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METHOD OF TRACING FLUID STREAMS

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This invention relates to a method of identifying or tracing flowing streams such as flowing streams of liquids or gases or fluidized solids streams. This invention is particularly useful for tracing and/or identifying underground streams. In one embodiment the practice of this invention is particularly applicable to a secondary recovery operation wherein a plurality of streams of a displacing fluid are introduced into a subsurface formation via injection wells to displace and drive petroleum hydrocarbons toward one or more producing wells wherein the displaced hydrocarbons are produced as well fluids.

In a secondary recovery operation employing a plurality of injection wells wherein a displacing fluid, such as brine, water, natural gas, liquefied normally gaseous or normally liquid hydrocarbons, liquid hydrocarbon solvents and the like are introduced into a petroleum producing formation via said injection wells to displace or otherwise drive petroleum hydrocarbons in said formation toward one or more production wells it often occurs that the well fluids produced at the production wells contain some of the fluids introduced into the petroleum producing formation via one or more of the injection wells. When this occurs it is usually desirable to halt the injection of the thus-produced driving fluid. However, in the situation wherein a plurality of injection wells is utilized, resulting in a plurality of injection fluid streams, it is first necessary to identify the injection well from which the produced driving fluid originates.

Accordingly, it is an object of this invention to provide an improved secondary recovery operation involving a plurality of injection wells to provide a method whereby the origin of the driving fluid produced at a producing well can be determined or otherwise identified.

It is another object of this invention to provide a method for readily identifying or "tagging" a plurality of flowing fluid streams wherein the same tracer may be employed to tag each of said separate flowing streams.

Still another object of this invention is to provide a method for controlling a secondary recovery operation wherein a plurality of separate streams of a displacing fluid are introduced into a petroleum containing formation via one or more injection wells to displace petroleum toward one or more producing wells wherein the resulting displaced petroleum is produced.

How these and other objects of this invention are attained will be apparent in the light of the accompanying disclosure. In at least one embodiment of the practice of this invention at least one of the foregoing objects will be attained.

In accordance with the practice of this invention a method of identifying a plurality of flowing streams is provided by introducing a tracer into each of said streams in a distinctive time pattern to impose an identifiable tracer-time pattern within each of said streams. The presence of the tracer in at least one of said streams is

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then detected at some location downstream thereof from the point of introduction of said tracer therein. Thereupon the tracer-time pattern within said stream is determined and the determined tracer-time pattern in said stream is correlated with the aforesaid originally imposed tracer-time patterns to identify the origin of said stream.

In the application of a practice of this invention to a secondary recovery operation wherein a plurality of streams of a displacing fluid are introduced into a petroleum bearing formation to displace or otherwise drive the petroleum toward one or more producing wells wherein the petroleum is produced as well fluids therefrom, there is introduced into the streams of driving fluid a tracer in a detectable amount. Each of the streams into which the tracer is introduced contains the tracer therein in a distinctive time pattern, that is, the tracer is introduced into each of said streams of driving fluid for a period or periods of time to impart to each of said driving fluids a distinctive, different and identifiable time pattern with respect to the tracer thus-introduced therein. For example, the concentration and/or presence of the tracer in the streams is varied with time to impart to each stream a separate, distinct and different identity with respect to the tracer therein. The thus-identified driving fluids are then employed to displace the petroleum toward one or more producing wells wherein eventually the thus-injected and identified driving fluids will appear and be produced in the well fluids. From time to time during the secondary recovery operation, that is, during the injection of the driving fluids and the production of the displaced petroleum from the production wells or well, the produced well fluids are tested in order to detect the presence therein or absence of a tracer. When the presence of a tracer is detected in the produced well fluids the tracer-time pattern in the well fluid is determined. This determination of the tracer-time pattern can be effected by simple chemical, physical or other suitable means depending upon the tracer employed in order to determine the period of time or times during which the tracer appears in the produced driving fluid. When the time pattern or time patterns have been determined by suitable correlation, comparison or reference back to the time patterns originally imposed on the various driving fluids introduced into the petroleum producing formation the origin of the produced driving fluid can readily be determined.

Various tracers or tagging elements, chemical compounds and the like may be employed in the practice of this invention. Suitable tracers include such chemical compounds as carbon dioxide, hydrogen sulfide, sulfur dioxide, ammonia, such elements as acetylene, helium, the normally gaseous halogens, e.g., fluorine and chlorine, and mixtures thereof. Other materials which are suitable as a tracer include fluorescein, the various organic dyes, the ultraviolet fluorescent polycyclic aromatic hydrocarbons and the like. In general, any suitable tracer (element, compound or physical admixture of materials) may be employed in the practice of this invention provided the presence of the tracer employed can be detected in the fluid stream or streams into which it is introduced.

Desirably the tracer employed in the practice of this invention should be compatible with the fluid stream of streams in contact therewith or into which it is injected. Also, the tracer employed should be compatible with the environment through which it flows. Certainly it is desirable that the tracer material employed in the practice of this invention should be distinct or should be employed in an amount distinctive from its environment, i.e., it is generally not desirable to employ a tracer which is a material which is present in the formation which is

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traversed by the flowing streams passing therethrough since otherwise spurious results might be obtained.

Radioactive tracer materials are particularly suitable and useful in the practice of this invention. Suitable radioactive tracer materials include the radioactive isotopic elements or compounds containing the same whose presence can be detected by suitable radioactivity detecting or electronic means. Suitable tracer materials include tritium, the hydrogen isotope having an atomic weight of 3; C_{14} , the carbon isotope having an atomic weight of 14; radioactive iodine, cobalt, phosphorus, radon, radium, nitrogen, and other radioactive isotopes. Preferred in the practice of this invention are the beta-emitting isotopes such as C_{14} and tritium since these materials are relatively safe to handle and possess a half life sufficiently long to make these elements or compounds containing these elements particularly attractive for use in a secondary recovery operation which might extend over periods of months, even years.

The time pattern imposed on an individual fluid stream in order to be able to identify the same may be any suitable or convenient time pattern. For example, the tracer employed may be introduced into one fluid stream in a detectable amount for about one hour, then injection stopped and resumed after an interval of five hours for another one hour. It is readily seen that there is available to an operator employing the practice of this invention a practically limitless number of time patterns useful for tagging or otherwise separately identifying fluid streams containing the same. In view of this apparently limitless number of time patterns available the operator should have no difficulty in selecting suitable tracer-time patterns so that when two or more driving fluids or fluid streams containing individually different tracer-time patterns imposed thereon converge the admixture of these fluid streams can be determined as well as the origin of the fluid streams which have so converged. Stated in other words, by suitable selection of the tracer-time patterns employed, intermixing of two or more fluid streams should not render it impossible for the operator to separately identify the streams which have intermixed.

In accordance with a preferred practice of this invention the tracer material, element or compound containing the same, is the same in each of the streams tagged, the only distinctive and identifiable characteristic of the streams being the tracer-time pattern imposed thereon.

In accordance with one practice of this invention it is also possible, besides employing varying tracer-time patterns to identify fluid streams, to employ tracer materials in the streams in varying amounts or concentrations. For example, it is possible in accordance with this feature of applicant's invention to separately identify streams having the same tracer-time pattern by employing different concentrations of tracer material in the streams.

Illustrative of the relatively minute amounts of tracer or tagging agent which might be employed in a practice of this invention it has been determined that ten million standard cubic feet of gas, such as natural gas, can be satisfactorily tagged with only 0.1 cc. of tritium or a gaseous compound containing the element tritium.

In a secondary recovery operation carried out in accordance with a practice of this invention and wherein natural gas is introduced into a petroleum producing formation via a plurality of injection wells at a rate of about one million standard cubic feet of gas per well per day there is introduced into the natural gas being injected into the formation via each of the injection wells tritium or a compound containing tritium such as methane CH_3T wherein T represents a tritium atom. Each of the streams of natural gas being thus introduced into the formation is tagged or otherwise identified with a distinctive tracer-time pattern. For example, in natural gas injection Well #1 tritium is continuously introduced at

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a rate of one part per 28 trillion parts by volume of gas for alternate one hour periods. In gas injection Well #2 tritium is introduced thereinto over alternate 15 minute periods. In still another gas injection Well #3 tritium is thus injected thereinto over alternate five hour periods. While these separate gaseous streams are being thus tagged and identified and introduced into the petroleum producing formation petroleum hydrocarbons are produced at a nearby production well spaced at a distance of about 400 feet from each of the injection wells. After a period of some time, for example, about three days, detecting means, such as a flow type beta counter, e.g., Libby-Kulp screen wall counter, would detect the presence of tritium, a beta emitter, in the produced well fluids. The radioactive detecting means thus monitoring the fluids produced at the producing well perhaps indicating beta activity in the produced fluid over alternate 15 minute periods. With this knowledge the operator is quickly apprised of the fact that the gas injected into the petroleum bearing formation via injection Well #2 is no longer effective or is substantially ineffective for the displacement of the petroleum with the formation undergoing treatment. Thereupon the operator can more efficiently carry out his secondary recovery operation by halting the injection of gas via injection Well #2, and more efficiently carry out the secondary recovery operation by injection gas only via Wells #1 and #3. Therefore, in view of the teachings of this invention an operator can more efficiently and effectively carry out a secondary recovery operation.

Although considerable emphasis has been placed in this disclosure on the applicability of this invention to the improvement of a secondary recovery operation it is realized that the practice of this invention is generally applicable as a method of separately identifying a plurality of flowing streams. For example, the practice of this invention is applicable for the tracing of paths of fluids through an intricate network of channels and conduits, such as through a sewerage collecting system, pipeline switching and collecting points, water distribution systems and the like.

As will be apparent to those skilled in the art many substitutions, changes and modifications are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A method of identifying a plurality of flowing fluid streams wherein a tracer is introduced into one of said streams for a period of time A and said tracer is introduced into another of said streams for a period of time B, said time periods A and B being different, detecting the presence of said tracer in said flowing streams at some location downstream thereof, determining the periods of time said tracer appears at said location in said flowing streams and correlating the period of time said tracer appears in said streams with the aforesaid periods of time to identify said streams.

2. A method of identifying a plurality of flowing fluid streams wherein a tracer is introduced into one of said streams in a time pattern A and said tracer is introduced into another of said streams in a time pattern B, said time patterns A and B being different, detecting the presence of said tracer in said streams at some location downstream thereof, determining the tracer-time pattern in said streams and correlating the determined tracer-time patterns in said streams with the tracer-time patterns A and B originally imposed on said streams to identify each of said streams.

3. A method of identifying a plurality of flowing streams wherein a tracer is introduced into each of said streams in a single distinctive time pattern to impose an identifiable tracer-time pattern within each of said streams, detecting the presence of said tracer in at least one of said streams at some location downstream thereof

from the point of introduction of said tracer therein,

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determining the tracer-time pattern within said stream wherein said tracer is detected and correlating the determined tracer-time pattern in said stream with the aforesaid originally imposed tracer-time pattern to identify said stream.

4. A method in accordance with claim 3 wherein said tracer comprises tritium.

5. A method in accordance with claim 3 wherein said tracer comprises the carbon isotope having an atomic weight of 14.

6. A method in accordance with claim 3 wherein said tracer comprises a radioactive iodine isotope.

7. A method in accordance with claim 3 wherein said tracer is a radioactive cobalt isotope.

8. A method in accordance with claim 3 wherein said tracer comprises fluorescein.

9. In the secondary recovery operation wherein petroleum hydrocarbons are produced from a subsurface formation containing the same by introducing into said formation at a plurality of locations a driving fluid to displace the petroleum hydrocarbons therefrom toward a producing well and wherein said driving fluid injected into said formation from at least one of said locations is eventually produced at a producing well, the method of determining from which location the produced driving fluid originates which comprises introducing a tracer into said driving fluid thus introduced into said producing formation, said tracer being introduced into said driving fluid at said locations for respectively different periods of time, detecting the presence of said tracer in

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the well fluid produced at said producing well, determining the periods of time said tracer appears in said produced well fluids and correlating the periods of time said tracer appears in said well fluids with the aforesaid periods of time to identify the driving fluid.

10. In the secondary recovery of hydrocarbons from a subsurface hydrocarbon producing formation wherein a plurality of fluid streams is injected into said subsurface formation at spaced locations to displace the hydrocarbons therein toward one or more production wells spaced from said locations of injection, the method of identifying the displacing fluid arriving at a producing well as to its location of injection which comprises adding to each of the injected streams a tracer in a distinctive time pattern to impose an identifiable tracer-time pattern within each of said streams, detecting the presence of said tracer in the well fluids produced at said producing well, determining the tracer-time pattern within the well fluids wherein said tracer is detected and correlating the determined tracer-time pattern in said well fluids with the aforesaid originally imposed tracer-time patterns as an indication of the origin of the displacing fluid in said well fluids.

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