June 10, 1941. E. V. FORAN 2,244,684

MEANS FOR AND METHOD OF FLOWING OIL AND GAS WELLS

Filed July 5, 1939

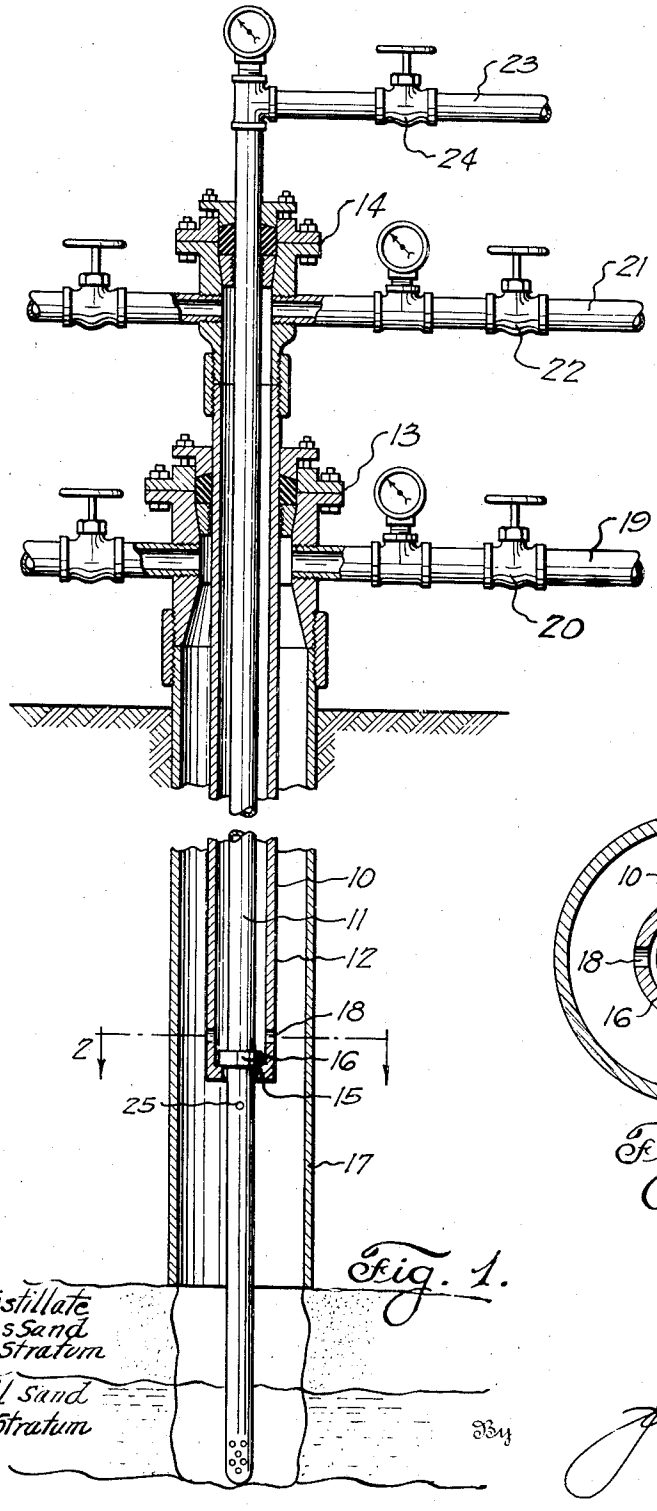


Fig. 1.

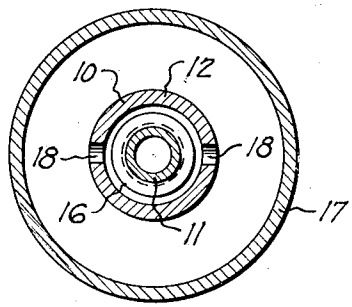


Fig. 2.

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Patented June 10, 1941 2,244,684

UNITED STATES PATENT OFFICE

2,244,684

MEANS FOR AND METHOD OF FLOWING OIL AND GAS WELLS

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Application July 5, 1939, Serial No. 282,836

5 Claims. (Cl. 166—1)

This invention relates to new and useful improvements in means for and methods of flowing oil and gas wells.

In the conducting of deeper oil and gas well exploratory operations in the more recent years, the oil and gas industry has observed, on many occasions, the occurrence of distillate gas and petroleum crude oil in the same common porous stratum, such as a producing sand stratum or a producing porous limestone stratum. The distillate gas overlies the oil and, being in direct permeable contact with it, normally has a simultaneous entry from the formation into the well bore when the well is producing or in operation.

In many cases, the major portion of the reservoir producing stratum may be occupied by the distillate gas and only a relatively small portion of the producing stratum occupied by the liquid pertroleum crude oil. Any water which may be present in the same producing stratum will, of course, underlie the liquid crude oil. When a well is completed in a stratum or formation under these conditions it often becomes extremely difficult or even impossible to produce, for example, the crude oil without at the same time producing undesirable and large quantities of distillate gas. Wells of this type or character are often referred to as "high gas-oil ratio wells," "combination wells" or "distillate wells." In those cases where there is no readily available or useful disposition of the excessive volumes of gas, after separation at the surface, it becomes necessary, in order to conform with the conservation laws of most oil and gas producing states, now in force, to return the gas to the sand, after having separated the gas from the oil at the surface.

If both the oil and gas are conducted from the bottom of the well to the surface through a common conductor or single string of tubing, in the conventional manner, it is obvious that the pressure at which the gas and oil are delivered at the surface will be much lower than the gas pressure would be, if the well were producing gas only from the same formation. Due to the lower pressure at which the oil and gas are delivered to the point of separation at the surface, the cost of recompressing the separated or residue gas sufficiently to return it to the same reservoir from which it came may, and often does, prove to be prohibitive. Under these circumstances, the well would either have to be shut in until acceptable disposition of the gas was obtained or the operator would be required to greatly reduce the daily amount of oil taken from it in order to avoid the otherwise excessive daily gas waste, which is prohibited by the conservation laws of the principal oil producing states. In some cases, it has been the practice to produce the liquid crude oil together with a more or less restricted amount of gas through a small string of tubing and at the same time conduct the excess distillate gas upwardly through the casing of the well.

In the high pressure, deeper reservoirs, having a high gas-oil ratio, the gas overlying the oil is in contact with the oil and the gas and oil are in a state of equilibrium, under which condition the gas is, of course, saturated with condensable vapors. These condensable vapors, which are carried by the gas, are stable in the gas phase only so long as the reservoir pressure and temperature are maintained and any lowering of either pressure or temperature, or both, will result in condensation of portions of said vapor.

It is well known that a natural drop in pressure and temperature takes place in transit between the point of entry from the formation at the bottom of the hole, and the point of discharge at the casing head on the surface. Gas, in its travel upwardly through the casing will, of necessity, have a very low velocity as compared to its velocity when travelling through the smaller tubing with the crude oil. This is true because of the larger cross-sectional area of the casing, as compared to the smaller cross-sectional area of the tubing. A considerable amount of distillate condensation will occur during the upward travel of the gas in the casing, due to the pressure and temperature drop, with the result that precipitation due to gravity will take place and the liquids derived from condensation, which are usually water-white in color, will gravitate downward to the bottom of the hole and become diluted or contaminated with the crude oil. Such precipitation occurs because the velocity of the gas flowing upwardly through the casing is insufficient to overcome the forces of gravity. Therefore, when the conventional single liquid conductor within the casing is employed, especially at moderate or low rates of flow, the condensates which precipitate from the gas flowing upwardly through the casing, dilute or contaminate the crude oil at the bottom of the well bore and are produced therewith through the single conductor. This is very undesirable when the distillate gas and oil are produced in this manner.

It is, therefore, one of the objects of the invention to provide a new and improved method wherein permanent, final and approximately

total separation of unstable reservoir distillate gas and crude oil takes place at the bottom of the well, in the immediate locality of the producing formation, thus segregating the unstable distillate gas from the oil at temperatures and pressures which do not permit appreciable condensation of the distillate gas, whereby the dilution of the crude oil by distillate condensate is minimized and at the same time, approximately the full initial condensate content of the unstable distillate gas entering the well bore remains preserved in the upward flowing gas stream.

A further object of the invention is to provide an improved method wherein the major portion of the distillate gas is separated from the crude oil in the immediate vicinity of the producing formation, or at the bottom of the well, and conducted to the top of the well and discharged therefrom with only such pressure drop or loss as is incidental to its travel up the well, whereby such gas may be delivered for processing, or other handling, on the surface, at such high pressures as to make for economic recompression of the residual gas for returning it to the subsurface or otherwise; at the same time utilizing a relatively small quantity of the gas for flowing the crude oil to the top of the well.

Another object of the invention is to cause such condensates as may be condensed from the gas during its travel up the well, due to natural cooling and pressure drops, to remain entrained with the gas and to be discharged from the well head therewith, thus preventing gravitation of such condensates to the bottom of the well and their admixture and production with the crude oil.

A particular object of the invention is to provide an improved method of flowing wells of the high gas-oil ratio type, wherein the distillate gas is conducted from the producing stratum or zone to the surface approximately without segregation, diversion or appreciable loss of any of the condensate vapors, whereby said gas is delivered to the surface with approximately the same total components which said gas contained at the point of entry into the well bore from the stratum.

Still another object of the invention is to provide an improved apparatus for carrying out the foregoing method including a dual conductor having an outer gas conducting pipe with gas inlet openings at its lower end and an inner oil conducting pipe extending through and below the gas conductor and having an oil inlet which is spaced a sufficient distance from the gas inlet to provide an adequate separating zone below said inlet.

A further object of the invention is to provide an improved apparatus which is so constructed that the distillate gas is conducted upwardly to the surface at a velocity which is sufficient, even at restricted rates of production, to prevent gravity precipitation of the condensates downwardly to the bottom of the well and other ultimate admixtures with the oil thereat; and also whereby condensates which might gravitate in the conductor are prevented from flowing therefrom into the separation zone and are thus trapped in the line of flow and ultimately discharged with gas streams.

A construction designed to carry out the invention will be hereinafter described, together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawing, in which an example of the invention is shown, and wherein:

Figure 1 is a transverse, vertical, sectional view of an apparatus for carrying out the method, and

Figure 2 is a horizontal, cross-sectional view taken on the line 2—2 of Figure 1.

In carrying out the method, there may be installed in the well, a dual conductor string 10, preferably in concentric form, as shown in the drawing. The string includes an inner smaller or lesser diameter pipe 11 which extends preferably below the liquid level in the reservoir or well bore, and as near to the bottom of the well as possible, as indicated in the drawing. The larger or outer diameter pipe 12 of the dual conductor serves to surround or jacket concentrically the smaller pipe but extends into the well at a point of lesser depth or higher elevation than that of the liquid or smaller conductor pipe; the base of the gas conductor tubing being located preferably 100 to 200 feet above the uppermost point at which the reservoir gas enters the well bore from the formation, but such distance is subject to considerable variation. When installed ready for operation, the larger diameter or outer pipe of the dual conductor string is supported from the casing head 13 of the well, and the smaller or inner pipe is, in turn, supported by the tubing head 14 which may be a continuation of the outer conductor pipe of the dual conductor. The inner pipe 11 will be referred to hereinafter as the oil pipe or tubing, while the outer pipe 12 will be designated as the gas pipe or conductor.

At the lower end of the gas pipe 12, a seat 15 is provided which receives a collar 16 fastened on the oil pipe 11, for partially supporting the oil pipe so that the entire weight of the smaller liquid conductor pipe shall not at all times be in tension from its surface support, as is conventional, but will be given partial tension relief due to the supporting ability of the gas conductor pipe. Oftentimes, when inner oil tubing is swung in tension, in great lengths, it may part at some point within the well and create a difficult mechanical recovery problem; whereas if it may be partly supported near the bottom, and at the same time confined within the larger of the two pipes of the dual conductor string, it would, therefore, be very easy to recover if for any reason it should part. Shortly above the seat 15, the outer gas pipe 12 is provided with inlet openings or ports 18 for admitting gas from the casing.

When the dual conductor is installed in the well and the well subsequently placed on production at relatively low rates of flow, as for example, one to two million cubic feet of gas daily, accompanied by some forty to fifty barrels of crude oil, it will be observed that under the existing high bottom hole pressures, a gas volume of say one to two million cubic feet daily, may travel upwardly within the well bore and the normal size well casing 17 at a low velocity; however, such flow will not have the ability to carry upwardly the crude oil liquid which entered the well bore with the gas from the formation. The gas, on rising upwardly through the well bore and through the extreme lower portion of the well casing to the point of entry near the base of the outer or larger pipe 12 of the dual conductor, will undergo little or no change in either temperature or pressure since it is still in the immediate locality of the formation from which it came. Since the well casing 17 is stop-cocked or shut in at the surface, the upwardly flowing gas is trapped or stored in the well casing and

can only enter the outer or larger member of the dual conductor. In passing from the casing chamber into that of the gas conductor pipe 12, the gas must pass through the restricted openings 18 near the base of the gas conductor pipe and then continue to flow upwardly in this larger member of the dual conductor. While in upward transit in the gas pipe 12, condensation from the vapor phase will take place due to a drop in temperature and pressure, as all high pressure distillate gases do when subjected to lowering of pressure and temperature. However, since the cross-sectional area of the pipe 12 is less than the cross-sectional area of the casing, velocities within the gas conductor pipe are much higher than velocities would be for the same volume of gas moving through the casing. Therefore, the liquids condensed from the gas within the pipe 12 are entrained and carried upwardly with the flowing gas stream because of the ability of the higher velocity to overcome the effect of gravity separation or precipitation of the condensates. Even though at times the velocity in this conductor tubing may fall below that necessary to produce continuous lifting of the liquids upwardly as they condense, in which case some liquids would, therefore, precipitate by gravity and fall downward toward the base of the gas conductor pipe, they could not reenter the well casing chamber, since the relatively high velocity through the openings 18, at the base of the gas pipe would prohibit any reverse passage. Only a limited amount of gravity precipitation can occur within the gas pipe since the sustained pressure of the upwardly flowing gas will, in a short time, lift the precipitated condensates in the form of a "head" or other temporary, irregular flow. Although the restricted ports 18 are preferably used, any means of preventing back flow into the casing may be employed.

On arriving at the surface the gas and its accompanying liquid particles, which latter were produced by condensation, would arrive under a very high pressure and could be processed for their products, and the residue gas cheaply recompressed and returned to the same formation very economically. At relatively restricted rates of oil and distillate gas production, with the type of installation shown in the drawing, the liquids entering the well bore from the formation, practically all of which would be the crude oil, can only enter the small conductor tubing 11 at its base. This crude oil will be accompanied by a limited amount of reservoir gas, either the gas naturally in solution in the oil and possibly small amounts of the free gas, and this limited volume of gas, together with its accompanied crude oil, will be conducted upwardly to the surface within the smaller oil pipe 11 of the dual conductor. It is pointed out that the size or area of each liquid inlet port of the small pipe 11, is subject to variation so as to restrict the volume of free gas which may also enter the pipe 11 with the oil. The liquid flowing upwardly through the pipe 11 will arrive at the surface at a relatively low pressure, due to the relatively small amount of gas which, latter, because of its relatively small volume, with respect to the oil may be disposed of in any legal manner, such as burning in flares or for lease gas operations, or otherwise. When operated in the manner described, the device shown in the drawing converts the lower portion of the well bore into a gravity type separating zone or chamber wherein liquids may gravitate downwardly to the liquid level and the gas allowed to freely separate and travel upwardly into a segregated channel such as the larger of the pipes of the dual conductor. Oftentimes, the situation arises wherein in reservoirs of this type, one party may own distillate gas rights in place, while another party owns the oil rights in place in the reservoir, and it becomes necessary to produce both products simultaneously through the same well. With the apparatus and method disclosed herein, this is readily and efficiently accomplished.

It will be noted that approximately all of the gas confined to that portion of the casing lying above the point of entry near the base of the gas conductor string, is substantially in a static condition, when the surface casing controls are closed. The casing gas could be packed off around the gas conductor and the gas in the lower portion of the hole confined below such packing but the apparatus would still operate as described. However, the arrangement shown in the drawing is preferred. If, for any reasons, surface operations resulted in a sudden increase in the rate of flowing gas from the well there would be a tendency for the liquids and gas, due to the sudden increase in velocity, to migrate upwardly together with a tendency for both oil and gas to enter the gas conductor string. Due to the fact that a large volume of high pressure gas is present at all times within the casing and is immediately available and having ready access at the point of entry into the gas conductor string, this gas would, of necessity, compensate any abnormal flow, and in that way prevent the rise, or tendency to rise, of the oil with the gas and increase of its flow from the bottom of the hole.

The casing head 13 may be provided with the usual outlet branches 19 having valves 20 therein, which are closed when the well is in operation. Branches 21 equipped with valves 22 extend from the tubing head 14. The oil tube 11 extends through the head 14 and connects with a lateral pipe 23 which includes a valve 24.

It is obvious that by separating the major portion of the gas at the bottom of the well and flowing the gas up the well, with only the impedance offered by the flow conductor, such gas is delivered with a minimum loss in pressure. Also such liquefiable fractions which are present in the gas, and particularly those which will condense in transit up the well, are delivered with the gas from the well head. A gas or gaseous stream so acquired has many advantages. Such a stream is particularly advantageous when utilized in methods such as are set forth in Patent No. 2,080,351 of which I am co-patentee, and an application filed by Jay P. Walker and myself March 23, 1939, Serial No. 263,658, as well as various other methods wherein advantages is taken of retrograde condensation and cooling.

The base of the gas tube 12 is sufficiently above the formation to create a separating chamber of such volume as to give the liquids full opportunity to separate from the gas and gravitate to the bottom of the well bore.

From the foregoing, it will be manifest that a separating zone is formed between the inlets 18 of the gas conductor and the inlets of the oil tubing. This zone is located in the immediate vicinity of the producing stratum or reservoir and therefore, separation of the gas and oil takes place under substantially the pressure and temperature conditions of the reservoir. Under such conditions, substantially no condensation of the

condensable vapors in the gas occurs, with the result that said vapors remain in the gas and enter the gas conductor 12 with said gas. This reduces to the practical minimum, condensation of the condensable vapors prior to their entry into the gas conductor 12 and thus; dilution or contamination of the crude oil by such condensates is likewise reduced to the practical minimum, and assures delivery of the maximum of such vapors and condensates with the gas. The cross-sectional area of the gas conductor 12 is such that the upwardly flowing gas stream will have sufficient velocity to maintain the condensates entrained therein, and thus ultimately deliver the said condensates to the surface with the gas.

It is pointed out that under some well conditions, a surging or heading of the flow of crude oil in the oil tubing 11 might occur and, if desired, a stabilizer port 25 may be provided in the oil tubing below the gas conductor 12. This port is preferably located immediately below the base of the gas conductor, as illustrated, but it may be at any point in the tubing between said gas conductor and the oil inlet at the lower end of said tubing 11. The port is relatively small and permits only a restricted amount of gas to flow from the separation zone into the oil tubing, such restricted flow being continuous at all times. This continuous admittance of a small volume of gas serves to steady the flow of oil through the tubing 11 and reduces heading or surging thereof. The port 25 is not essential to the invention and may be omitted without effecting the operation of the apparatus or the practice of the method, as herein disclosed.

The valves 22 and 24 may be of any type suitable for use in this method, as for instance, they may be regulating or choke valves for controlling or regulating the flow from the two conductors or one of them, or for reducing the pressure of the flow. It is to be understood that any water or other liquids entering the well bore will be separated and produced in the same manner as the crude oil.

What I claim and desire to secure by Letters Patent, is:

1. The method of flowing high pressure oil and gas wells from subsurface reservoirs wherein the gas which is under pressures and at temperatures within the range of retrograde condensation overlies the oil and is in contact therewith which includes, separating the oil from the major portion of the gas at the bottom of the well with substantially no precipitation from the gas of condensible components, whereby the oil is segregated from the gas and its condensible content, conducting the oil up the well in a segregated path, and conducting the separated gas up the well in a path separate from the oil while maintaining the condensible content entrained therewith.

2. The method of flowing high pressure oil and gas wells from subsurface reservoirs wherein the gas which is under pressures and at temperatures within the range of retrograde condensation overlies the oil and is in contact therewith which includes, separating the oil from the major portion of the gas at the bottom of the well with substantially no precipitation from the gas of condensible components, whereby the oil is segregated from the gas and its condensible content, conducting the oil up the well in a segregated path, and conducting the separated gas up the well in a path separate from the oil and under such velocity as to maintain the condensate in suspension in the gas stream, whereby the gas is delivered to the surface with substantially all of its condensates entrained therein and the oil is delivered to the surface substantially free from such condensates.

3. The method of flowing high pressure oil and gas wells from subsurface reservoirs wherein the gas which is under pressures and at temperatures within the range of retrograde condensation overlies the oil and is in contact therewith which includes, separating the oil from the major portion of the gas at the bottom of the well with substantially no precipitation from the gas of condensible components, whereby the oil is segregated from the gas and its condensible content, storing gas above the point of oil and gas separation for providing a static body of gas for compensating abnormal flows of gas from the formation, conducting the oil up the well in a segregated path, and conducting the separated gas up the well in a path separate from the oil while maintaining the condensible content entrained therewith.

4. In an apparatus for flowing high pressure oil and gas wells wherein distillate gas at pressures and temperatures within the range of retrograde condensation overlies crude oil, the combination of, means for shutting in the well to trap gas, an oil string extending up the well from the lower portion of the formation through said means, and a gas string surrounding the oil string and having its upper end extending through said means, the lower end of the gas string terminating a substantial distance above the top of the formation, whereby a gas and oil separation zone between the lower end of said gas string and the top of the oil formation is provided.

5. An apparatus for flowing high pressure oil and gas as set forth in claim 4 wherein the gas string is provided with a restricted gas inlet at its lower end for maintaining a high velocity gas inlet to the string.

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