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CA 2419325 C 2008/05/06

(11)(21) 2 419 325

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 2003/02/17
(41) Mise à la disp. pub./Open to Public Insp.: 2003/08/18
(45) Date de délivrance/Issue Date: 2008/05/06
(30) Priorité/Priority: 2002/02/18 (CA2,372,360)

(51) Cl.Int./Int.Cl. *E21B 43/24* (2006.01), *E21B 43/30* (2006.01)

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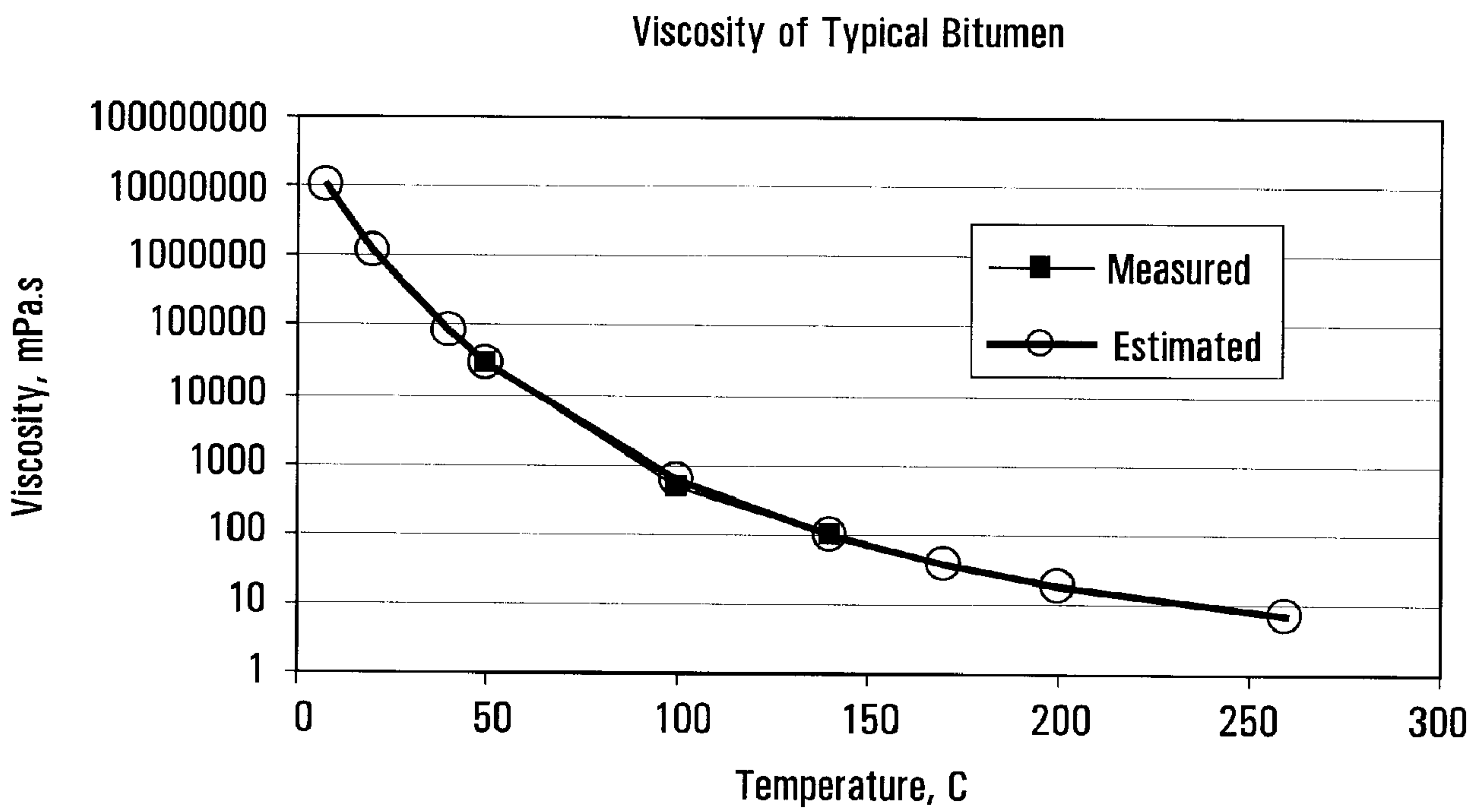
(54) Titre : PROCEDE DE DRAINAGE ASSISTE PAR CHAUFFAGE PAR CONDUCTION POUR RECUPERER DU PETROLE LOURD ET DE L'ASPHALTE

(54) Title: CONDUCTION HEATING AIDED DRAINAGE PROCESS FOR THE RECOVERY OF HEAVY OIL AND BITUMEN



(57) Abrégé/Abstract:
A process for the recovery of viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir or formation includes the step of transmitting heat into the reservoir by closed loop circulation of a hot fluid heat transfer medium through slanted wells (up-dip or down-dip) placed inside the reservoir, thus indirectly heating the reservoir matrix and thereby causing a significant viscosity reduction in the reservoir fluids viz. heavy oil and bitumen, which drain by gravity to the flow conduit in the slanted well. This oil and bitumen flows through and along the slanted well to the heel (for the up-dip well) or to the toe (for the down-dip well) or to a vertical or horizontal producer hole drilled near the toe of the down-dip slanted well. As the heavy oil and bitumen comes in contact with the high temperature closed loop heating in the slanted well, lighter components of the heavy oil and bitumen are

(57) Abrégé(suite)/Abstract(continued):
vaporized. These vaporised lighter components move into the colder section of the reservoir and are capable of causing viscosity reduction when redissolved in the heavy oil and bitumen. This provides an additional benefit of solvent dilution effect in the drainage process. Vaporized lighter components (as described above) and vaporized connate water create a convection current in the reservoir matrix and increase the heat transfer which in turn enhances the extraction rate. The accumulated oil at the heel or toe of the slanted well or at the vertical or horizontal producer well is produced to the surface using either natural or artificial lifts.

Abstract

A process for the recovery of viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir or formation includes the step of transmitting heat into the reservoir by closed loop circulation of a hot fluid heat transfer medium through slanted wells (up-dip or down-dip) placed inside the reservoir, thus indirectly heating the reservoir matrix and thereby causing a significant viscosity reduction in the reservoir fluids viz. heavy oil and bitumen, which drain by gravity to the flow conduit in the slanted well. This oil and bitumen flows through and along the slanted well to the heel (for the up-dip well) or to the toe (for the down-dip well) or to a vertical or horizontal producer hole drilled near the toe of the down-dip slanted well. As the heavy oil and bitumen comes in contact with the high temperature closed loop heating in the slanted well, lighter components of the heavy oil and bitumen are vaporized. These vaporised lighter components move into the colder section of the reservoir and are capable of causing viscosity reduction when redissolved in the heavy oil and bitumen. This provides an additional benefit of solvent dilution effect in the drainage process. Vaporized lighter components (as described above) and vaporized connate water create a convection current in the reservoir matrix and increase the heat transfer which in turn enhances the extraction rate. The accumulated oil at the heel or toe of the slanted well or at the vertical or horizontal producer well is produced to the surface using either natural or artificial lifts.

CONDUCTION HEATING AIDED DRAINAGE PROCESS FOR THE RECOVERY OF HEAVY OIL AND BITUMEN

SPECIFICATION

Field of the Invention

This invention relates to a process for the recovery of high viscosity hydrocarbon resources from subterranean hydrocarbon bearing reservoirs by heating the reservoir through conduction and convection using a special well configuration.

References of Interest

1. Butler, R.M., "Method for Continuously Producing Viscous Hydrocarbons by gravity Drainage while Injecting Heated Fluid", Canadian Patent 130,201, August 24, 1982, US patent 4,344,485, Aug 17, 1982.
2. Das, S.K., "In Situ Recovery of Heavy Oil and Bitumen Using Vaporized Hydrocarbon Solvents", Ph.D. Thesis, University of Calgary, 1995.
3. Nzekwu, B.I., Sametz, P.D. and Pelensky, P.J., "Single Horizontal Wellbore Gravity Drainage Assisted Steam Flooding Process", US patent 5,626,193, May 6, 1977.
4. Process for Recovery of Extremely Shallow Heavy Oil – W. Terry Osterloh and Jeff Jones, SPE Western Regional Meeting, Bakersfield, CA, 2001.
5. Mitigation of Fouling in Bitumen Furnaces by Pigging – Richard J. Parker and Richard A. McFarlane – AIChE Spring National Meeting, Houston, TX, 1999.
6. Canadian Patent Applications Serials Nos. 2,281,276 and 2,304,938 filed August 31, 1999 and April 10, 2000 in the name of Suncor Energy Inc.

Background of the Invention

Highly viscous hydrocarbons, known as heavy oil and bitumen, exist inside the fine pores of the subterranean porous formation, called the reservoir, buried a varying depth below the earth's surface. Although there is an enormous amount of resources potentially available in the form of heavy oil and bitumen, their high viscosities prevent their flow in the formation. The efficient extraction of these hydrocarbons out of the porous formation poses a challenge for conventional technologies.

These resources, especially bitumen, are also found in very shallow reservoirs. In some places it is very close to the earth's surface making if accessible to open pit mining. There currently are three major operations in Northern Alberta where this bitumen-laden sand is mined using open pit mining techniques. The mined oil sand is processed in a plant to separate the bitumen, which is then upgraded chemically to synthetic crude. For the mining operation the earth and clay on top of the sand body have to be removed before excavation of the oil sand. As the depth of the sand body increases more and more earth and clay need to be removed to access the sand body. These mining projects have an economic limit of overburden to oil sand thickness ratio, beyond which the mining operations are not viable.

In reservoirs deeper than 150 m, various in situ recovery techniques have been contemplated and are being attempted. The objective of these processes is to mobilize the bitumen inside the porous formation and allow it to flow to well hoes drilled inside the formation. The mobilized hydrocarbon is then brought to the surface and processed for its end use.

Depending on the reservoir temperatures and the type of resources, the mobility of the fluid varies. In large areas of the underground Alberta oil sand in Athabasca, the reservoir temperature is in the range of 10°C and the hydrocarbons in the formation are a few million times more viscous than water at ambient conditions. Under this reservoir condition the hydrocarbon has a thick, semi-solid appearance and is substantially immobile even outside the formation. In the heavy oil reservoirs the mobility is usually higher than at the Athabasca oil sand reservoirs; however, the conventional recovery techniques have been unsuccessful in recovering these resources. The high viscosity of these resources demands special recovery techniques.

The mobility of these hydrocarbons increases with increase in temperature. Based on this principle, various thermal recovery techniques have been applied for the recovery of these hydrocarbons. One of the successful processes, the steam assisted gravity drainage (SAGD) (Canadian Patent No. 130201, 1982), a steam based process using a pair of horizontal wells drilled into the reservoir and placed one vertically above the other, has been used successfully for the recovery of these high viscosity resources. In this process steam is injected in the upper well of the well pair. The injected steam condenses inside the reservoir and heats the formation and hydrocarbons. The hot mobilized oil and the condensed water drain to the lower horizontal well by gravity. This hot fluid is produced to the surface by natural or artificial lift. Heat transfer over a huge surface area along the edge of the steam chamber formed during the process and the gravity head are the key factors in achieving a high extraction rate in this process. Various other well configurations have also been attempted.

The viscosity of heavy oil and bitumen may also be reduced by injection of solvents into the reservoir. This forms the theoretical basis for any solvent recovery process. One of the published processes (named VAPEX) proposes injection of vaporized hydrocarbon solvents into the reservoir through an injector and the diluted oil due to its lower viscosity drains to a production well (Das, 1995 above). This process has so far been investigated in laboratory experiments and field pilot tests are expected to start in 2003. In the solvent-based extraction processes, the solvent recovery at the surface is crucial for the economic success of the process and requires significant capital investment.

A combination of heat and solvent has been visualized as a solution for this problem in the published patent application of Suncor Energy noted above. A near well bore heating mechanism in the production well is used to revaporize the solvent and the solvent vapour condenses at the solvent-bitumen interface inside the reservoir. This solvent action dilutes the oil that drains to the horizontal producer. Thus, the same solvent is utilized inside the reservoir. A small amount of make up solvent is injected through a horizontal producer. Production through these horizontal wells, especially in case of two or three phase flow situations, is quite complicated and it is difficult to maintain a gravity stable drainage process along the entire length (~ 1000 m) of the production well. Most of the time this may end up in solvent vapour bypassing (as it happens in the above-described steam process, SAGD).

All of the above prior art processes propose injection of one or more fluids into the reservoir for the extraction process. In a shallow reservoir the operating pressure limits the injection of high pressure steam or other fluids. Confinement of the injected fluid within the reservoir pattern and failure of the caprock pose serious challenges in this regard.

Osterloh et al. undertook a numerical investigation of conduction heating of a very shallow Californian heavy oil reservoir for indirect heating. Horizontal steam conductors are placed 10 ft apart and vertical producers are placed 40 ft apart. This may be viable in shallow (~100 ft deep) reservoirs where cheap drilling techniques can be applied. However, as depths become greater than 300 ft, the costs of drilling and completing multiple wells are considerably higher and may make the recovery process uneconomic.

Summary of the Invention

In accordance with an illustrative embodiment of the invention, there is provided a process for the recovery of viscous hydrocarbons from an underground hydrocarbon bearing formation or reservoir by application of indirect heating. Heat is transmitted into the reservoir by closed loop circulation of a hot fluid heat transfer medium through substantially slanted well portions (up-dip or down-dip) placed inside the reservoir, thus indirectly heating the reservoir matrix. (This eliminates the requirement for direct injection of fluid into the reservoir and thereby eliminates the need for confinement of any injected fluid). The heat is thus transferred to the formation matrix and the fluid contained therein. The heating causes a significant viscosity reduction of the heavy oil and bitumen in the reservoir. This hot low viscosity fluid drains by gravity to the flow conduit in the slanted well portion. This hot oil and bitumen flow through and along the slanted well portion to the heel (for the up-dip well) or to the toe (for the down-dip well) or to a vertical or horizontal producer hole drilled near the toe of the down-dip slanted well portion. The hot oil and bitumen flowing in a set of these substantially slanted well portions may drain to a horizontal producer that connects the lowest point on these slanted well portions. The horizontal producer acts as a gathering well. The hot oil and bitumen accumulated in this producer is pumped to the surface either by natural lift or suitable artificial lifts.

In a typical embodiment the slanted well, drilled down-dip from the heel is provided with the above-noted closed loop circulation heating arrangement. Steam or any other hot fluid is circulated through a pair of tubes defining the closed loop circulation heating system to transmit heat to the reservoir fluid without directly contacting the reservoir with steam thus providing what is (termed as indirect heating). Due to the indirect nature of the heating system, the return condensed water is not contaminated by reservoir fluids and does not require elaborate surface treatment for the purpose of recycling or disposal, thereby significantly reducing the required surface facilities. This also eliminates the operating pressure and temperature constraints, which are dictated by the fracture pressure of the formation. A high pressure and temperature heating fluid system may be used inside the closed loop system without subjecting the reservoir to the same high pressure.

As the heavy oil and bitumen come in contact with the high temperature closed loop heating tubes in the slanted well portions, lighter components of the heavy oil and bitumen are vaporized. These vaporized lighter components move into the colder sections of the reservoir and are capable of causing viscosity reduction when re-dissolved in the heavy oil and bitumen. This provides the additional benefit of solvent dilution effect in the drainage process. Vaporized lighter components and vaporized connate water create a convection current in the reservoir matrix and increase the heat transfer, which in turn enhances the extraction rate. To enhance the convection process it is desirable to pump and remove the fluid mobilized to the well to bring in more fluid and induce the convection by making room for vapor. Flow of colder bitumen through the heated zone will scavenge the heat counter current to the conduction process. However, this will increase the driving force for conductive heat transfer, the temperature difference, and unlike the stationary case the heat will tend to move further. Also, if heat does not move the flow will stop by itself thus reducing this heat scavenging. An equilibrium situation will be established through this process.

A considerable volume of the known bitumen resources are present at a depth of (~100 m), which is deeper than the current mining capability but shallower than the capability of the currently available in situ recovery technologies. The present Conduction Heating Assisted Drainage (CHAD) process is aimed at recovering these shallow non-mineable oil sand resources. Some of the conventional in situ recovery technologies using a pair of horizontal wells may not be applicable in these reservoirs due to the challenges presented in drilling horizontal wells in shallow reservoirs. Use of slanted wells, as in illustrative embodiments of the present invention, appears to be useful for recovering these reserves. In many of these shallow reservoirs, there is no competent cap rock for confinement and recovery methods involving injecting steam or solvent are not suitable for these resources. In the CHAD process the heat transfer fluids do not contact the reservoir directly. Hence, the operating reservoir pressure in a CHAD operation can be controlled to a lower range suitable for this situation. The indirect heating method should provide a suitable recovery process if enough heat can be transferred to the formation matrix. It is well known that thermal conduction in the formation is a very slow process. However, the convection effect generated as a result of the vaporization of some components of the reservoir fluid will enhance the process.

In accordance with another illustrative embodiment of the invention, there is provided a process for the recovery of viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir. The process includes transmitting heat into the reservoir by closed loop circulation of a hot heat transfer medium, through a slanted well including an elongated slanted well portion extending at a slanted angle inside the reservoir, to indirectly heat a reservoir matrix sufficiently to cause a viscosity reduction of reservoir fluids including heavy oil and bitumen. This viscosity reduction is sufficient to promote drainage by gravity of the fluids to a flow conduit provided in the slanted well portion, permitting the fluids to flow through and along the flow conduit to a collector. The process further includes producing the fluids up to the surface to be recovered.

As the heavy oil and bitumen are heated with the closed loop circulation heating in the slanted well, lighter components of the heavy oil and bitumen may be vaporized, with these vaporized lighter components moving into colder sections of the reservoir and causing further viscosity reduction when re-dissolved in the heavy oil and bitumen, thus providing an additional benefit of solvent dilution effect on the drainage of the fluids.

The vaporized lighter components and any vaporized connate water may create a convection current in the reservoir matrix and increase the heat transfer rate which in turn enhances the extraction rate of the fluids.

Accumulated fluids at the collector may be produced to the surface using either natural or artificial lifts.

The heat transfer medium may be caused to travel through tubular elements defining closed loop circulation paths in the slanted well to effect the indirect heating.

The slanted well may include liner means for receiving the heated fluids and forming the flow conduit for flow of the heated fluids therein.

The heat may be transmitted into the reservoir at a temperature below that at which coke formation in or on the slanted well occurs.

The reservoir matrix may be heated solely via the indirect heating and without direct injection of a heated fluid or solvent into the reservoir matrix.

In accordance with another illustrative embodiment of the invention, there is provided a system for the recovery of the viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir. The system includes means for transmitting heat into the reservoir including a slanted well comprising an elongated slanted well portion extending at a slanted angle inside the reservoir which provides for closed loop circulation of a hot heat transfer medium to indirectly heat a reservoir matrix sufficiently to cause a viscosity reduction of reservoir fluids comprising heavy oil and bitumen. This viscosity reduction is sufficient to promote drainage by gravity of the fluids. A flow conduit is provided in the slanted well portion to receive and permit the fluids to flow through and along the flow conduit. The system further includes a collector to receive the flow and from which collector the fluids may be produced up to the surface to be recovered.

The flow conduit may include a plurality of flow conduits, which may include tubular elements defining closed loop circulation paths for the heat transfer medium in the slanted well to effect the indirect heating.

The slanted well may include liner means for receiving the heated fluids and forming the flow conduits for flow of the heated fluids therein.

In illustrative embodiments of such processes and systems, the elongated slanted well portion may extend at the slanted angle inside the reservoir over a length between $2x10^2$ and $2x10^3$ metres, for example.

The slanted angle may be between ½ and $1x10^1$ degrees, for example.

If desired, the slanted angle may vary within the reservoir.

The slanted angle may be a down-dip angle. Alternatively, the slanted angle may be an up-dip angle.

The elongated slanted well portion may include a first slanted well portion having a slanted down-dip angle and a second slanted well portion having a slanted up-dip angle.

Other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

Brief Description of the Drawings

Figure 1 is a schematic of the CHAD process;

Figure 1A is a cross-section view of the slanted well portion;

Figure 1B is a cross-section of a horizontal producer;

Figure 2 is a plot of the viscosity of typical bitumen as a function of temperature;

Figure 3 presents the temperature profile inside the formation due to heat conduction;

Figure 4 presents the steam condensation rate at the well bore;

Figure 5 is a schematic of the details of the CHAD well design; and

Figure 6 is a schematic of the CHAD process typical well arrangements.

Detailed Description of Illustrative Embodiments

One embodiment of the present method of in-situ recovery of heavy oil and bitumen, using a combination of heat and vaporized solvents is depicted in Figure 1. Heavy oil and bitumen are present in underground reservoir 1 in a highly viscous and immobile form. Heat is transmitted into the reservoir through a slanted heater well 2, by an arrangement described here to provide indirect heating, in which a hot fluid transfer medium is circulated through a closed loop of tubing placed inside the slanted well.

The slanted heater well 2 is drilled from the ground surface 3 through the overburden 4' into the reservoir 1 and completed with a casing 4 extending from the surface to the slanted segment 2' and cemented. In the slanted portion or segment 2' the well is completed with slotted liners 7 defining flow conduits for the heated oil and bitumens (as illustrated in Figs. 1, 5 and 6), or one of wire mesh wrapped screens, prepacked liners, perforated casing, open hole 5 or any combination of these. The closed loop circulation heating system 6 consists of a pair of parallel tubes 6' placed inside the well and extending from the surface to the end (toe) of the well completion string or open hole inside the formation containing the viscous hydrocarbon. The two tubes 6' are joined together at the toe with an attachment such that fluid can flow from one tubing length to the other under sealed conditions. Steam or any other hot fluid is injected into one of the tubes 6' and as it flows through the length of the slanted well portion 2', it transfers heat to the reservoir medium external to it and the colder fluid at the toe returns to the surface through the other parallel tubing. The same heat transfer can also be achieved by using a pair of concentric tubes. In this case the external tube of the pair of concentric tubes is closed with a plug at the toe. The inner tube is of a smaller diameter than the external tube, creating an annular space between the two tubings. Hot fluids including steam are injected through the inner tubing and condensed liquid with or without any vapor returns to the surface through the closed annulus. Alternatively the hot fluid is injected through the annulus of the concentric tubing and the condensed liquid and associated vapor, if any, is produced through the inner tubing. Segments of the entire length of these tubings may be insulated or may be provided with fins to control the heat transfer. The heat is transmitted from the hot fluid heat transfer medium inside the tubing to the formation and fluids outside without the fluids physically contacting each other and hence the heat transfer process is termed as indirect heating. There are many advantages to this indirect heating method compared to the previously described hot direct fluid injection into the formation to heat the formation. In the indirect heating according to the present embodiment, the heating fluid does not get contaminated and hence it can be recycled through the heating system (which is usually a boiler), with minimum pretreatment. This eliminates the necessity of an elaborate treatment plant (e.g. a water treatment plant in the case of steam injection into the formation) which is usually the case for direct heating processes.

Heat is transmitted to the formation by heat conduction through the formation matrix, primarily sand, and by heat convection enabled by the vaporization of the interstitial water and the lighter hydrocarbon components of the bitumen. Heat transfer at the bitumen interface reduces bitumen viscosity due to increase in temperature. A typical relationship between the bitumen viscosity and temperature is presented in Figure 2. Viscosity is reduced by several orders of magnitude as the temperature increases from the formation temperature to 200°C. The hot and mobile oil drains from the formation by gravity to the slanted well portion 2'. Once in the slanted well portion 2' it flows along the sloping well through the slotted liner 7 (which forms a flow conduit for the bitumen) to a slotted horizontal producer 8 (Figure 1B) or to a vertical drain hole (not shown). Along its journey through the well to the production end, the heated bitumen liberates the lighter hydrocarbon components and the water in the produced fluids is also vaporized. This vapor goes back to the reservoir and develops a convection cell that enhances the heat transfer process. The heated mobilized oil is withdrawn continuously and is produced to the surface, either by natural lift or using any artificial lift in well known fashion.

Figure 3 presents the temperature profiles inside the formation as a function of time due to the conduction heating only. It appears that if the heat is transferred by conduction only, the heat front at 150°C will move to a radial distance of 12 m in 10 years time. This calculation does not include the impact of bitumen flow counter current to the heat flow. Also the convective flow of heat is also ignored. Therefore this represents a very conservative scenario. In a real situation each of the heater wells 2 may be operating for more than 20 years delivering heat to the formation and mobilizing bitumen. Therefore a well spacing of higher than 30 m may not be unrealistic.

In the process of heating the bitumen, the formation matrix consisting of sand or any other components is also heated to the same temperature. Therefore in terms of heat efficiency the process is similar to other steam based processes. Figure 4 presents the amount of heat that can be transmitted by conduction only, through a 1000m long hole in an oil sand formation as a function of the interface temperature. For each temperature both a 9 $^5/_8$ in. and a 10 ¾ in. diameter hole were considered. Heat transfer is expressed as the equivalent quantity of steam that yields the same heat upon condensation to water. Although initially the higher interface temperature allowed more steam condensation at the interface, with time the quantity of steam reduced to ~30 m^3/day after 20 years. This translates to an equivalent production of 16-20 m^3/day of bitumen from this heater arm which may satisfy the economic viability criteria.

Figure 5 presents one of many possible CHAD well designs. The top section of the figure shows the schematic of the heater well, which may be substantially slanted along the length with different slant angles for different well portions 2". Also it may be a V shaped well with opposite slants on the either side. The steam or other hot fluid supply and return tubing 6" may be inside or external to the bitumen flow conduit (e.g. slotted liner 7). Portions of the lengths of these tubings may be insulated to control heat flow. The lowest points of several of these heater wells 2' are connected with an underlying horizontal or slanted producer well 8 placed at the base of the reservoir. This schematic is presented in the bottom section of the Figure 5.

Figure 6 presents one of the possible arrangements of these heater and producer wells for a commercial application. A set of heater wells 2 each including a slanted well portion 2" is drilled from a cluster pad or a linear pad and a producer well 8" orthogonal to the slanted well portions 2" is drilled from another pad. The heater arms transmit heat and facilitate the flow of gravity drained bitumen to the producer well 8". The hot and mobile bitumen collected in the producer well 8" is pumped to the surface facilities using an artificial lift system.

In a typical CHAD operation the slanted well portions 2', 2" may be in the range of 200 to 2000 m in length with a dip angle between ½ to 10°. Depending on the well length and the reservoir characteristics, steam will be circulated into the closed loop heating system at a rate of 10-100 m^3/day. Operating pressure inside the reservoir will be slightly higher than the saturation pressure of the lighter fractions of the solvent at the original reservoir temperature. The estimated extraction rate is in the range of 15-40 m^3/day of bitumen or heavy oil produced per heater well. Higher temperature at the interface increases the heat transfer rate. However, at very high temperature these high viscosity crudes form coke at the interface. Coke, being a poor conductor of heat, may form an impediment for the process. A study of the fouling behaviour of bitumen on the surface of a coker furnace was carried out by Parker et al. Their conclusion was that "coke deposition is virtually non existent at temperatures below 350°C". Thus the higher limit of temperature in the CHAD process would be 350°C, although this may change with the properties of the crude.

Advantageously, illustrative embodiments of the present invention involve indirect heating of the formation without physically contacting the formation with the heating fluid, thereby reducing the heating fluid treatment requirement, and providing an efficient and economic process for the recovery of heavy oil and bitumen from shallow reservoirs.

Illustrative embodiments of the invention have been described by way of example. Those skilled in the art will realize that various modifications and changes may be made while remaining within the spirit and scope of the invention. Hence the invention is not to be limited to the embodiments as described but, rather, the invention encompasses the full range of equivalencies as defined by the appended claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A process for the recovery of viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir comprising: transmitting heat into the reservoir by closed loop circulation of a hot heat transfer medium through a slanted well comprising an elongated slanted well portion extending at a slanted angle inside the reservoir to indirectly heat a reservoir matrix sufficiently to cause a viscosity reduction of reservoir fluids comprising heavy oil and bitumen, which reduction is sufficient to promote drainage by gravity of said fluids to a flow conduit provided in the slanted well portion, permitting said fluids to flow through and along said flow conduit to a collector and then producing said fluids up to the surface to be recovered.

2. The process of claim 1 wherein said elongated slanted well portion extends at said slanted angle inside the reservoir over a length between $2x10^2$ and $2x10^3$ metres.

3. The process of claim 1 or claim 2 wherein said slanted angle is between ½ and $1x10^1$ degrees.

4. The process of any one of claim 1 to claim 3 wherein said slanted angle varies within the reservoir.

5. The process of any one of claim 1 to claim 4 wherein said slanted angle is a down-dip angle.

6. The process of any one of claim 1 to claim 4 wherein said slanted angle is an up-dip angle.

7. The process of any one of claim 1 to claim 6 wherein said elongated slanted well portion comprises a first slanted well portion having a slanted down-dip angle and a second slanted well portion having a slanted up-dip angle.

8. The process of any one of claim 1 to claim 7 wherein, as the heavy oil and bitumen are heated with said closed loop circulation heating in the slanted well, lighter components of the heavy oil and bitumen are vaporized, with these vaporized lighter components moving into colder sections of the reservoir and causing further viscosity reduction when re-dissolved in the heavy oil and bitumen thus providing an additional benefit of solvent dilution effect on the drainage of said fluids.

9. The process of claim 8 wherein the vaporized lighter components and any vaporized connate water create a convection current in the reservoir matrix and increase the heat transfer rate which in turn enhances the extraction rate of said fluids.

10. The process of any one of claim 1 to claim 9 wherein accumulated fluids at said collector are produced to the surface using either natural or artificial lifts.

11. The process of any one of claim 1 to claim 10 wherein the heat transfer medium is caused to travel through tubular elements defining closed loop circulation paths in said slanted well to effect the indirect heating.

12. The process of claim 11 wherein said slanted well includes liner means for receiving the heated fluids and forming said flow conduit for flow of the heated fluids therein.

13. The process of any one of claim 1 to claim 12 wherein the heat is transmitted into said reservoir at a temperature below that at which coke formation in or on said slanted well occurs.

14. The process of any one of claim 1 to claim 13 wherein the reservoir matrix is heated solely via said indirect heating and without direct injection of a heated fluid or solvent into the reservoir matrix.

15. A system for the recovery of the viscous hydrocarbons from a subterranean hydrocarbon bearing reservoir comprising: means for transmitting heat into the reservoir including a slanted well comprising an elongated slanted well portion extending at a slanted angle inside the reservoir which provides for closed loop circulation of a hot heat transfer

medium to indirectly heat a reservoir matrix sufficiently to cause a viscosity reduction of reservoir fluids comprising heavy oil and bitumen, which reduction is sufficient to promote drainage by gravity of said fluids, a flow conduit being provided in the slanted well portion to receive and permit said fluids to flow through and along said flow conduit, and a collector to receive said flow and from which collector said fluids may be produced up to the surface to be recovered.

16. The system of claim 15 wherein said flow conduit comprises a plurality of flow conduits, said flow conduits comprising tubular elements defining closed loop circulation paths for the heat transfer medium in said slanted well to effect the indirect heating.

17. The system of claim 16 wherein said slanted well includes liner means for receiving the heated fluids and forming said flow conduits for flow of the heated fluids therein.

18. The system of any one of claim 15 to claim 17 wherein said elongated slanted well portion extends at said slanted angle inside the reservoir over a length between $2x10^2$ and $2x10^3$ metres.

19. The system of any one of claim 15 to claim 18 wherein said slanted angle is between ½ and $1x10^1$ degrees.

20. The system of any one of claim 15 to claim 19 wherein said slanted angle varies within the reservoir.

21. The system of any one of claim 15 to claim 20 wherein said slanted angle is a down-dip angle.

22. The system of any one of claim 15 to claim 20 wherein said slanted angle is an up-dip angle.

23. The system of any one of claim 15 to claim 22 wherein said elongated slanted well portion comprises a first slanted well portion having a slanted down-dip angle and a second slanted well portion having a slanted up-dip angle.

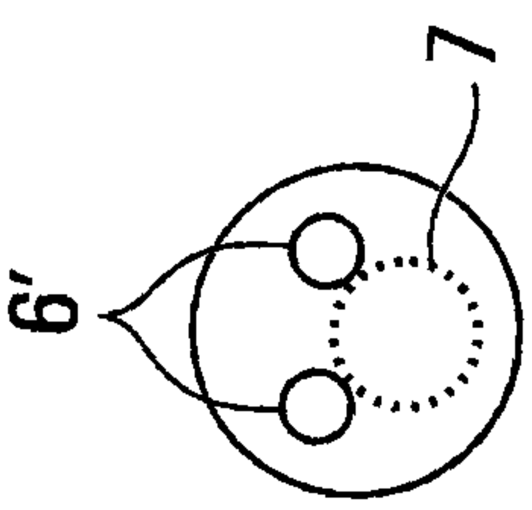


FIG. 1A

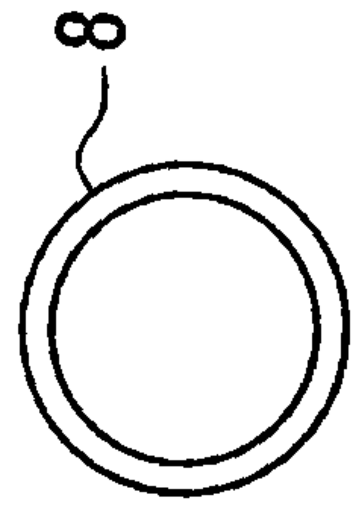


FIG. 1B

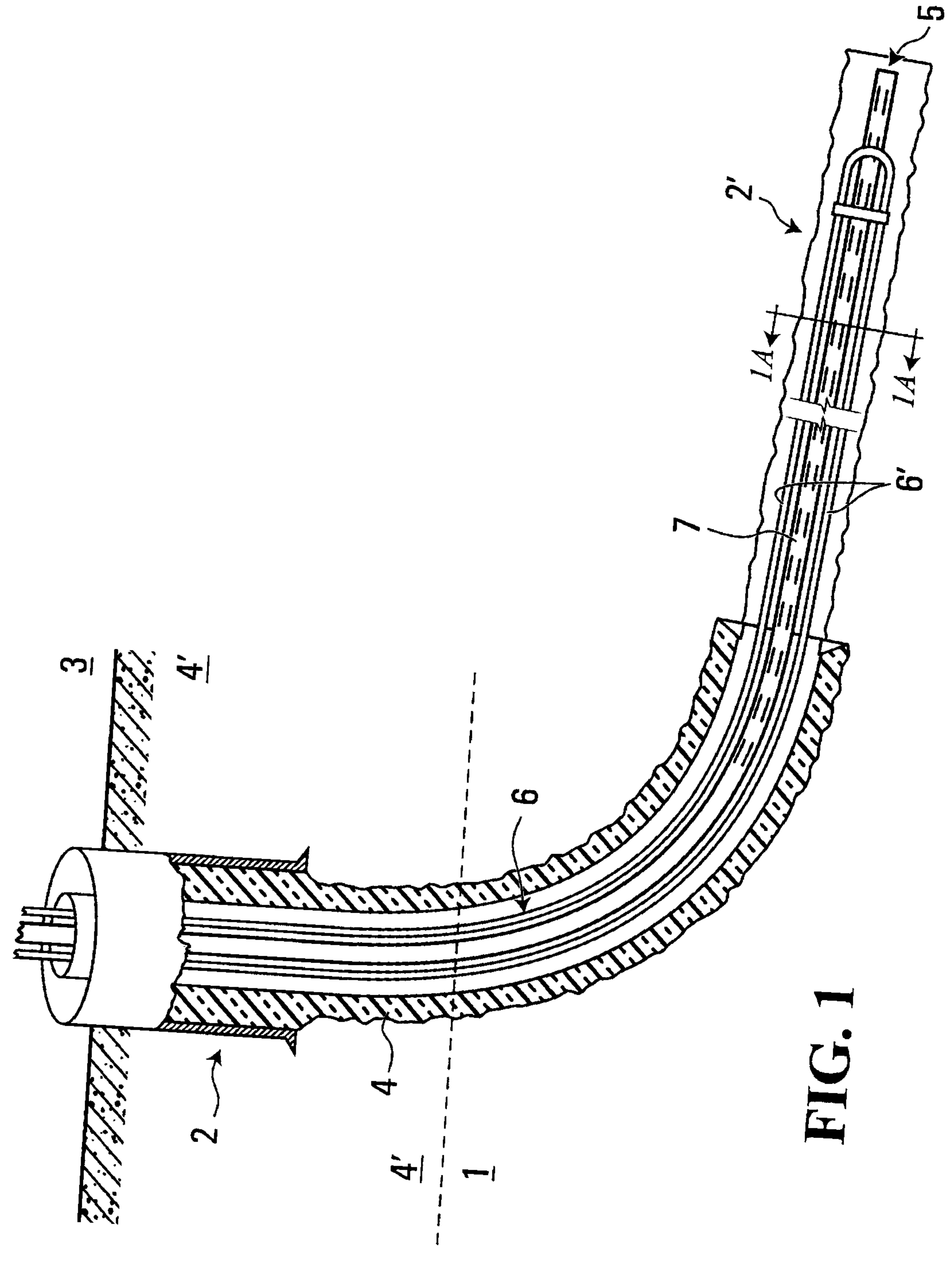


FIG. 1

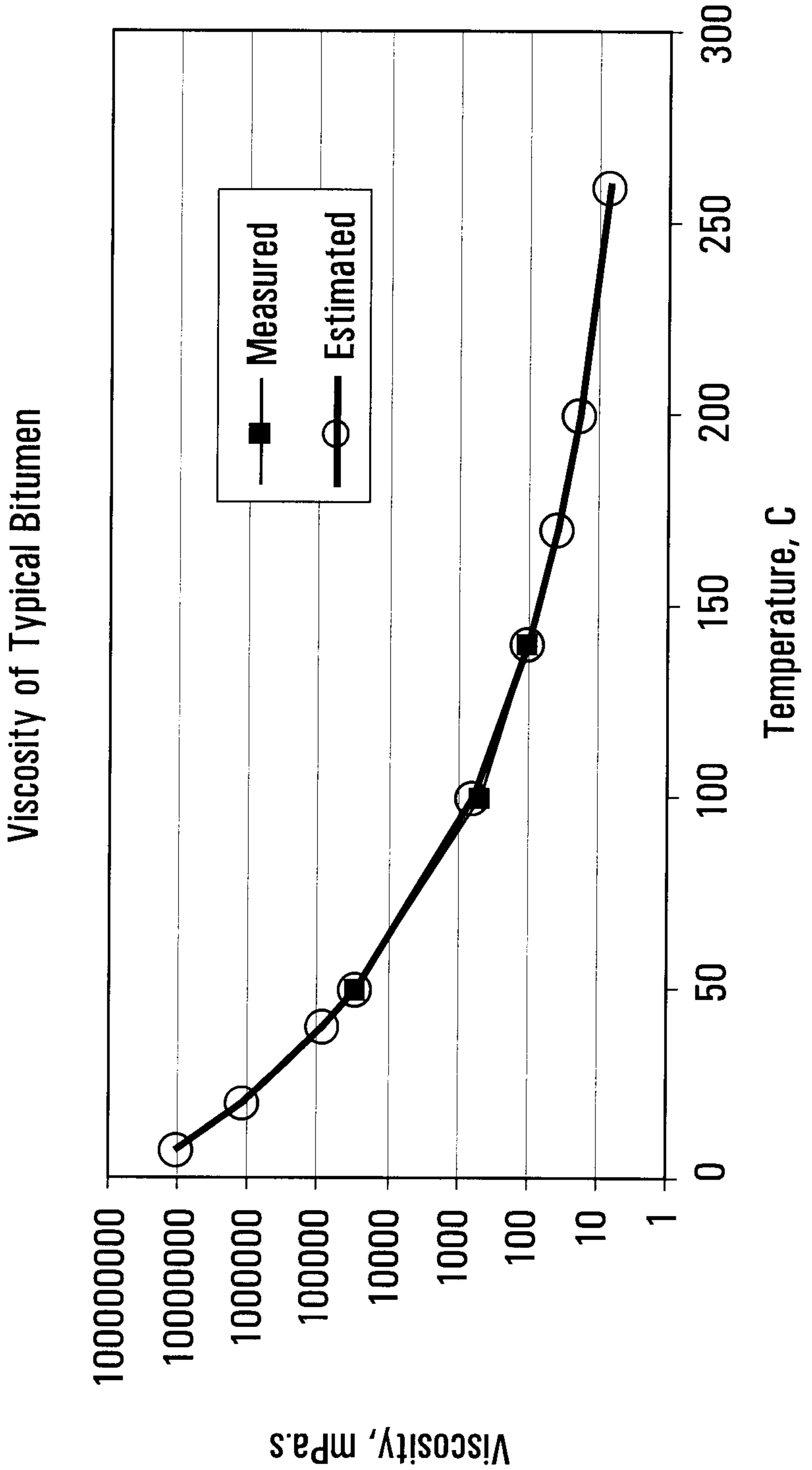

Viscosity of Typical Bitumen
Measured
Estimated
Viscosity, mPa.s
100000000
10000000
1000000
100000
10000
1000
100
10
1
Temperature, C
0
50
100
150
200
250
300

FIG. 2

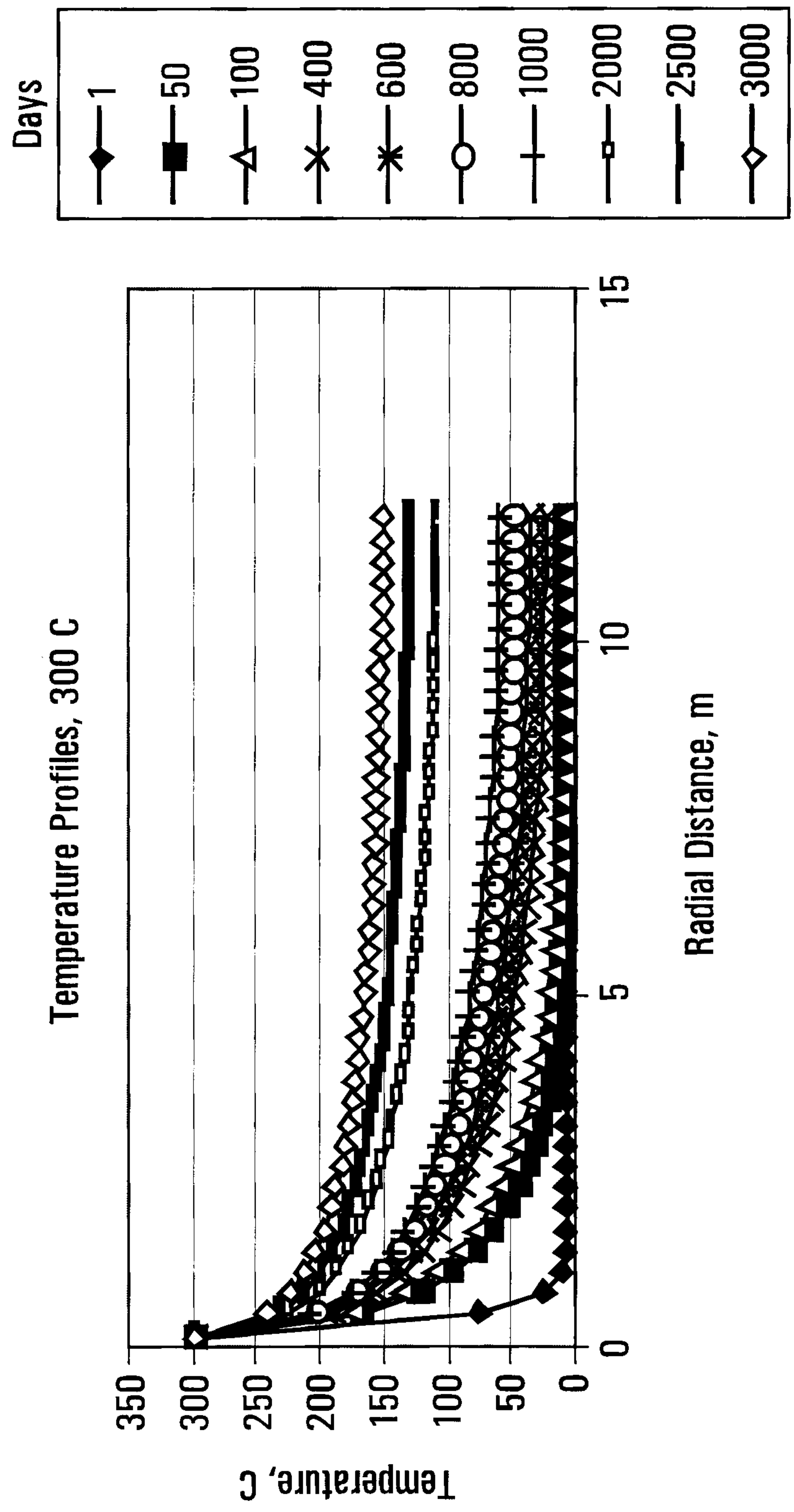
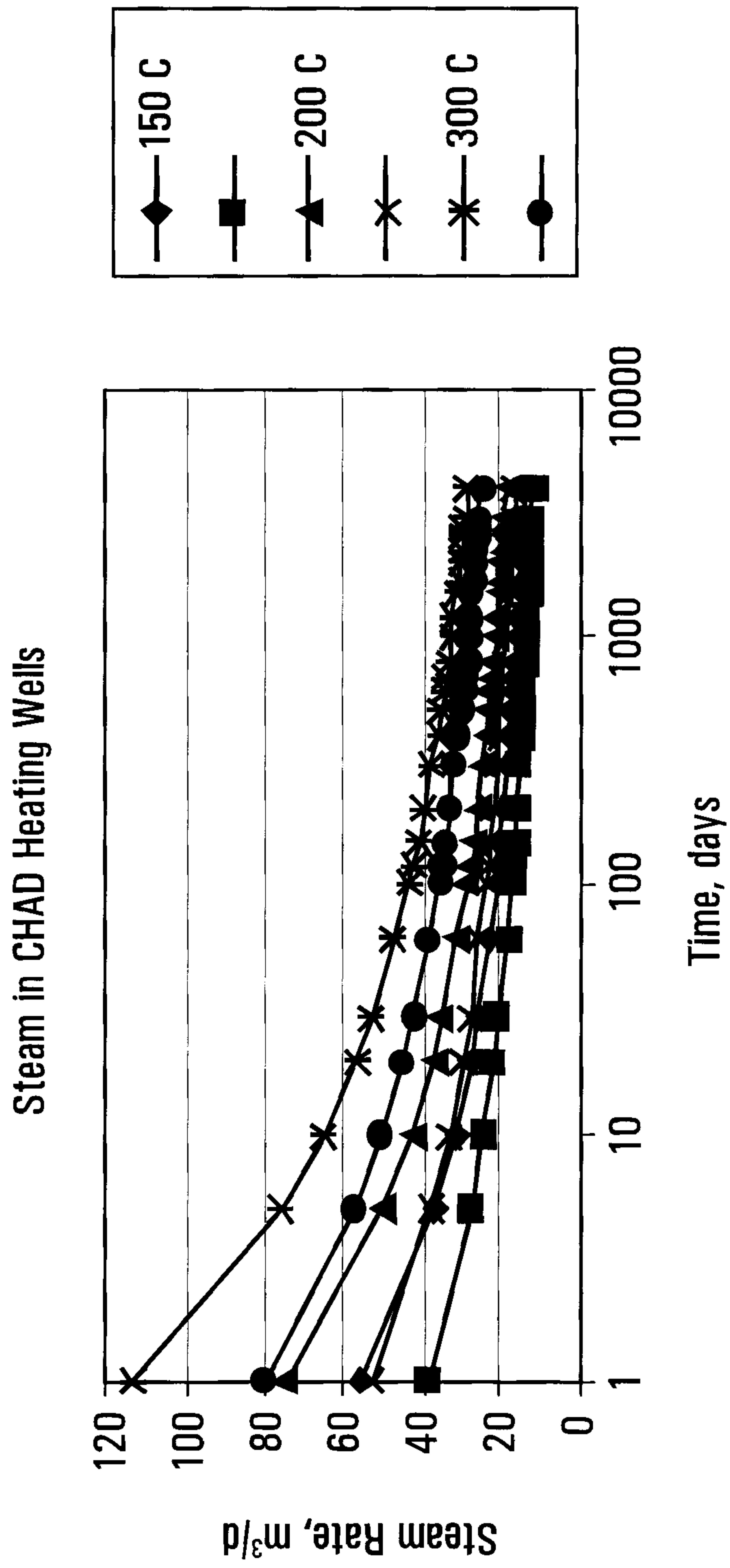

Temperature Profiles, 300 C
Temperature, C
350
300
250
200
150
100
50
0
0
5
10
15
Radial Distance, m
Days
1
50
100
400
600
800
1000
2000
2500
3000

FIG. 3



Steam in CHAD Heating Wells
150 C
200 C
300 C
Steam Rate, m3/d
120
100
80
60
40
20
0
1
10
100
1000
10000
Time, days

FIG. 4

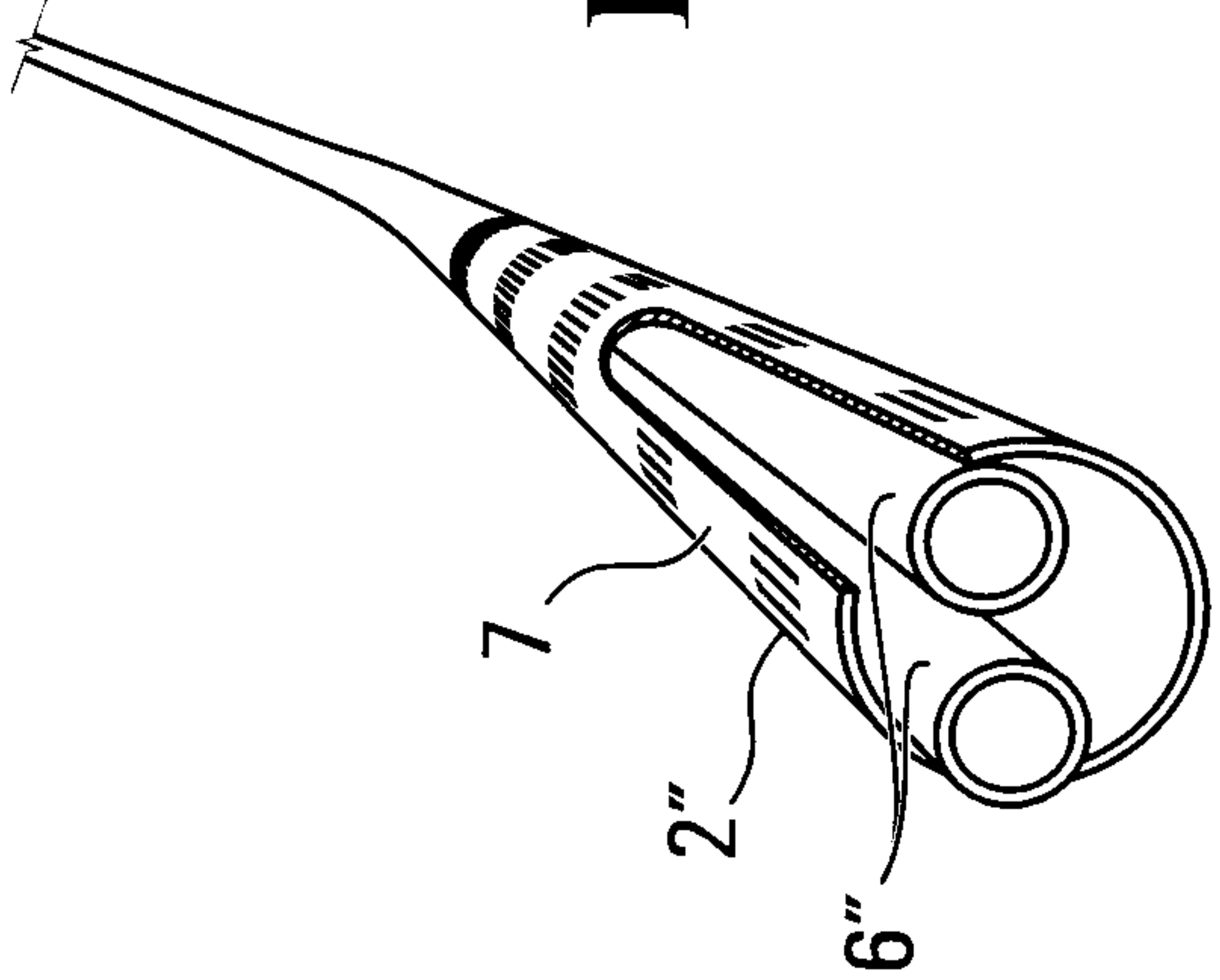


FIG. 5A

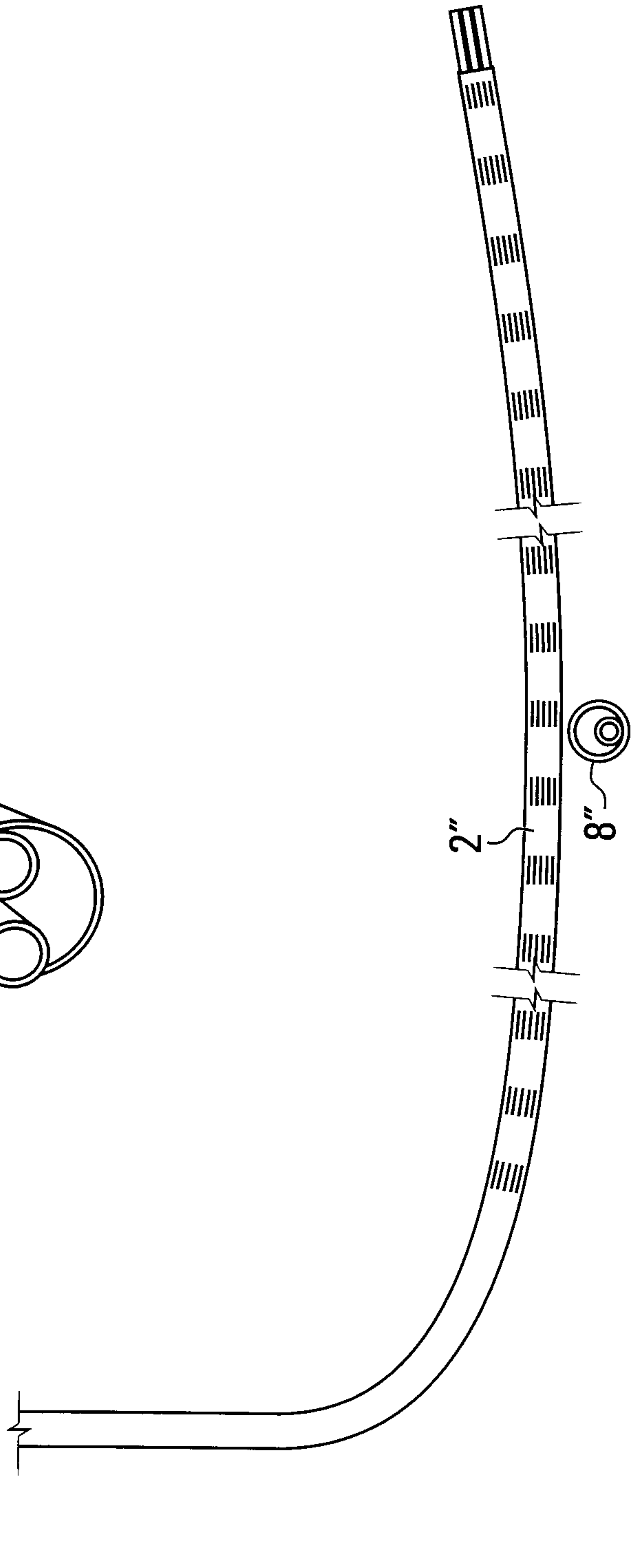


FIG. 5B

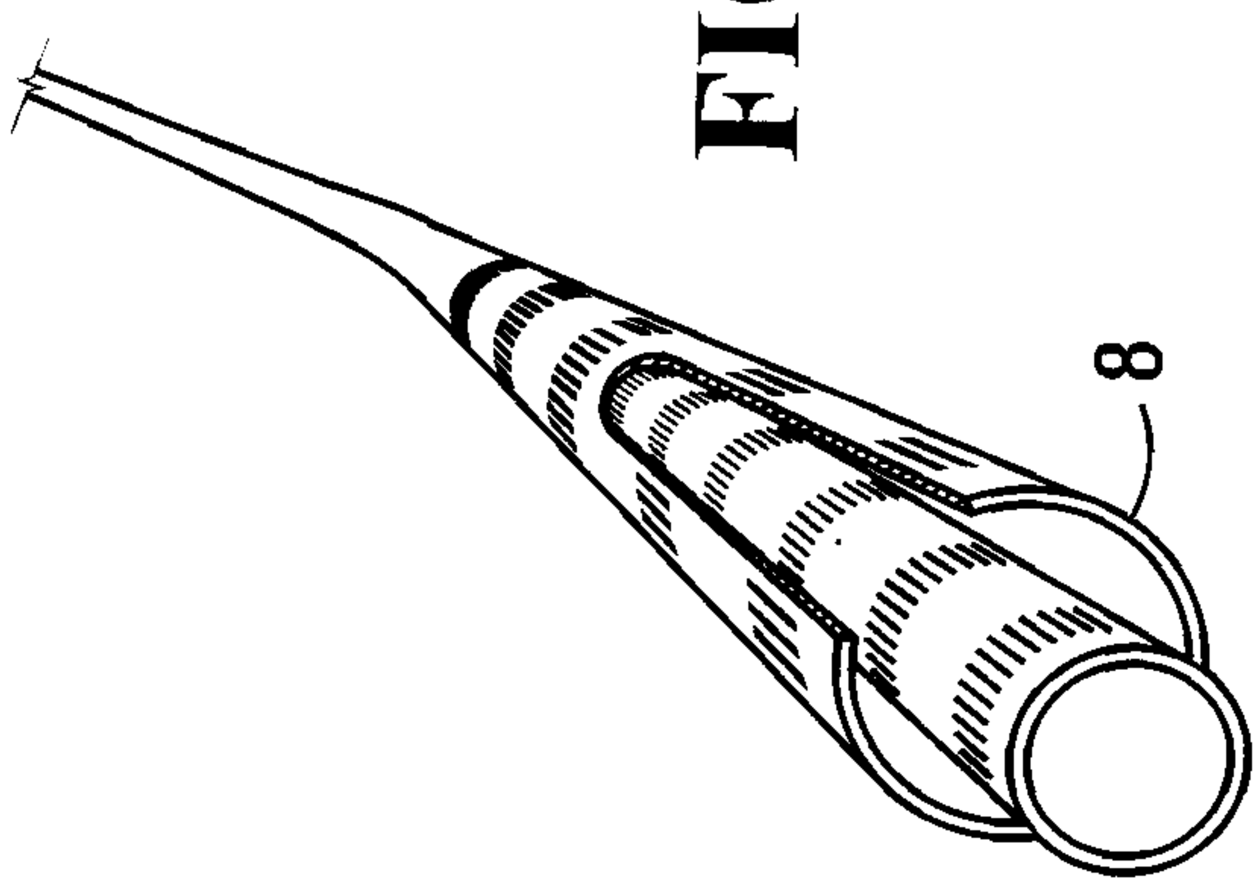


FIG. 5C

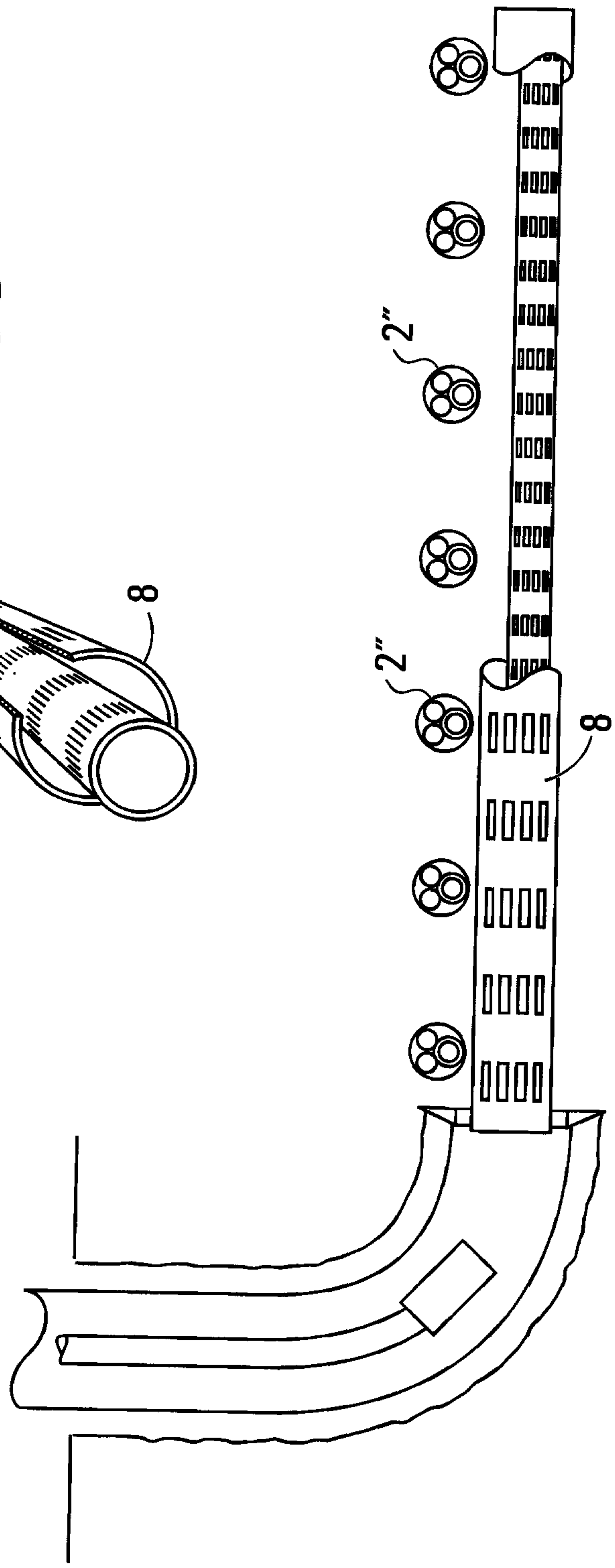


FIG. 5D

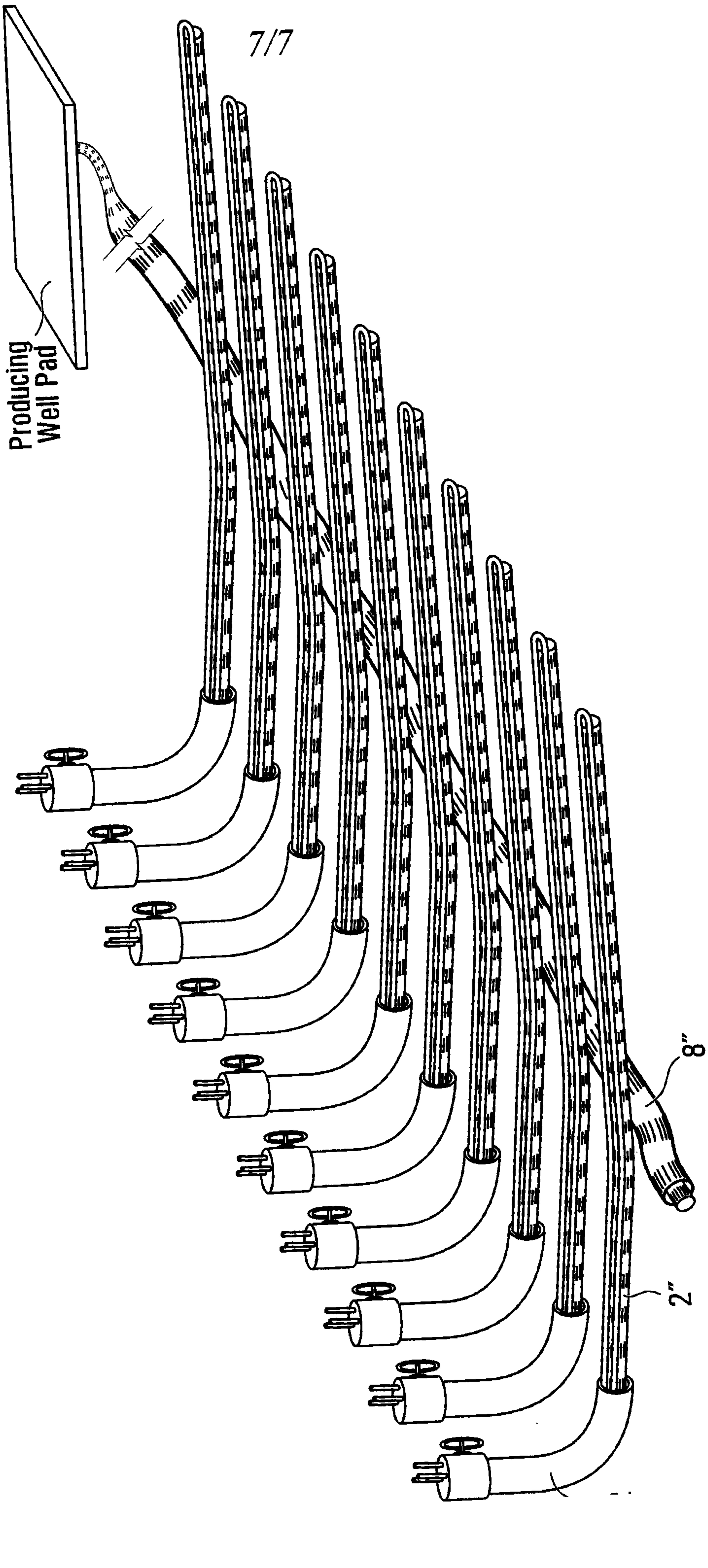


FIG. 6

Viscosity of Typical Bitumen
100000000
10000000
1000000
100000
10000
1000
100
10
1
Viscosity, mPa.s
0
50
100
150
200
250
300
Temperature, C
Measured
Estimated