United States Patent Office

2,734,579

Patented Feb. 14, 1956

2,734,579

PRODUCTION FROM BITUMINOUS SANDS

Lloyd E. Elkins, Tulsa, Okla., assignor to Stanolind Oil and Gas Company, Tulsa, Okla., a corporation of Delaware

No Drawing. Application June 28, 1952, Serial No. 296,250

1 Claim. (Cl. 166—11)

This invention pertains to the art of recovering oil from a solid bituminous deposit, such as the Athabaska tar sands or the like.

Various methods have been proposed for recovery of petroleum from bituminous deposits, such as tar sands, in which the bituminous deposit is normally in a solid state intermixed with more or less sand or the like. The methods proposed can be generally classified as either mining the deposit with subsequent treatment of the bituminous deposit in a mill or retort with water, solvents, heat, etc., to separate the recoverable petroleum from the sand, or solvent treatments to remove petroleum from the tar sand in place. Neither of these classes has proved commercially successful.

I have found that oil can be recovered from a solid bituminous deposit by application of heat to the material in place, in which a part of the deposit is volatilized and driven off, leaving a combustible residue. This combustible residue is oxidized or burned in place by an oxidizing gas driven into the deposit. The hot gaseous products of combustion are forced through the deposit, carrying with them at least a part of the volatilized constituents of the tar sands. Ordinarily, the temperature at the zone of combustion in the bituminous body is regulated to lie in the range of approximately 400° F. to about 1,000° or 1,200° F. Under these conditions, part of the heavier hydrocarbons present in the deposit will be cracked; therefore, the petroleum fractions which are driven by the hot gases to the producing wells will be of considerably higher A. P. I. gravity than were the original deposits. As a result, the oil reaching the production well or wells will be liquid and can be removed from the well by conventional pumping means. Additionally, the passage of the lighter petroleum fractions through the bituminous deposits, together with the local heating of these deposits, causes part of the heavier materials to be dissolved in the lighter fraction. This, therefore, results in a recovery of the major part of the bitumen present in the deposit in the form of a liquid. This liquid can be treated by ordinary refining methods to produce gasoline, kerosense, naphtha, lubricating oil fractions, etc., as is already well-known in the art. The combustion process completely consumes the last residuum from the bituminous deposit, leaving simply the noncombustible sand or the like. As will be shown subsequently, it is only a relatively minor part of the combustibles originally present in the tar sands, the least desirable heavy ends, which are consumed by the combustion process, and the major part of the oil, that is, the liquid components of the bitumen, present is transported to the producing wells for recovery.

Frequently, it will be found that the permeability of the bituminous deposit is too low initially to permit forcing a gas between an input well and a producing well. In such cases, it is necessary to isolate a zone in the input well by means of packers or the like, as is now well-known, and carry out in the confined zone a fracturing process; for example, by using the techniques outlined in U. S. Patents Nos. 2,596,843 Farris and 2,596,844 Clark. By use of this process, it is possible to form a fracture or series of fractures between injection and production wells located a considerable distance apart, and, accordingly, one can develop initial permeability sufficient for gas to flow between these wells. In such an instance it may be necessary to maintain air injection pressures at high enough levels to keep the fracture open until it becomes thoroughly heated up with hot oil, thus preventing solidification and plugging of the fracture.

In carrying out the process, first, injection and production wells are drilled into the deposit and cased in the usual manner. After the wells are completed, a gas compressor is connected to the input well and an attempt made to force gas between this well and the surrounding production wells. If it is impossible to secure a reasonable flow of air between these wells, the Hydrafrac process, as described in the patents given above, or equivalent, is employed. In any case, after gas permeability has been secured, the compressed air, which may or may not be enriched by addition of oxygen from a small oxygen plant, is forced into the injection well at pressures of the order of about 250 p. s. i. up to approximately 500 p. s. i., or higher.

Before routine injection of the air, it is desirable to place a heating source in the injection well at the level of the bituminous deposit; for example, a suitable down-the-hole heater may be run in the injection well. Several types of such down-the-hole heaters have already been given in the art. One is shown in U. S. Patent 1,457,479 Wolcott. This is simply an electrical heater which can be placed at a desired elevation in the well. If combustible gas is available, it may be forced into the well together with the oxygen-containing gas, in which case the down-the-hole heater can be a burner at the bottom of the well furnished with a spark plug or other ignition means. A third possibility consists in combusting a solid fuel at the deposit in the well, for example, by mining from the more accessible parts of the bituminous deposit a supply of bituminous sand and crushing this sand to pass through, for example, a ten-mesh sieve. This material is then placed loosely in the bottom of the well and burned, for example, by temporary injection of heated air at a temperature of 500° F. to 1,000° F. This causes combustion of this loose deposit. Other suitable heaters are found in the following U. S. patents: 2,186,035 Niles, 2,362,680 Troupe, and 2,332,708 Freeman.

In all cases, the down-the-hole heater is temporarily employed in conjunction with the inflow of the oxygen-containing gas under pressure to heat the surface of the deposit adjacent the well and an area around the well from approximately two feet to approximately ten feet in diameter, by the combined action of radiation, convection, and conduction. This combined heat-generating action heats this area up to a temperature somewhere between 400° F. and about 1,000° F. Once this temperature level has been developed in this small area, combustion of bitumen occurs. The heater can then be withdrawn, and continued injection of air thereafter will supply oxygen to the heated bituminous sand to maintain this combustion reaction. During this reaction, the bitumen is liquefied in place, part of it is at least partially cracked and distilled, leaving a coke or heavy hydrocarbon residue on the natural formation rock material. As the air comes in contact with this coke residue, the coke is burned and additional heat is generated. The products of combustion are forced through the sand, driving the liquefied, cracked, and distilled hydrocarbons and water along in the permeable paths toward the producing wells.

The entire contacted sand zone behind the combustion front is completely cleaned of all hydrocarbon and water content. The heat generated in the process is dissipated partially by the cracking process, but largely by the conductance of the heat away from the production zone. The heat flowing from the combustion zone to the producing wells (transferred by the hot gaseous products of combustion and the warmed liquid oil) tends to increase continuously the permeability to fluid flow through the deposit by the gradual liquefaction and removal of solid bitumen.

The liquid oil is produced from the adjacent producing wells in any conventional manner. Often the gaseous products of combustion are adequate to flow the oil; otherwise, conventional pumping units can be employed.

It is important to control the temperature within the reaction zone. I have found that the minimum temperature of this zone at which combustion normally can be maintained is of the order of approximately 400° F. It is desirable to maintain the temperature higher than this value up to temperatures from 800° F. to 1,000° F. When the temperature rises substantially higher than these values, roughly above 1,200° F., combustion takes place too rapidly, the recoverable cracked products are minimized, the liquefaction occurs considerably ahead of the combustion zone, and, in general, the loss of valuable petroleum products in the combustion itself will become sufficiently great to make the process a good deal less economical. Control of the temperature within the reaction zone can be maintained in several ways. The increase in volume of oxygen-containing gas by application of higher injection gas pressure will increase this temperature. The higher temperature is maintained primarily by the fact that the time available for the loss of sensible heat to the formations adjacent and downstream from the combustion zone is minimized. In addition, the higher rate of injection and the increased supply of oxygen at the reaction zone by virtue of the higher pressures consumes additional oil in combustion above that required at lower rates and thereby generates more heat. To keep the temperature from becoming too high, it is possible to dilute the air with inert gas, for example, by separating the inert gaseous products of combustion (principally oxides of nitrogen and carbon) from the produced hydrocarbons, and introducing it into the injection stream. This slows down the rate of heat generated and provides additional time for sensible heat loss to adjacent formations as well as to the formation itself in front beyond the combustion zone. Decreasing the injection gas pressure also decreases the combustion zone temperature.

Ordinarily, it will be found that when air is used as the oxygen-containing gas, it should be furnished to the formation at a rate which is initially low and which rises roughly linearly with time. Approximately 200 to about 1,000 cubic feet of air per hour, for example 500 cubic feet per hour, should be supplied to the burning zone per square foot frontage of this zone. Thus, for example, if the bituminous deposit is 10 feet thick and the burning zone is at a diameter of approximately 32 feet, the combustion zone will have a circumference of roughly 100 feet, an area of approximately 1,000 square feet, and should be supplied compressed air at the rate of approximately 50,000 standard cubic feet per hour. It will be found that gas rates near the upper end of this range, i. e., around 1,000 standard cubic feet per hour per square foot, will produce temperatures in the average bituminous deposit of around 1,000° F. to 1,200° F., which is about as high as the combustion temperature should be carried without excessive losses. When the median rate of 500 standard cubic feet per square foot per hour is employed using Athabaska tar sand, I found a recovery of approximately 70 to 90 per cent of the hydrocarbons in the deposit, having an everage gravity of 19° A. P. I., whereas the original bitumen had a gravity ranging from 6° to 7° A. P. I. This particular sample of the tar sands had a content of approximately 90 per cent bitumen and 10 per cent sand by weight. It is apparent from this that there was a considerable amount of cracking, which increased the gravity of the oil.

As a matter of fact, one of several tests which can be used to determine whether the air rate being used at a particular time is optimum consists in determining the gravity of the produced oil. Greater air flow causes a higher combustion front temperature, greater cracking, and a higher gravity product. Accordingly, when the gravity of the resultant oil becomes above about 20° A. P. I., the rate of supplying the oxygen-containing gas should be decreased, whereas if it drops much under 17° A. P. I., this rate should be increased. It is also found that a simple analysis for the amount of unsaturated hydrocarbons present in the recovered oil can also be employed to regulate the rate at which gas is injected. The greater the degree of unsaturation, the greater is the amount of air being supplied. Accordingly, by such a test, it is possible to determine when the rate of air is insufficient or excessive. Other tests which can be employed are determining the gas/oil ratio of the recovered hydrocarbons, which ratio increases with increased air flow to the combustion front, and measuring the temperature somewhere near the combustion front. As already stated, this temperature should roughly lie between 400° F. and 1,200° F., for example, 1,000° F. It is possible to drill a small hole or the like through the deposit somewhere near the front and measure the formation temperature directly as the combustion front passes. Or, if the burning is progressively outward past a first series of wells and then to a second series of wells, the deposit temperature as the combustion front passes the first series of wells can be used as an indication of the oxygen rate thereafter. Modifications of these methods of measurement will be apparent to those skilled in this art.

Another means for adjusting the combustion zone temperature involves the injection of water into a solid bituminous sand adjacent to but either above or below the zone being subjected to combustion drive. It is frequently found in such tar sand deposits that there are narrow impervious streaks of shale or the like interbedded with the bituminous deposit. These furnish barriers to vertical flow of gas and liquid products in the combustion drive described, but do not stop the flow of heat. Typically, initially solid bitumen becomes less and less viscous as the temperature increases and, therefore, after a combustion front has been going for some time, it is often possible to inject water into an adjacent warmed zone of previously solid bitumen, and drive liquefied products from this adjacent zone into a well for production. For example, if the ten-foot zone previously discussed were being subjected to combustion, and if heat loss from that zone elevates the temperatures on adjacent zones separated from the combustion zone by an impervious shale barrier up to, say, 200° to 300° F., these latter zones can be very satisfactorily water flooded to produce increased amounts of hydrocarbons. Frequently, relatively thin zones in a thick tar sand region are separated by shale beds thin but relatively impervious. By the water flooding technique, particularly if the flood water is heated nearly to its boiling point before injection, the zones separated by shale stringers from the zone in which combustion takes place can be depleted of their bitumen content. The water flooding both aids in producing additional hydrocarbons from a previously solid bitumen bed, and also in temperature control of the combustion zone. It is found desirable to arrange the oxygen-containing gas injection wells as dual completion wells, so that through one conduit compressed air, for instance, can be injected into the combustion zone, while a water flood in the opposite direction from the flow of hot gas is forcing liquid bitumen products into another conduit of the same well for production. The water injection wells may in turn be dual completion wells producing bitumen products from the combustion zone, or can be other wells near the combustion zone.

It will be understood that numerous modifications and variations in the systems of production outlined above can be carried out without departing from the spirit of this invention, which is best defined by the scope of the appended claim.

I claim:

In a method for recovering oil from a solid deposit of bitumen in which at least two wells have been driven into said deposit and in which combustion of said bitumen heats said deposit and drives oil therefrom to production wells, said deposit being separated from an adjacent zone by an impervious barrier, the improvement involving maintaining the temperature in the region of combustion in said deposit within a predetermined range lying between approximately 400° F. and 1200° F. by measuring a physical characteristic of the fluids driven to said production wells indicative of said temperature, injecting water into said adjacent zone when said measurement indicates said temperature exceeds said range, and increasing the flow rate of said injected air when said measurement indicates said temperature is nearing the low end of said range.

References Cited in the file of this patent

UNITED STATES PATENTS

1,237,139	Yeomans	Aug. 14, 1917
1,457,479	Wolcott	June 5, 1923
2,382,471	Frey	Aug. 14, 1945
2,390,770	Barton et al.	Dec. 11, 1945
2,481,051	Uren	Sept. 6, 1949
2,584,605	Merriam et al.	Feb. 5, 1952
2,584,606	Merriam et al.	Feb. 5, 1952
2,642,943	Smith et al.	June 23, 1953