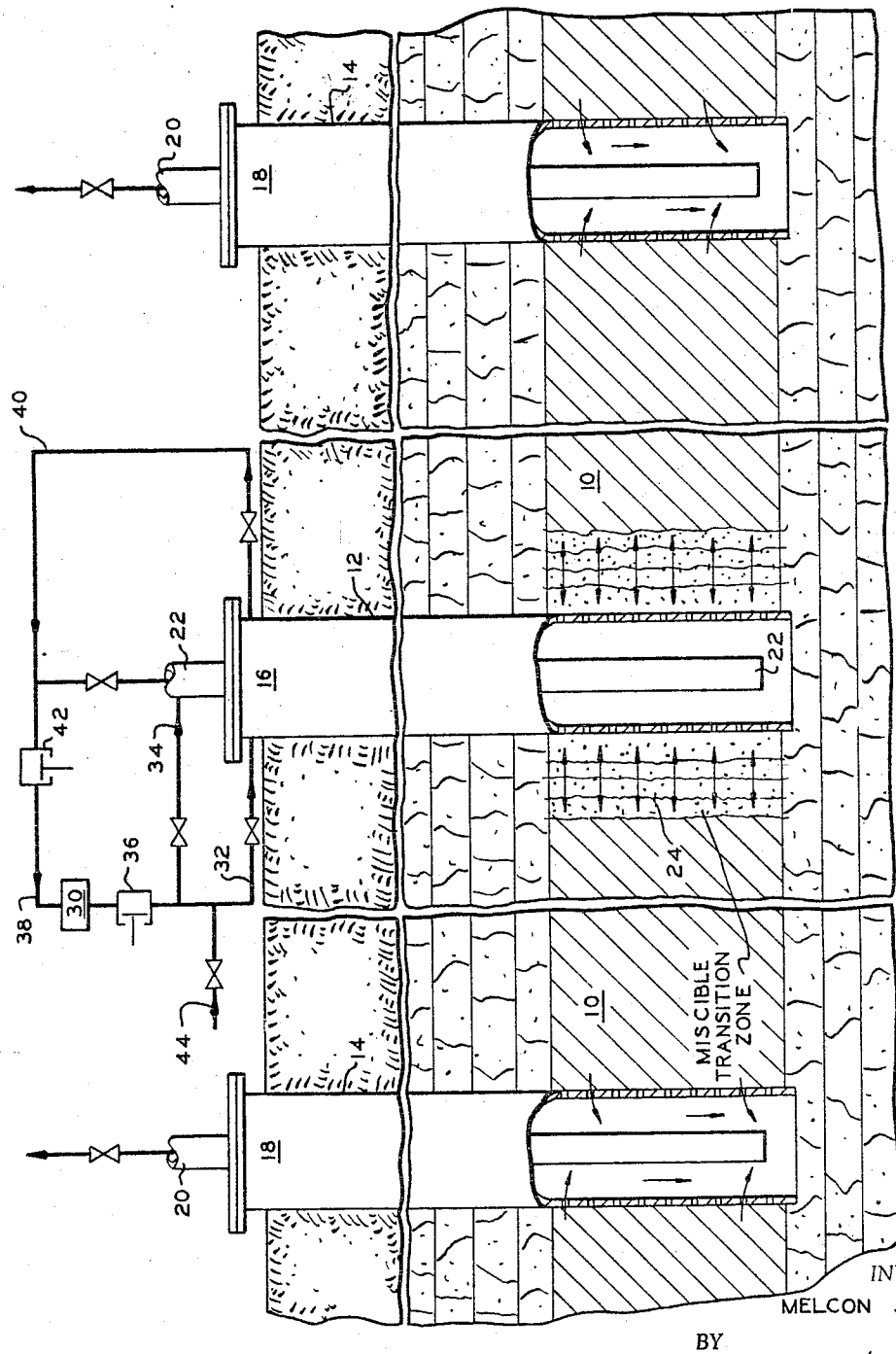
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TRANSITION ZONE FORMATION IN OIL PRODUCTION

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TRANSITION ZONE FORMATION IN OIL PRODUCTION

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This invention relates to a method of establishing a transition zone downhole around an injection well in a miscible fluid drive process in recovering oil from an oil-bearing stratum and utilizing this method in such a fluid drive process to produce oil.

The need for a transition zone in a miscible fluid flood or drive of a miscible fluid transition zone thru an oil-bearing stratum to produce oil thru one or more production wells is clearly taught in U.S. Patent 2,867,277 to C. F. Weinaug et al. The prior art method utilizing this technique involves mixing some of the oil from the stratum to be produced with a less viscous, miscible fluid which forms a mixture of intermediate viscosity relative to the petroleum and to the miscible displacement fluid. The premix is formed above ground and injected into the stratum thru an injection well to displace oil radially outwardly from the injection well and a driving fluid is then injected to drive the transition phase thru the stratum toward the production wells thereby producing oil in the production wells.

This invention is concerned with a unique method of forming a better transition zone in the stratum around an injection well and to the use of this zone in displacing oil from the stratum by fluid drive.

Accordingly, it is an object of the invention to provide an improved method of forming a miscible phase transition zone in an oil bearing stratum around an injection well. Another object is to provide an improved transition zone which varies gradually in viscosity from the forward area adjacent the in-place oil to the area adjacent the injection well and in which the viscosity gradually varies substantially from that of the in-place oil to that of the miscible fluid utilized in forming the transition zone with the oil. A further object is to provide an improved fluid drive utilizing a more efficient transition zone. Other objects of the invention will become apparent upon consideration of the accompanying disclosure.

A broad aspect of the invention comprises injecting into an oil-bearing stratum through an injection well therein a fluid miscible with the oil in the stratum and containing a substantial concentration of CO_2 so as to build up a substantial pressure in an annulus of the stratum around the well of at least 500 p.s.i.g. and up to about 4000 p.s.i.g., thereafter releasing or reducing the fluid pressure in the well so that the pressure in the stratum produces oil containing dissolved injected fluid by solution gas drive; when the well pressure is returned substantially to normal, the produced fluid is forced into the stratum through the well and additional miscible fluid is injected so as to again build up the pressure in the stratum to the aforementioned range. The foregoing procedure is repeated as many times as required to build up an annular transition zone around the well extending a substantial distance radially into the stratum, the concentration of oil in this transition zone being highest at the most remote fringe of the transition zone and lowest at the well bore, while the concentration of the injected miscible fluid is highest at the well bore and lowest at the most remote fringe of the zone. After the foregoing procedure has built up the desired transition zone, a driving fluid is injected through the injection well to drive the fluid transition zone toward one or more offset production wells, thereby producing oil from the stratum through these production wells.

The purpose of the formation and driving of the transition zone through an oil-bearing stratum is to avoid or decrease substantially the effects of viscous fingering which is a common basic problem in the various flooding techniques utilized in secondary recovery methods including gas injection, water flooding, LPG flooding, etc. It has been found that a transition zone, properly formed in a stratum around an injection well greatly reduces viscous fingering when the transition zone is driven through the stratum in advance of a driving fluid.

The invention utilizes a slug of gas consisting of CO_2 and hydrocarbon gases, preferably of 2–4 carbon atoms, or nitrogen, air, H_2S, flue gases, and similar gases as the gaseous mixture is injected into the well to establish the transition zone. It is preferred that the gas mixture have a composition of 50 percent CO_2 and a substantial concentration of C_2–C_4 hydrocarbon gases therein such as 10–50 percent. (Percents are by volume.) Such gas compositions have a very high solubility in the reservoir oil. The volume of the gas mixture injected to form the transition zone is at least 0.05 pore volume and up to 1.0 pore volume of the stratum to be produced. It is preferred to inject a gas mixture having a volume in the range of 0.1 to 0.5 pore volume. While the invention is particularly advantageous in reservoirs containing viscous fluids of low API gravity, it is also applicable to and advantageous in reservoirs containing less viscous hydrocarbons such as those of an API gravity above 35.

As a result of injecting the slug of gas selected for the operation, the reservoir pressure is raised sufficiently (to the range of 500–4000 p.s.i.g.) so that the injection well is readily converted to a producing well by termination of the injection procedure and allowing the reservoir pressure to be rapidly lowered to normal pressure, such as around 100 p.s.i.g. The driving force during this producton is the solution gas drive established by the injection procedure. This process, which may be repeated as many times as desired, establishes an in situ graded viscosity zone in the reservoir from the oil viscosity to that of the gas mixture viscosity. As the gas and produced fluid is injected back into the same well, it provides partial miscibility, unless the injection pressure for a given gas mixture and reservoir oil is sufficient for total miscibility. The invention is applicable to virgin reservoirs as well as to partially depleted reservoirs. The graded viscosity zone, when driven through the stratum prevents or greatly reduces viscous fingering with improved sweep efficiency, and the CO_2 promotes higher displacement efficiency.

After establishing the transition zone, the same is driven through the stratum or reservoir. The last slug of gas or fluid injected into the stratum is followed by the principal displacing fluid which may be natural gas, air, water, steam, flue gases, or combinations thereof.

A more complete understanding of the invention may be had by reference to the accompanying schematic draw-

ing which is an elevation of a partial section of an arrangement of wells penetrating an oil-bearing stratum for use in effecting the invention.

Referring to the drawing, an oil-bearing stratum **10** is penetrated by an injection well **12** and offset production wells **14**. The wells are provided with casings **16** and **18**, respectively, which extend thru stratum **10** and are perforated for ingress and egress of fluids. The production wells **14** are provided with tubing strings **20** and injection well **12** contains a tubing string **22** which extends approximately to the bottom of the stratum. The transition zone established around well **12** is designated **24**.

Storage tank **30** is connected with casing **16** through line **32** and with tubing **22** through line **34** for injection of fluid under the impetus of pump **36**. Line **38** connects tubing string **22** with storage tank **30** for flow of produced fluid when producing through the tubing. Line **40** connects the well annulus through casing **16** with line **38** for flow of produced fluids when producing through the annulus. Pump **42** is positioned in line **38** to assist in flow of produced fluids to the storage tank when this is necessary. Line **44** connects with line **32** for the injection of the principal driving fluid after the transition zone has been established.

To start the operation, the selected gas mixture is injected either through line **32** or through line **34**. The source of this gaseous mixture may be storage tank **30** or a source (not shown) to which line **44** is connected. For the purposes of illustration, it will be assumed that the gas slug is injected through lines **44** and **34** into tubing string **22** from which the gaseous mixture passes to the bottom of the well and into the stratum into zone **24**. Injection is continued until the desired pressure is reached which is preferably close to 4000 p.s.i.g. During this injection the production wells are preferably shut-in so as to facilitate the building up of pressure. After the maximum desired pressure has been built up in the well adjacent the stratum, it is desirable in some applications to maintain the pressure at the maximum level for an extended period of time such as one day to a week or longer to provide time for the injected gas to go into solution and migrate deep into the formation. However, in some applications this is not necessary and immediate release of pressure on the injection well effects the desired production by solution gas drive. During the production phase of the transition zone build-up, the produced fluids are passed into storage tank **30** and this produced fluid is then reinjected into the well either through tubing **22** or through the surrounding annulus. After the produced fluid has been reinjected, additional miscible gaseous mixture from line **44** is injected until the pressure is again built up to the desired maximum. At this point, the drive of the transition zone through the stratum to the production well(s) may be effected; however, it is more effective to repeat the production and reinjection steps at least once and, preferably, several times in order to establish a sizable transition zone with a good miscibility gradient and then follow the last injection of the produced fluids with the principal driving fluid or with a slug of the gaseous mixture followed by the principal driving fluid.

Upon injecting the principal driving fluid through line **44**, wells **14** are opened to production and as the transition zone is forced toward these wells, oil is produced therein and recovered through tubing **20**.

Well **12** represents either a central well in a 5, 7, or 9-spot pattern or one well in a line of wells in a parallel line drive process, while wells **14** represent either the ring wells or production wells in two lines of wells parallel with the line of injection wells represented by well **12**.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A method of establishing a transition zone downhole around an injection well for use in a miscible fluid drive process in recovering oil from an oil-bearing stratum prior to injection of a driving fluid and forcing same thru said stratum from said injection well to at least one offset production well, which method comprises the steps of:

(1) injecting into said stratum thru said injection well, a fluid miscible with the oil in said stratum and containing a substantial concentration of CO_2;

(2) continuing the injection of said fluid into said stratum until the well pressure reaches at least 500 p.s.i.g.;

(3) thereafter, releasing the fluid pressure in said well so that fluid pressure built up in said stratum and solution gas drive causes fluid flow into said injection well thereby producing fluid containing a substantial concentration of stratum oil;

(4) forcing the produced fluid of the preceding step into said stratum to again build up a pressure therein of at least 500 p.s.i.g.;

(5) repeating step (3); and

(6) repeating step (4), thereby establishing a substantial transition zone around said injection well wherein the oil in the resulting solution is of decreasing concentration from the innermost boundary thereof to the well and the injected fluid is of increasing concentration in the same direction.

2. The process of claim **1** wherein the injected fluid of step (1) is at least 50 volume percent CO_2.

3. The process of claim **2** wherein the injected fluid contains a concentration of normally gaseous hydrocarbons in the range of 10 to 50 volume percent.

4. A process for producing oil from an oil-bearing stratum penetrated by an injection well and at least one offset production well which comprises the steps of:

(1) establishing a transition zone around said injection well by the method of claim **1** while maintaining said at least one production well shut-in;

(2) thereafter, opening said at least one production well to flow and driving the oil solution in said transition zone outwardly from said injection well toward said at least one production well so as to produce oil therein by injecting a driving fluid into said injection well; and

(3) recovering produced oil from said at least one production well.

5. The process of claim **4** wherein the volume of the injected fluid in step (1) is in the range of 0.01 to 1.0 pore volume of the stratum produced.

6. The process of claim **4** wherein the fluid injected in step (1) is a mixture of CO_2 and normally gaseous hydrocarbons of 2 to 4 carbon atoms per molecule and the volume thereof is in the range of 0.01 to 1.0 pore volume of the stratum produced.

7. A process for establishing a transition zone in an annular section of oil-bearing stratum around an injection well therein for use in a fluid drive production process which comprises the steps of:

(1) injecting a gaseous mixture of CO_2 and C_1 to C_4 hydrocarbons into said stratum thru said injection well until the pressure therein is raised to at least 500 p.s.i.g., thereby forming a solution of said mixture in the oil in said annulus;

(2) thereafter, discontinuing the injection of said mixture and decreasing the pressure in said well so as to allow substantial production of said solution in said well by solution gas drive;

(3) thereafter, injecting the solution produced in the preceding step into said stratum and continuing the injection of the gaseous mixture of step (1) so as to again build up the pressure in said well to at least 500 p.s.i.g.;

(4) and repeating steps (2) and (3) until a substantial annulus of said stratum adjacent said well is filled with a solution of oil, CO_2, and said hydrocarbons wherein the concentration of oil decreases toward said well and the concentration of CO_2 and said hydrocarbons increases in the same direction.

8. The process of claim 7 wherein the injected mixture is in the range of 0.01 to 1.0 pore volume of the stratum to be produced.

9. The process of claim 8 wherein the concentration of CO_2 in said gaseous mixture is at least 50 percent by volume and the balance is said hydrocarbons.

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