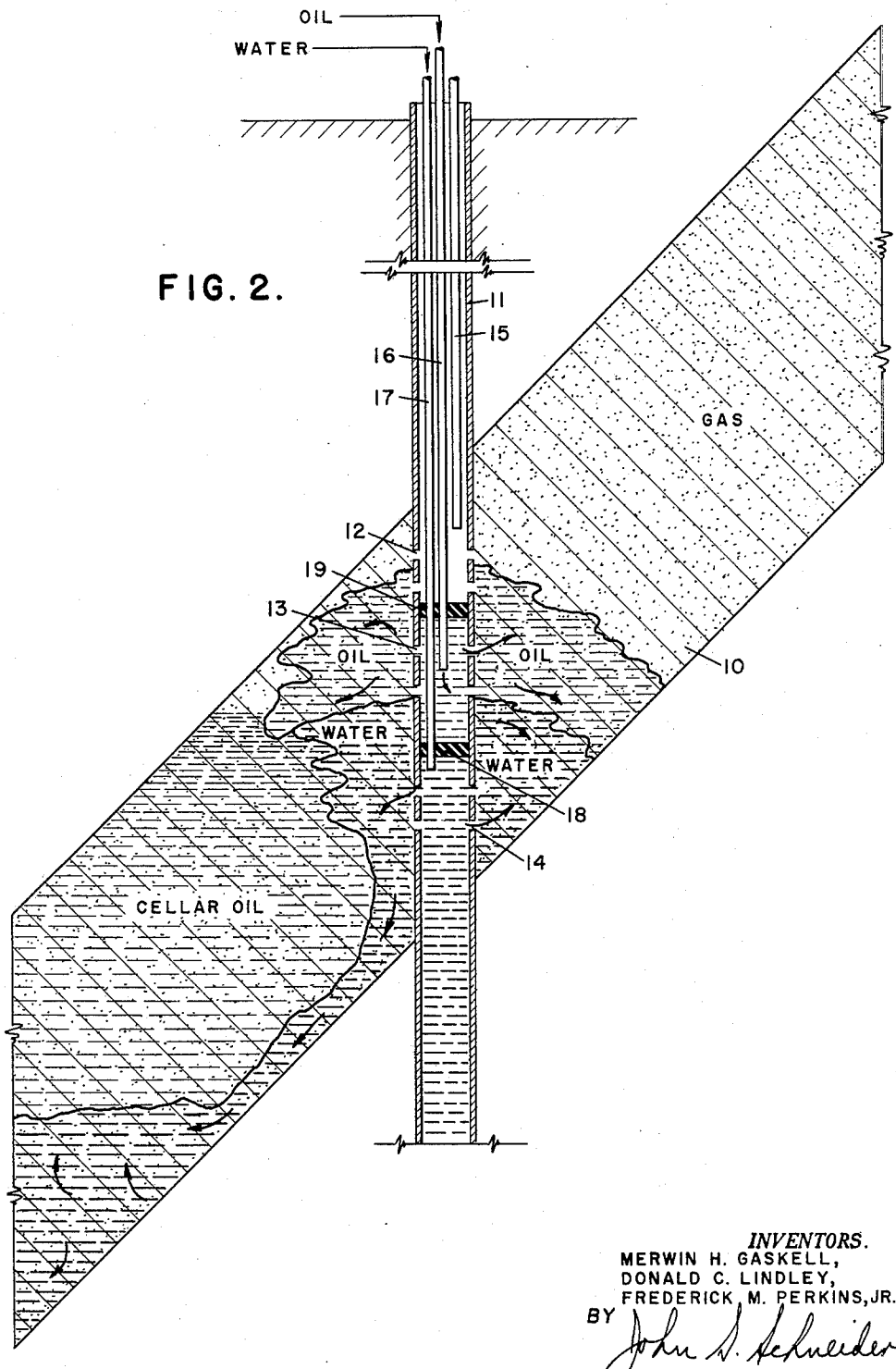

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CELLAR OIL RECOVERY BY WATER DISPLACEMENT

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FIG. 2.



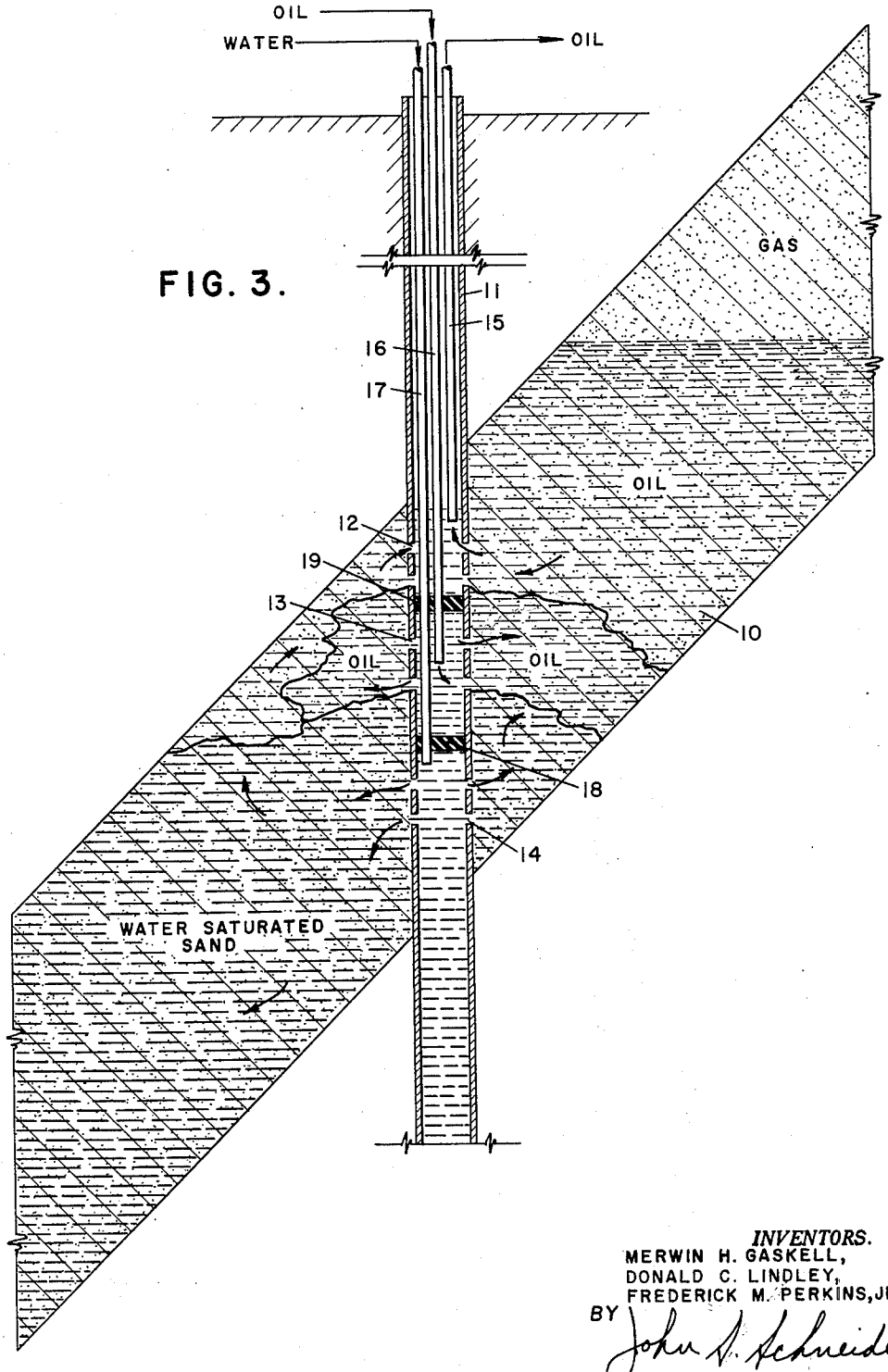

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FIG. 3.




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# CELLAR OIL RECOVERY BY WATER DISPLACEMENT

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2 Claims. (Cl. 166—9)

This invention concerns recovery of oil located below the structurally lowest well in reservoirs in which a natural water drive is not present.

Small, steeply inclined reservoirs without natural water drives are often found associated with salt domes or other highly faulted structures. Frequently, only one well may be economically justified in these reservoirs and oil is produced by an expanding gas-cap drive or by a dissolved gas drive. Although a large fraction of the oil up-structure from the well may be recovered during primary depletion, because of gravity effects, only a small fraction of the down-dip oil can be produced. The down-dip oil where no natural water drive is present is defined as cellar oil in contradistinction to attic oil, which is the oil above the structurally highest well in reservoirs where a natural water drive is present.

A primary object of the present invention is an improved method for the recovery of cellar oil.

It is possible after producing a reservoir of this type for a period of time to inject into the reservoir a limited quantity of water. This technique repressurizes the reservoir and moves the oil up-dip by the gravitational segregation of the injected water down-dip. In some instances in this type of operation, because of perhaps a reduced permeability to oil adjacent the well, the length of time required for injection of water and the length of time required for gravity segregation of water, the total length of time required to produce the reservoir may be excessive, causing subsequent loss of recoverable oil.

It has also been proposed to inject water through perforations located in the lower part of the well opposite the lower part of the penetrated portion of the reservoir and isolated from a set of perforations located in the upper part of the well opposite the uppermost part of the penetrated portion of the reservoir and while injecting water into the lower perforations, producing oil from the upper set of perforations. However, this technique is operational only if the pressure gradients caused by injection of water are sufficiently low to allow gravity acting on the oil and water to maintain the oil-water contact below the upper set of perforations. This condition can be achieved by injecting water at sufficiently low rates; but once again, the time required for depleting the reservoir may be prohibitively long.

The method of the present invention overcomes difficulties inherent in the known techniques for producing cellar oil by injecting water through a tubing string which opens into the lowermost section of the well bore, injecting oil or another suitable fluid through a second tubing string which opens into the center section of the well bore, and producing oil from a third tubing string which opens into the uppermost section of the reservoir. The production rate is set to exceed the rate of injection of fluid into the center section. The fluid injected into the center section has the effect of blocking off water entering through the lowermost section. By proper adjustment of the two injetcion rates and the production rate, the cellar oil is produced at an economical rate.

The above noted object and other objects of the invention will be apparent from a more detailed description of the invention taken in conjunction with the drawings wherein FIGS. 1, 2, and 3 are cross-sectional views of a well bore penetrating an inclined subsurface reservoir and serve to illustrate the mechanics of the operation of the method at different stages.



Referring to the drawings in greater detail, in FIGS. 1, 2, and 3 is shown a reservoir **10** inclined at an angle and penetrated by a well pipe **11**, which is perforated at **12** in the upper portion, at **13** in the center portion, and at **14** in the lower portion of the reservoir. Three tubing strings, **15**, **16**, and **17**, are arranged in pipe **11**. Tubing string **15** extends to and fluidly communicates with upper perforations **12**; tubing string **16** extends to and fluidly communicates with the center perforations **13**; and tubing string **17** extends to and fluidly communicates with the lower perforations **14** of pipe **11**. A lower packer **18** is arranged on tubing string **17** in pipe **11**, and sealingly closes off the space between tubing string **17** and the interior wall of pipe **11** between lower perforations **14** and center perforations **13**. An upper packer **19** is arranged on tubing strings **16** and **17** in pipe **11** and sealingly closes off the space between these tubing strings and the interior wall of pipe **11** between upper perforations **12** and center perforations **13**.

As seen in FIG. 1, initially, water is injected through tubing string **17** into formation **10**, through perforations **14** in casing pipe **11**, and simultaneously a fluid such as oil is injected through tubing string **16** into reservoir **10** through center perforations **13**. The injected oil keeps the injected water down, and the water works its way along the lower side of the reservoir underneath the cellar oil and displaces the cellar oil upwardly.

As the injection of fluids is continued, water continues to displace cellar oil upwardly, and as seen in FIG. 2, the cellar oil has begun to mingle with the injected oil above the water level.

The simultaneous production of oil through upper perforations **12** and tubing string **15** in conjunction with continued injection of oil and water is illustrated in FIG. 3, and as seen therein, the cellar oil has been forced upwardly by the injected water to adjacent to and above the upper perforations.

In practice, to determine the most desirable rates of water and oil injection, there will be a first step of short duration of injection of water and oil through tubing strings **16** and **17** and production of oil through tubing string **15**. The oil production is restricted to a very low rate to ascertain that the water is all being directed down-structure by the injection of oil in the center region of the well bore through pipe string **16** and center perforations **13** in the center region of the well bore. This operational phase is stopped when fresh reservoir oil appears in the production stream flowing through tubing string **15**. The appearance of fresh reservoir oil is recognized by a change in the gas-oil ratio, since the injected oil will be dead; i.e., free of dissolved gas. In this phase, water may be injected at a high rate; the oil is injected only in sufficient amounts to block the water injected from rising up-structure. Following completion of this step, the rates of injection are controlled by the desired rate of production of net oil from the well. The rate of water injection equals the net rate of oil production, and the rate of oil injection is adjusted so that it is just sufficient to prevent water production. Oil is produced in an amount equal to the net oil amount desired plus the volume of oil injected to block off the water, since the well will remain at substantially equilibrium conditions. The absolute rates of injection and production will vary from well to well and are best determinable in the well itself.

All of the injected oil will be recovered in this method of operation. The method is not a repressurizing process, and it allows the oil to be recovered at the low pressure existing in the reservoir. Therefore, the method has

substantial economic advantages, because it avoids the need for injecting large volumes of fluids at high pressures.

Having fully described the objects, nature, operation, and method of the invention, we claim:

1. A method of recovery of cellar oil from an inclined reservoir in which no natural water drive is present and which is penetrated by a well pipe perforated along a portion of its length located in said reservoir comprising simultaneously injecting water into said reservoir through the lowermost perforations in said well pipe to displace oil from the lower to the upper portions of said reservoir and injecting oil into said reservoir through the middle perforations in said well pipe and producing fluids from said reservoir through the uppermost perforations in said well pipe; the rate of water injection, oil injection, and oil production being selected such that water-free oil is produced.

2. A method of recovery of cellar oil from an inclined reservoir in which no natural water drive is present and which is penetrated by a well pipe perforated along a portion of its length located in the reservoir comprising initially, simultaneously injecting water into said reservoir through the lowermost perforations in said well pipe to displace oil from the lower to the upper portions of said reservoir and injecting oil into said reservoir through the middle perforations in said well pipe and producing fluids from said reservoir at a low rate through the uppermost perforations in said well pipe until fresh reservoir oil appears in the oil produced through the uppermost perforations in said well pipe and then continuing to inject water and oil into said reservoir and produce fluids from said reservoir in the same way, the rates of injection being controlled by the desired rate of production of net oil from the well, the rate of water injection being equal to the net rate of oil production, the rate of oil injection being adjusted to that just sufficient to prevent water production, and the oil produced being equal to the net oil desired plus the volume injected to block off the water.



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