Aug. 20, 1968 C. W. OWENS ET AL 3,397,745

VACUUM-INSULATED STEAM-INJECTION SYSTEM FOR OIL WELLS

Filed March 8, 1966

FIG. 1.

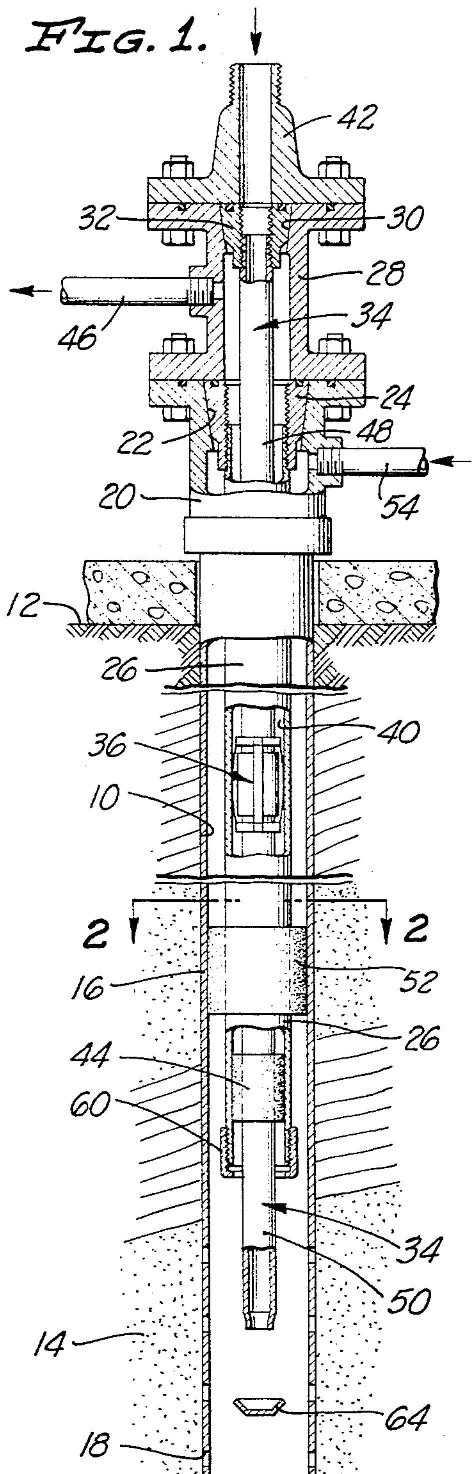


FIG. 2.

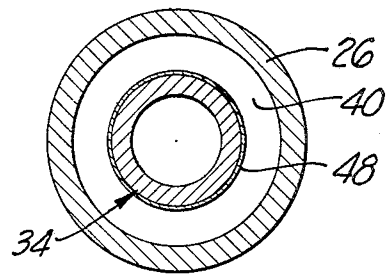


FIG. 3.

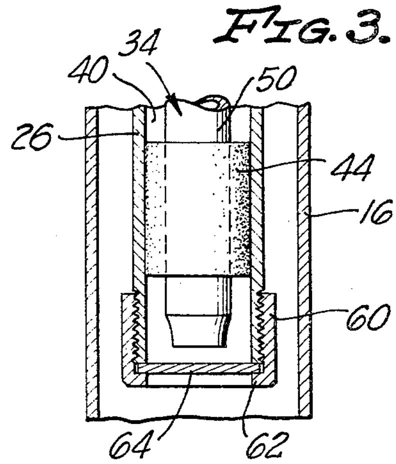
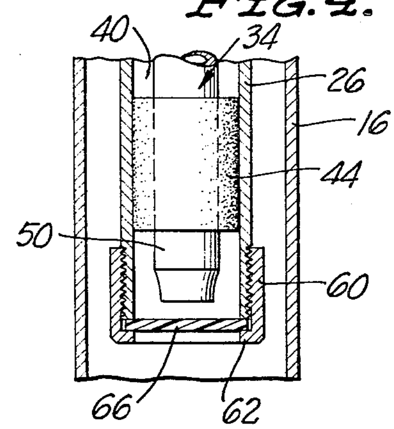


FIG. 4.



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VACUUM-INSULATED STEAM-INJECTION SYSTEM FOR OIL WELLS

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ABSTRACT OF THE DISCLOSURE

In an apparatus for delivering a heated fluid to a subterranean productive formation having a well drilled thereinto, the combination of an inner, injection tubing in the well and communicating at its lower end with the productive formation, an outer, insulating tubing surrounding said injection tubing and having an inside diameter greater than the outside diameter of said injection tubing to provide a space between said insulating and injection tubings, means closing the upper and lower ends of said space, means connected to the upper end of said injection tubing for introducing a heated fluid thereinto, means connected to the upper end of said space for at least partially evacuating same, said means closing the lower end of said space including packer means carried by the lower portion of one of said tubes and slidably engaging and sealing with the other of said tubes to accommodate relative longitudinal expansion and contraction of said tubings, and means maintaining the tubings in radial spaced relationship.

The present invention relates in general to increasing the production of wells drilled into subterranean formations containing materials the fluidities of which can be increased by the application of heat thereto. More particularly, the invention relates to injecting heated fluids into the subterranean productive formations to increase the fluidities of the materials therein which are to be produced.

The invention is particularly applicable to increasing the production of oil wells drilled into subterranean productive formations containing heavy, i.e., viscous, crudes. By injecting steam at high temperatures and pressures into heavy crude formations, the viscosities of the crude oils therein frequently can be reduced sufficiently to increase production materially. Consequently, the invention will be considered in such an environment herein for convenience.

Stimulation of crude oil production by steam injection is currently carried out in two different ways. In accordance with one practice, steam at high temperature and high pressure is injected into the productive formation continuously from a central injection well. Concurrently, the formation is produced from production wells spaced outwardly from the injection well. The high temperature and high pressure steam introduced into the formation through the injection well in accordance with this practice not only heats the oil in the formation to reduce its viscosity, but also drives it outwardly away from the injection well and toward the production wells.

In accordance with another current practice, commonly referred to as "push-pull" steam injection, high pressure and high temperature steam is injected into the formation from a well drilled thereinto for a matter of days or even weeks. After the desired quantity of steam has been injected, the well may be permitted to "soak" for

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several days to provide time for the heat from the injected steam to penetrate the formation substantial distances, and thus reduce the viscosity of the oil therein. Subsequently, the well is produced, usually by pumping, and achieves materially increased production rates as the result of the reduction in the viscosity of the oil achieved by the heat from the injected steam. Frequently, materially higher production rates are maintained for several months or more. Ultimately, when production falls off excessively, this push-pull injection technique can be repeated.

The present invention may be utilized to inject steam into an oil producing formation in accordance with either of the injection and production techniques hereinbefore discussed.

When steam is injected into an oil producing formation in accordance with practices currently in use, the steam flowing downwardly through an injection tubing in the well loses a tremendous amount of heat, primarily through radiation from the injection tubing, before it ever reaches the level of the subterranean productive formation into which it is to be injected. A typical heat loss is 200,000 B.t.u. per hour per foot of injection tubing. Since the injection tubing may be several thousand feet long, it will be apparent that the hourly heat loss can amount to many million B.t.u.

Not only is the foregoing heat loss highly undesirable from the economic point of view, but it can also result in serious damage to the well. For example, in most wells, various fluid-bearing formations are cemented off to prevent entry into the well of undesirable fluids, such as water. The cement utilized to seal off such formations ultimately deteriorates, from the effects of heat radiated by conventional steam injection tubings, to such an extent that it is no longer effective, thereby permitting the entry into the well of undesired fluids.

With the foregoing as background, the primary object of the present invention is to minimize heat losses from the injection tubing, thereby resulting in substantial economic savings and minimizing well damage.

More particularly, an important object of the invention is to minimize heat losses from the injection tubing by maintaining at least a partial vacuum around the injection tubing, preferably throughout substantially its entire length.

Still more particularly, an important object of the invention is to provide an injection system wherein an outer, insulating tubing surrounds the injection tubing, preferably throughout substantially the entire length of the injection tubing, and wherein at least a partial vacuum is maintained in the space between the injection and insulating tubings to provide a heat insulating barrier minimizing heat losses from the injection tubing. With this construction, the heat losses from the injection tubing can be held to but a small percentage of the heat losses from an uninsulated injection tubing, which is an important feature of the invention.

Considering the present invention more specifically now, important objects thereof are to provide an injection system which includes: an inner, injection tubing in the well and communicating at its lower end with the productive formation; and outer, insulating tubing surrounding the injection tubing and having an inside diameter greater than the outside diameter of the injection tubing to provide a space between the insulating and injection tubings; means closing the upper and lower ends of such space; means connected to the upper end of the injection tubing for introducing steam, or other heated fluid, thereinto; and means connected to the upper end of the space between the two tubings for at least partially evacuating such space. Preferably, the injection system includes means for substantially centering the injection tubing within the insulating tubing in radial directions so as to make the space between the insualting and injection tubings substantially an annular space or annulus.

An important object of the invention is to provide an injection system for the foregoing nature wherein at least one of the tubings is provided with a reflective coating to further minimize heat losses from the injection tubing. A related object is to provide the outer surface of the injection tubing with such a reflective coating.

Another important object is to provide packer means, for closing the lower end of the annulus between the injection and insulating tubings, which is carried by the insulating tubing and relative to which the injection tubing is axially slidable to accommodate axial expansion and contraction of the injection tubing. In this connection, it might be pointed out that the injection tubing may lengthen many feet as its temperature increases upon the introduction of high temperature steam into the upper end thereof, such axial expansion being accommodated by the packer means mentioned.

Another object is to provide means for confining the steam discharged from the lower end of the injection tubing to the zone of the well opposite the productive formation to be injected. Related objects are to provide a confining means which includes a packer carried by the lower end of the insulating tubing and engaging the wall of the well, or includes means for introducing a fluid under pressure between the insulating tubing and the wall of the well.

Another object of the invention is to provide removable closure means for temporarily closing the lower end of the insulating tubing until such time as the lower end of the injection tubing is inserted through the packer means for closing the lower end of the annulus between the insulating and injection tubings. With this construction, entry of well fluid into the interior of the insulating tubing is prevented, which is desirable since such well fluid might interfere with developing at least a partial vacuum in the annulus between the two tubings, damage the reflective external coating on the injection tubing, and the like.

Another object is to at least partially fill the interior of the injection tubing with water, or other suitable liquid, after running it through the packer means for closing the lower end of the annulus between the injection and insulating tubings, and before removal of the temporary closure means at the lower end of the insulating tubing, so as to prevent a pressure surge within the injection tubing upon removal of the temporary closure means at the lower end of the insualting tubing.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the well injection art in the light of this disclosure, may be achieved with the exemplary embodiments describėd in detail hereinafter and illustrated in the accompanying drawing, in which:

FIG. 1 is a vertical sectional view of an oil well having installed therein a steam-injection system embodying the invention;

FIG. 2 is an enlarged, horizontal sectional view of the steam-injection system of the invention which is taken as indicated by the arrowed line 2—2 of FIG. 1; and

FIGS. 3 and 4 are enlarged, fragmentary, vertical sectional views showing alternative removable closures for temporarily closing the lower end of an insulating tubing forming part of the injection system of the invention.

Referring to FIG. 1 of the drawing, illustrated therein is a well or well bore **10** drilled from the surface **12** (which may be a submerged surface) downwardly into an oil producing formation **14**. In the particular installation illustrated, the well **10** is shown as provided with a casing **16** having performations **18** opposite the productive formation **14**.

Surmounting and connected to the upper end of the casing **16** is casing head **20** which provides a tapered seat **22**. Engaging the tapered seat **22** is a tapered collar **24** from which is suspended an insulating tubing **26** terminating adjacent the top of the productive formation **14**.

Surmounting the casing head **20** is a tubing head **28** provided with a tapered seat **30**. Engaging the tapered seat **30** is a tapered collar **32** from which is suspended an injection tubing **34** disposed within the insulating tubing **26**. When the injecting system of the invention is in operation, the injection tubing **34** preferably projects below the lower end of the insulating tubing **26** into the productive formation **14**.

As is conventional in oil well tubings, the insulating and injection tubings **26** and **34** are made up of tubing sections suitably interconnected in end-to-end relation, as by means of couplings, not shown. It will be understood that the insulating and injection tubings **26** and **34** may be thosuands of feet in length.

The insulating tubing **26** is preferably substantially coextensive, lengthwise, with the injection tubing **34**. In other words, the insulating tubing **26** extends substantially from the upper end of the injection tubing substantially to the lower end thereof.

The injection tubing **34** is preferably radially centered within the insulating tubing **26** by means of suitable centering devices, one of which is designated in FIG. 1 by the numeral **36**, spaced apart vertically along the length of the injection tubing. These are conventional centering devices carried by the injection tubing **34** and engaging the insulating tubing **26**. Their function is to maintain an annular space or annulus **40** between the insulating and injection tubings **26** and **34** to minimize heat conduction from the injection tubing to the insulating tubing. To provide an indication of the radial dimensions of the annulus **40**, the insulating tubing **26** may be three-inch tubing and the injection tubing **34** may be two-inch tubing. However, other tubing sizes may be used.

When the injection system of the invention is in operation, steam at high temperature and high pressure from any suitable source is introduced into the upper end of the injection tubing **34** through a suitable fitting **42**. The steam flows downwardly through the injection tubing **34** and is discharged from the lower end of the injection tubing into the well **10** adjacent the productive formation **14**. As hereinbefore discussed, the steam penetrates the productive formation **14** to heat the oil therein, thereby rendering the oil less viscous.

In order to minimize radially outward heat losses from the injection tubing **34** intermediate its upper and lower ends, at least a partial vacuum is maintained in the annulus **40** between the insulating and injection tubings **26** and **34**. Considering how this is accomplished, the upper end of the annulus **40** is closed by seating of the tapered collars **24** and **32** on the respective tapered seats **22** and **30**. The lower end of the annulus **40** is closed by a packer means or packer **44** through which the injection tubing **34** extends. The upper end of the annulus **40** is connected to a suitable source of vacuum, not shown, as by means of a vaccum line **46** connected to the tubing head **28** in communication with the upper end of the annulus **40**. For example, the vacuum line **46** may lead to a suitable vacuum pump, not shown. Preferably, the vacuum source is operated continuously to compensate for any leaks in the system.

Preferably, a vacuum of the order of 25 inches of mercury, or more, is maintained in the annulus **40**, although this may be varied without departing from the spirit of the invention. With a vacuum in the annulus **40** of this order of magnitude, heat losses by radiation and conduction from the injection tubing **34** are greatly reduced, which is an important feature of the invention.

To further reduce heat losses from the injection tubing, the injection system is provided with one or more highly reflective coatings for reflecting radiated heat back into the injection tubing **34**. While more than one reflective coating may be used, and while such coatings may be applied to various of the surfaces of the insulating and injection tubings **26** and **34**, it is preferable, as a practical matter, to utilize a single reflective coating **48** on the external surface of the injection tubing **34**. The reflective coating **48** may be made of such materials as aluminum (foil or anodized), chromium, silver, or gold. In many instances, the coating material may be plated on the external surface of the injection tubing.

The combined actions of the partial vacuum in the annulus **40** and the reflective coating **48** on the injection tubing **34** greatly reduce heat losses from the insulating tubing **26**. For example, heat loss reductions of in excess of 90% may be achieved with the invention, thereby providing substantial economic savings and minimizing possible damage to the well, which are important features.

Because of the high steam temperatures used in oil-well steam injection, the injection tubing **34** may expand many feet in length upon the introduction of steam thereinto. To allow for such axial expansion, the injection tubing **34** has a sliding fit with the packer **44**. To minimize wear as the injection tubing **34** slides relative to the packer **44** in expanding and contracting, the injection tubing preferably includes a lower section **50** havinga polished external surface. The length of such lower section is sufficient to accommodate the entire range of axial expansion and contraction of the injection tubing **34**.

The invention provides means for confining the injected steam in a zone of the well **10** opposite the productive formation **14**. Such confining means may include a conventional packer **52** carried by the insulating tubing **26** adjacent the lower end thereof and engaging the wall of the well **10**, i.e., the casing **16** in the construction illustrated. Alternatively, the upward escape of injected steam into upper zones of the annulus between the insulating tubing **26** and the casing **16** may be prevented by pressurizing such annulus with fluid under pressure through a line **54** connected to the casing head **20** in communication with the upper end of the annulus in question. Preferably, the fluid utilized to pressurize the upper portions of the annulus between the casing **16** and the insulating tubing **26** is an inert gas, such as nitrogen, to prevent possible subterranean combustion.

In running the insulating and injection tubings **26** and **34** into the well **10**, it is preferable to run the tubing **26** first, and then run the injection tubing **34**. As the injection tubing **34** is run in, the lower section **50** thereof ultimately enters the packer **44**, as shown in the drawing.

In accordance with the invention, the lower end of the insulating tubing **26** is temporarily closed until such time as the lower section **50** of the injection tubing **34** engages the packer **44** to close the lower end of the annulus **40**. The reason for this is to prevent the entry of any fluids in the well **10** into the interior of the insulating tubing **26** since such fluids might interfere with developing the desired vacuum in the annulus **40**, corrode the reflective coating **48**, and the like.

Referring to FIG. 3 of the drawing, the lower end of the insulating tubing **26** is shown as having threaded thereon a collar **60** terminating in an inwardly directed annular flange **62**. Clamped between the flange **62** and the lower end of the insulating tubing **26** is a disc **64** which may be suitably sealed, not shown, to exclude fluids from the interior of the insulating tubing. The disc **64** is provided with sufficient strength to withstand an external pressure due to a head of fluid in the well **10**. However, the strength of the disc **64** is insufficient to withstand the weight of the injection tubing **34** and any load which may be added to the upper end thereof. Consequently, when the lower end of the lower section **50** of the injection tubing **34** passes through the packer **44** and

engages the disc **64**, it deforms the disc sufficiently to withdraw the periphery of the disc from between the flange **62** and the lower end of the insulating tubing **26**. The deformed disc **64** then drops to the bottom of the well **10**, as suggested in FIG. 1 of the drawing.

FIG. 4 of the drawing illustrates a similar structure utilizing a disc **66** of thermoplastic material having sufficient strength at normal temperatures to withstand any external pressure due to a head of liquid in the well **10**. However, after exposure to bottom hole temperatures for a time, the disc **66** softens sufficiently to release itself, assuming the bottom hole temperatures are sufficiently high for this purpose. If not, it can be knocked out by means of the injection tubing **34**, or the structure of FIG. 3 can be used.

After the injection tubing **34** has been inserted through the packer **44**, it is preferably filled with water, or other suitable liquid, at least approximately to the level of any liquid in the wall **10**, this being done prior to removing the temporary closure at the lower end of the insulating tubing **26**. The purpose of this is to prevent any sudden surge of liquid upwardly in the injection tubing **34** upon removal of the closure at the lower end of the insulating tubing **26**, which surge might have undesirable shock effects.

Although exemplary embodiments of the invention have been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions can be incorporated in such embodiments without departing from the spirit of the invention as defined by the claims which follow.

What is claimed is:

1. In an apparatus for delivering a heated fluid to a subterranean productive formation having a well drilled thereinto, the combination of:

(a) an inner, injection tubing in the well and communicating at its lower end with the productive formation;

(b) an outer, insulating tubing surrounding said injection tubing and having an inside diameter greater than the outside diameter of said injection tubing to provide a space between said insulating and injection tubings;

(c) means closing the upper and lower ends of said space;

(d) means connected to the upper end of said injection tubing for introducing a heated fluid thereinto;

(e) means connected to the upper end of said space for at least partially evacuating same;

(f) said means closing the lower end of said space including packer means carried by the lower portion of one of said tubes and slidably engaging and sealing with the other of said tubes to accommodate relative longitudinal expansion and contraction of said tubings; and

(g) means maintaining the tubings in radial spaced relationship.

2. An injection system according to claim **1** wherein said means maintaining the tubings in radial spaced relationship includes longitudinally spaced centering devices carried by the injection tubing and slidably engaging the insulating tubing to center said injection tubing within said insulating tubing and out of heat conducting contact therewith.

3. An injection system as defined in claim **1** wherein said packer means closes the lower end of said annular space.

4. An injection system according to claim **1** wherein said injection tubing is provided with a heat reflective jacket about its exterior.

5. An injection system as defined in claim **1** wherein said well is provided with a casing having perforations where it extends into the productive formation, said insulating tubing having a packer spaced above its lower end to seal between said insulating tubing and the casing above the perforations to prevent the flow of heated fluid upwardly in the well about the insulating tubing.

6. An injection system according to claim 1 wherein said insulating tubing is adapted to be first arranged in the well and said injection tubing is adapted to be subsequently engaged through the injection tubing, a removable closure means carried by the lower end of said insulating tubing for temporarily closing same preparatory to engagement of the injection tubing therethrough and including a deformable closure disc extending transverse the insulating tubing and adapted to be engaged and displaced by the lower end of the injecting tubing.

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