METHOD OF DETECTING LEAKAGE IN OIL WELLS

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The present invention relates in general to oil well production and particularly to the production of oil from wells traversing two or more productive horizons. More especially, the invention concerns the detection of leakage of oil from one productive horizon to another.

In many oil fields, it is not uncommon that separate withdrawal of oil from two horizons may be involved, necessitating separate production from each horizon. The separate withdrawal of oil from two productive zones through a single well generally has been accomplished by setting a packer in the annular space between the tubing and casing to seal off the two zones and then allowing the well to produce from the lower zone through the tubing while permitting it to produce from the upper zone through the annular space. However, it has been found in actual practice that difficulty often is encountered in getting a permanent seal between the two productive zones, and it is not uncommon that leakage of oil from the zone of higher pressure to the lower pressure zone develops. Whenever such contamination of oil of one zone by that of another occurs, it is desirable that it be detected in order that proper preventive measures may be taken without delay. Accordingly, there is a need for a rapid and simple method of detecting such contamination.

Several of the usual methods employed in testing crude oils have been tried for this purpose but none of these has proved satisfactory. For example, when distillation tests were tried, they proved to be not sufficiently diagnostic to detect contamination even of substantial degree and also to be more time consuming than desired for practical use.

The present invention provides a method of detecting contamination of oil from one horizon by that of another, whereby leakage of oil between horizons may readily be indicated. In accordance with the invention, such leakage is detected by observing changes in the absorption characteristics of the oil for light radiation having a wave length above a certain value. It has been discovered that, whereas oils from different horizons have substantially the same absorption characteristics for light radiation of wave length below about 5500 Angstroms, such oils differ substantially in absorption characteristics when the wave length is above the aforesaid value. On this basis, it has been found that there is a marked tendency for the oil within a single productive zone not to exhibit a real variation in these absorption characteristics to any large extent, although, in some cases, there may be a minor amount of such variation. Accordingly, by subjecting samples of the oil, as production from the well proceeds, to suitable spectroscopic tests employing light radiation of wave length above 5500 Angstroms, and then comparing the results with predetermined absorption characteristics obtained under similar conditions for the uncontaminated oil and noting any substantial change in these characteristics, contamination of oil of one horizon by that of another is readily indicated.

In testing the oil to determine its absorption characteristics (or, from another viewpoint, its transmission characteristics), a spectrophotometer or absorption meter is employed. Instruments of this kind are well known and generally comprise a source of light radiation, an optical system for separating the radiation into its constituent wave lengths and for transmitting rays of the desired wave lengths through the sample, and means for measuring the intensity of the radiation emerging from the sample. Some of these instruments are designed so that the wave length of the radiation passed into the sample may be varied over a desired range in order that the per cent transmission may be determined from each wave length within the range. Such apparatus is described in an article appearing in "Industrial and Engineering Chemistry," analytical edition, volume 13, pages 667—754 (1941), entitled "Instrument methods of chemical analysis," particularly on pages 684—692. Spectrophotometers of this type may be used if desired, although, for the purposes of the invention, it is unnecessary that the per cent transmission be determined at various wave lengths and it is sufficient to make a single determination using either monochromatic radiation or a radiation band of relatively wide spectral range. Spectrophotometers or absorption meters which utilize a single restricted band of wave lengths are available and, due to their simplicity and low cost, are particularly suitable for practicing the invention.

For the purpose of illustrating the type of results obtained by spectroscopic tests as applied...
In the present invention, there is attached here to a single sheet of drawings showing in graphical form the results of tests on oils made by means of a Hardy spectrophotometer (described in the previously referred to article). By means of this instrument, the per cent transmittance of monochromatic light over the spectral range of 4000-7000 Angstroms was determined. The curves shown in the drawing are for two oils (designated as A and B) derived from the same field but from different horizons, as well as for several blends of the two oils. The relationships between per cent transmittance and wave length are represented for oil A and for oil B by the upper and lower curves, respectively, while the intermediate curves represent the various blends.

A comparison of the curves shows clearly that there is no substantial difference in the absorption characteristics of the oils for light of wave length below about 5500 Angstroms. Above this value, however, the curves diverge and the difference in absorption characteristics becomes more pronounced as the wave length is increased. Thus at 7000 Angstroms, there is a very marked difference in absorption characteristics. It is further to be noted, as indicated by a comparison of the curves for the blends with those of the uncontaminated oils, that the oils taken into consideration for compositions of the blends, that the tests afford an approximation of the amount of contamination of oil from one horizon by that of another.

Although the data presented graphically in the drawing include wave lengths only up to 7000 Angstroms, it is to be understood that radiation of still higher wave length may be used in accordance with the invention. In fact, in some cases it may be desirable to work at higher wave lengths in order to render the test method more sensitive in differentiating between oils. However, this has the drawback that wave lengths greater than about 7000 Angstroms are outside of the visible light range and within the range of infrared radiation, so that more complicated and expensive instruments are required. From a practical aspect, it is generally preferable to work in the visible light range and preferably within a range of about 6500-7000 Angstroms, but it is to be clearly understood that the invention is not necessarily limited to the range of visible radiation.

As evidence of the difference in absorption characteristics of oils from different horizons as well as of the substantial uniformity of oil within a given horizon, the following test data for various oil samples representing four productive horizons in one particular field are illustrative. The tests were made with light radiation having a wave length of 7000 Angstroms. Each result listed represents a different well within the particular field, many of which were widely spaced throughout the field even for the same producing zone.

Per cent transmittance at wave length of 7000 Angstroms:

Oil from zone A—34.8, 32.3, 32.0, 38.3
Oil from zone B—4.2, 2.8, 2.6, 4.3
Oil from zone C—66.7, 63.0
Oil from zone D—9.6, 7.0, 8.5, 9.2, 7.1, 7.3, 8.5, 8.9

These results clearly show that there is a marked difference between oils from different productive horizons but that any areal variation for the oil within a given horizon is relatively small.

In practicing the invention, absorption characteristics for oils of the various horizons in question preferably are predetermined in order to afford a comparison with the test results obtained as production proceeds. Uncontaminated samples, representative of the various horizons, may be obtained in any suitable manner, one particularly reliable manner being to sample the flow streams of singly completed wells within the field. Before testing a sample, it is distinctly preferable to subject the sample to treatment adapted to remove water and sediment therefrom, since it has been found that such impurities may cause the test results to be inconsistent and unreliable. For this purpose, either centrifugation or filtration serves as a particularly convenient and effective type of treatment.

In the case where two or more productive horizons are traversed by a bore hole and one of the horizons is known to be under relatively low pressure, leakage to this horizon may be detected by observing substantial changes in the absorption characteristics as production proceeds, even in the absence of any absorption characteristic data for other horizons. However, this affords no indication of how much oil is in absorbing place. Accordingly it is generally preferable to know the absorption characteristics for oil of the other horizons or horizon so that the amount of leakage may be estimated. Since leakage cannot take place from a lower pressure zone to one of higher pressures, it is not essential in carrying out the invention that the oil from a higher pressure zone be tested as production proceeds, although at times it may be desirable to do so for the sake of following minor variations of absorption characteristics.

The invention is also useful even in the absence of predetermined absorption characteristics. In such cases, any initial leakage between productive horizons would not be detected. However, it has been found that leakage is apt to come progressively worse as production proceeds, so that even though the actual absorption characteristics of uncontaminated oil of a given horizon may not be known, it is possible to detect any substantial increase in the rate of leakage to that horizon by noting changes in the absorption characteristics of the oil stream drawn therefrom as the well continues to produce.

Having described our invention, what we claim and desire to protect by Letters Patent is:

1. In the production of oil from a single bore hole traversing at least two productive horizons and in which leakage of oil from a horizon of higher pressure to one of lower pressure is apt to occur, the method of detecting such leakage as production proceeds which comprises determining the absorption characteristics of oil withdrawn during production from said lower pressure horizon for light radiation of wave length substantially above 5500 Angstroms and comparing the determined absorption characteristics with the absorption characteristics of oil previously withdrawn from said lower pressure horizon for light radiation of the same wave length, thereby to detect any substantial change in said characteristics as production proceeds and thus afford an indication as to whether leakage of oil from the higher pressure horizon to the lower pressure horizon has occurred.

2. The method defined in claim 1 wherein each of the said absorption characteristics are for light radiation of wave length within the range of 6500-7000 Angstroms.
3. In the production of oil from a single bore hole traversing at least two productive horizons and in which leakage of oil from a horizon of higher pressure to one of lower pressure is apt to occur, the method of detecting initial leakage as production is begun which comprises determining the absorption characteristics of oil withdrawn as production is begun from said lower pressure horizon for light radiation of wave length substantially above 5500 Angstroms and comparing the determined absorption characteristics with the absorption characteristics of uncontaminated oil from said lower pressure horizon for light radiation of the same wave length, thereby to detect any substantial difference in said characteristics as production is begun and thus afford an indication of initial leakage between said horizons.

4. The method defined in claim 1 wherein the said oil withdrawn during production and the said oil previously withdrawn are each subjected to treatment adapted to remove water and sediment therefrom before being tested to determine the absorption characteristics.

5. In the production of oil from a single bore hole which traverses a productive horizon of lower pressure and a second productive horizon of higher pressure, and where, during the production of oil from said horizon of lower pressure, leakage of oil from the horizon of higher pressure to that of lower pressure is apt to occur, the method of detecting such leakage as production proceeds which comprises first determining the absorption characteristics of oil withdrawn during production from said lower pressure horizon for light radiation of wave length substantially above 5500 Angstroms, determining the absorption characteristics of oil subsequently withdrawn from said lower pressure horizon for light radiation of the same wave length, and comparing the determined absorption characteristics of oil withdrawn from the same horizon under the two conditions to detect any substantial difference in the two determinations indicative of leakage of oil from the higher pressure horizon to the lower pressure horizon.

6. In the production of oil from a single bore hole which traverses a productive horizon of lower pressure and a second productive horizon of higher pressure, and where leakage of oil from the horizon of higher pressure to that of lower pressure is apt to occur, the method of detecting such leakage as production proceeds which comprises determining the absorption characteristics of uncontaminated oil from said lower pressure horizon for light radiation of wave length substantially above 5500 Angstroms, and also determining the absorption characteristics of oil withdrawn from said lower pressure horizon during production from said single bore hole for light radiation of the same wave length, and comparing the determined absorption characteristics to detect any substantial difference in the two determinations indicative of leakage of oil from the higher pressure horizon to the lower pressure horizon.

7. In the production of oil from a single bore hole traversing at least two productive horizons and in which leakage of oil from a horizon of higher pressure to one of lower pressure is apt to occur, the method of detecting such leakage as production proceeds which comprises determining the absorption characteristics of oil withdrawn during production from said lower pressure horizon for light radiation of wave length substantially above 5500 Angstroms, comparing the determined absorption characteristics with the absorption characteristics of uncontaminated oil from said lower pressure horizon and to thus afford an indication of leakage between said horizons, and also comparing the determined absorption characteristics with the absorption characteristics of uncontaminated oil from said higher pressure horizon for light radiation of the same wave length to thereby afford an indication of the amount of leakage between said horizons.

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