(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 December 2010 (09.12.2010)

PCT

(10) International Publication Number
WO 2010/141195 A2

(51) International Patent Classification:
E21B 43/08 (2006.01)

(21) International Application Number:
PCT/US2010/034747

(22) International Filing Date:
13 May 2010 (13.05.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/476,843 2 June 2009 (02.06.2009) US

(71) Applicant *(for all designated States except US)*: **BAKER HUGHES INCORPORATED** [US/US]; Po Box 4740, Houston, Texas 77210-4740 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **JOHNSON, Michael H.** [US/US]; 6230 Clear Canyon Drive, Katy, Texas 77450 (US). **KIM, Namhyo** [KR/US]; 16410 Stone Prairie Drive, Houston, Texas 77095 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: PERMEABILITY FLOW BALANCING WITHIN INTEGRAL SCREEN JOINTS AND METHOD

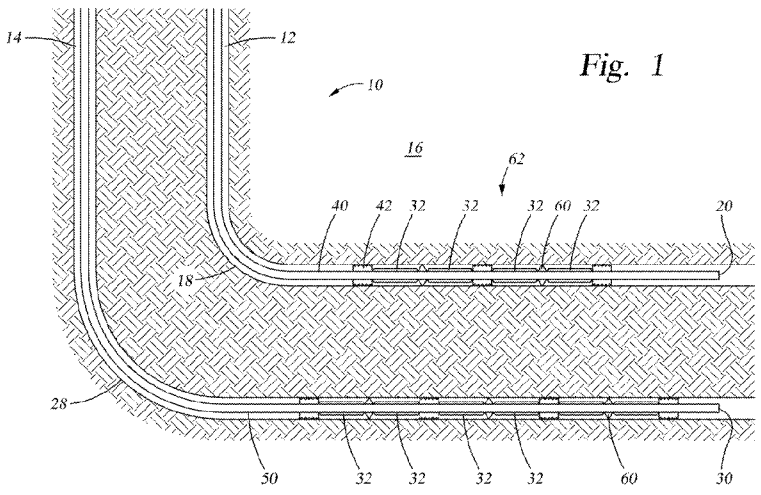


Fig. 1

(57) **Abstract**: A method for uniform heating of a formation including applying a high temperature fluid to a tubular located within an open hole formation borehole; modifying a permeability of the tubular along its length by reducing permeability at a heel of the borehole and by increasing permeability towards a toe of the borehole; and impeding annular movement of the heated fluid by radially extending one or more baffles from the tubular.

WO 2010/141195 A2

PERMEABILITY FLOW BALANCING WITHIN INTEGRAL SCREEN JOINTS AND METHOD

BACKGROUND

[0001] Viscous hydrocarbon recovery is a segment of the overall hydrocarbon recovery industry that is increasingly important from the standpoint of global hydrocarbon reserves and associated product cost. In view hereof, there is increasing pressure to develop new technologies capable of producing viscous reserves economically and efficiently. Steam Assisted Gravity Drainage (SAGD) is one technology that is being used and explored with good results in some wellbore systems. Other wellbore systems however where there is a significant horizontal or near horizontal length of the wellbore system present profile challenges both for heat distribution and for production. In some cases, similar issues arise even in vertical systems.

[0002] Both inflow and outflow profiles (e.g. production and stimulation) are desired to be as uniform as possible relative to the particular borehole. This should enhance efficiency as well as avoid early water breakthrough. Breakthrough is clearly inefficient as hydrocarbon material is likely to be left in situ rather than being produced. Profiles are important in all well types but it will be understood that the more viscous the target material the greater the difficulty in maintaining a uniform profile.

[0003] Another issue in conjunction with SAGD systems is that the heat of steam injected to facilitate hydrocarbon recovery is sufficient to damage downhole components due to thermal expansion of the components. This can increase expenses to operators and reduce recovery of target fluids. Since viscous hydrocarbon reserves are likely to become only more important as other resources become depleted, configurations and methods that improve recovery of viscous hydrocarbons from earth formations will continue to be well received by the art.

SUMMARY

[0004] A method for uniform heating of a formation including applying a high temperature fluid to a tubular located within an open hole formation borehole; modifying a permeability of the tubular along its length by reducing permeability at a heel of the borehole and by increasing permeability towards a toe of the borehole; and impeding

annular movement of the heated fluid by radially extending one or more baffles from the tubular.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Referring now to the drawings wherein like elements are numbered alike in the several figures:

[0006] Figure 1 is a schematic view of a wellbore system in a viscous hydrocarbon reservoir;

[0007] Figure 2 is a chart illustrating a change in fluid profile over a length of the borehole with and without permeability control.

DETAILED DESCRIPTION

[0008] Referring to Figure 1, the reader will recognize a schematic illustration of a portion of a SAGD wellbore system 10 configured with a pair of boreholes 12 and 14. Generally, borehole 12 is the steam injection borehole and borehole 14 is the hydrocarbon recovery borehole but the disclosure should not be understood as limiting the possibilities to such. The discussion herein however will address the boreholes as illustrated. Steam injected in borehole 12 heats the surrounding formation 16 thereby reducing the viscosity of the stored hydrocarbons and facilitating gravity drainage of those hydrocarbons. Horizontal or other highly deviated well structures like those depicted tend to have greater fluid movement into and to of the formation at a heel 18 of the borehole than at a toe 20 of the borehole due simply to fluid dynamics. An issue associated with this property is that the toe 20 will suffer reduced steam application from that desired while heel 18 will experience more steam application than that desired, for example. The change in the rate of fluid movement is relatively linear (declining flow) when querying the system at intervals with increasing distance from the heel 18 toward the toe 20. The same is true for production fluid movement whereby the heel 28 of the production borehole 14 will pass more of the target hydrocarbon fluid than the toe 30 of the production borehole 14. This is due primarily to permeability versus pressure drop along the length of the borehole 12 or 14. The system 10 as illustrated alleviates this issue as well as others noted above.

[0009] According to the teaching herein, one or more of the boreholes (represented by just two boreholes 12 and 14 for simplicity in illustration) is configured with one or more

permeability control devices 32 that are each configured differently with respect to permeability or pressure drop in flow direction in or out of the tubular. The devices 32 nearest the heel 18 or 28 will have the least permeability while permeability will increase in each device 32 sequentially toward the toe 20 and 30. The permeability of the device 32 closest to toe 20 or 30 will be the greatest. This will tend to balance outflow of injected fluid and inflow of production fluid over the length of the borehole 12 and 14 because the natural pressure drop of the system is opposite that created by the configuration of permeability devices as described. Permeability and/or pressure drop devices 32 useable in this configuration include inflow control devices such as product family number H48688 commercially available from Baker Oil Tools, Houston Texas, beaded matrix flow control configurations such as those disclosed in USSN 61/052,919, 11/875,584 and 12/144,730, 12/144,406 and 12/171,707 the disclosures of which are incorporated herein by reference, or other similar devices. Adjustment of pressure drop across individual permeability devices is possible in accordance with the teaching hereof such that the desired permeability over the length of the borehole 12 or 14 as described herein is achievable. Referring to figure 2, a chart of the flow of fluid over the length of borehole 12 is shown without permeability control and with permeability control. The representation is stark with regard to the profile improvement with permeability control.

[0010] In order to determine the appropriate amount of permeability for particular sections of the borehole 12 or 14, one needs to determine the pressure in the formation over the length of the horizontal borehole. Formation pressure can be determined/measured in a number of known ways. Pressure at the heel of the borehole and pressure at the toe should also be determined/measured. This can be determined in known ways. Once both formation pressure and pressures at locations within the borehole have been ascertained, the change in pressure (ΔP) across the completion can be determined for each location where pressure within the completion has been or is tested. Mathematically this is expressed as ΔP location = P formation – P location where the locations may be the heel, the toe or any other point of interest.

[0011] A flow profile whether into or out of the completion is dictated by the ΔP at each location and the pressure inside the completion is dictated by the head of pressure associated with the column of fluid extending to the surface. The longer the column, the higher the pressure. It follows, then, that greater resistance to inflow will occur at the toe

of the borehole than at the heel of the completion. In accordance with the teaching hereof permeability control is distributed such that pressure drop at a toe of the borehole is in the range of about 25% to less than 1% whereas pressure drop at the heel of the borehole is about 30% or more. In one embodiment the pressure drop at the heel is less than 45% and at the toe less than about 25%. Permeability control devices distributed between the heel and the toe will in some embodiments have individual pressure drop values between the percentage pressure drop at the toe and the percentage pressure drop at the heel. Moreover, in some embodiments the distribution of pressure drops among the permeability devices is linear while in other embodiments the distribution may follow a curve or may be discontinuous to promote inflow of fluid from areas of the formation having larger volumes of desirable liberatable fluid and reduced inflow of fluid from areas of the formation having smaller volumes of desirable liberatable fluid.

[0012] Referring back to Figure 1, a tubing string 40 and 50 are illustrated in boreholes 12 and 14 respectively. Open hole anchors 42, such as Baker Oil Tools WBAnchor™ may be employed in the borehole to anchor the tubing 40. This is helpful in that the tubing 40 experiences a significant change in thermal load and hence a significant amount of thermal expansion during well operations. Unchecked, the thermal expansion can cause damage to other downhole structures or to the tubing string 40 itself thereby affecting efficiency and production of the well system. In order to overcome this problem, one or more open hole anchors 42 are used to ensure that the tubing string 40 is restrained from excessive movement. Because the total length of mobile tubing string is reduced by the interposition of open hole anchor(s) 42, excess extension cannot occur. In one embodiment, three open hole anchors 42, as illustrated, are employed and are spaced by about 90 to 120 ft from one another but could in some particular applications be positioned more closely and even every 30 feet (at each pipe joint). The spacing interval is also applicable to longer runs with each open hole anchor being spaced about 90-120 ft from the next. Moreover, the exact spacing amount between anchors is not limited to that noted in this illustrated embodiment but rather can be any distance that will have the desired effect of reducing thermal expansion related wellbore damage. In addition the spacing can be even or uneven as desired. The determination of distance between anchors must take into account. The anchor length, pattern, or the number of anchor points per foot in order to adjust the anchoring effect to optimize performance based on formation type and formation strength tubular dimensions and material.

[0013] Finally in one embodiment, the tubing string 40, 50 or both is configured with one or more baffles 60. Baffles 60 are effective in both deterring loss of steam to formation cracks such as that illustrated in figure 1 as numeral 62 and in causing produced fluid to migrate through the intended permeability device 32. More specifically, and taking the functions one at a time, the injector borehole, such as 12, is provided with one or more baffles 60. The baffles may be of any material having the ability to withstand the temperature at which the particular steam is injected into the formation. In one embodiment, a metal deformable seal such as one commercially known as a z-seal and available from Baker Oil Tools, Houston Texas, may be employed. And while metal deformable seals are normally intended to create a high pressure high temperature seal against a metal casing within which the seal is deployed, for the purposes taught in this disclosure, it is not necessary for the metal deformable seal to create an actual seal. That stated however, there is also no prohibition to the creation of a seal but rather then focus is upon the ability of the configuration to direct steam flow with relatively minimal leakage. In the event that an actual seal is created with the open hole formation, the intent to minimize leakage will of course be met. In the event that a seal is not created but substantially all of the steam applied to a particular region of the wellbore is delivered to that portion of the formation then the baffle will have done its job and achieved this portion of the intent of this disclosure. With respect to production, the baffles are also of use in that the drawdown of individual portions of the well can be balanced better with the baffles so that fluids from a particular area are delivered to the borehole in that area and fluids from other areas do not migrate in the annulus to the same section of the borehole but rather will enter at their respective locations. This ensures that profile control is maintained and also that where breakthrough does occur, a particular section of the borehole can be bridged and the rest will still produce target fluid as opposed to breakthrough fluid since annular flow will be inhibited by the baffles. In one embodiment baffles are placed about 100 ft or 3 liner joints apart but as noted with respect to the open hole anchors, this distance is not fixed but may be varied to fit the particular needs of the well at issue. The distance between baffles may be even or may be uneven and in some cases the baffles will be distributed as dictated by formation condition such that for example cracks in the formation will be taken into account so that a baffle will be positioned on each side of the crack when considered along the length of the tubular.

[0014] While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

CLAIMS

1 A method for uniform heating of a formation comprising:
applying a high temperature fluid to a tubular located within an open hole formation borehole;
modifying a permeability of the tubular along its length by reducing permeability at a heel of the borehole and by increasing permeability towards a toe of the borehole; and
impeding annular movement of the heated fluid by radially extending one or more baffles from the tubular.

2 A method as claimed in claim 1 wherein the method further comprises anchoring a plurality of portions of the tubular; and
Restricting thermal growth of the tubular with the plurality of anchors.

3 A method as claimed in claim 1 wherein the impeding is by sealing an annulus defined between the tubular and the formation.

4 A method as claimed in claim 1 wherein the impeding is by extending the baffles into proximity with the formation.

5 A method as claimed in claim 1 wherein the applying is by injecting steam into the tubular.

6 A method as claimed in claim 1 wherein the modifying is by positioning one or more permeability control devices in the tubular to control pressure drop across the tubular.

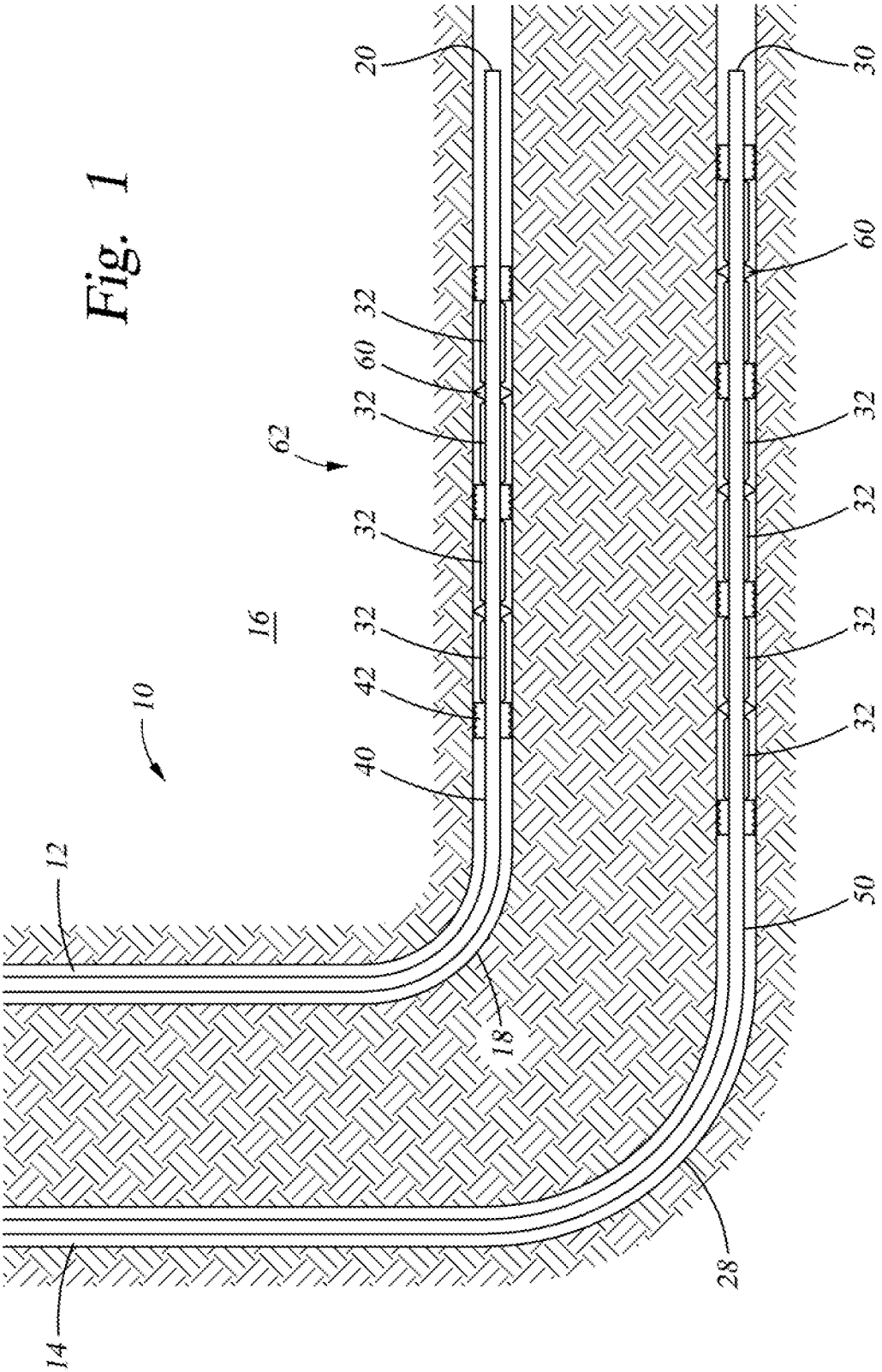
7 A method as claimed in claim 6 wherein the permeability control devices are configured to be less permeable at a heel of the borehole than at a toe of the borehole.

8 A method as claimed in claim 6 wherein the one or more permeability control devices is a number of devices positioned in the tubular each having a distinct permeability which increases as the devices become closer to the toe.

9 A method as claimed in claim 1 wherein the impeding is forcing high temperature fluid to enter the formation in discrete areas between the one or more baffles.

10 A method as claimed in claim 1 further includes creating a uniformly distributed temperature profile in the formation.

Fig. 1



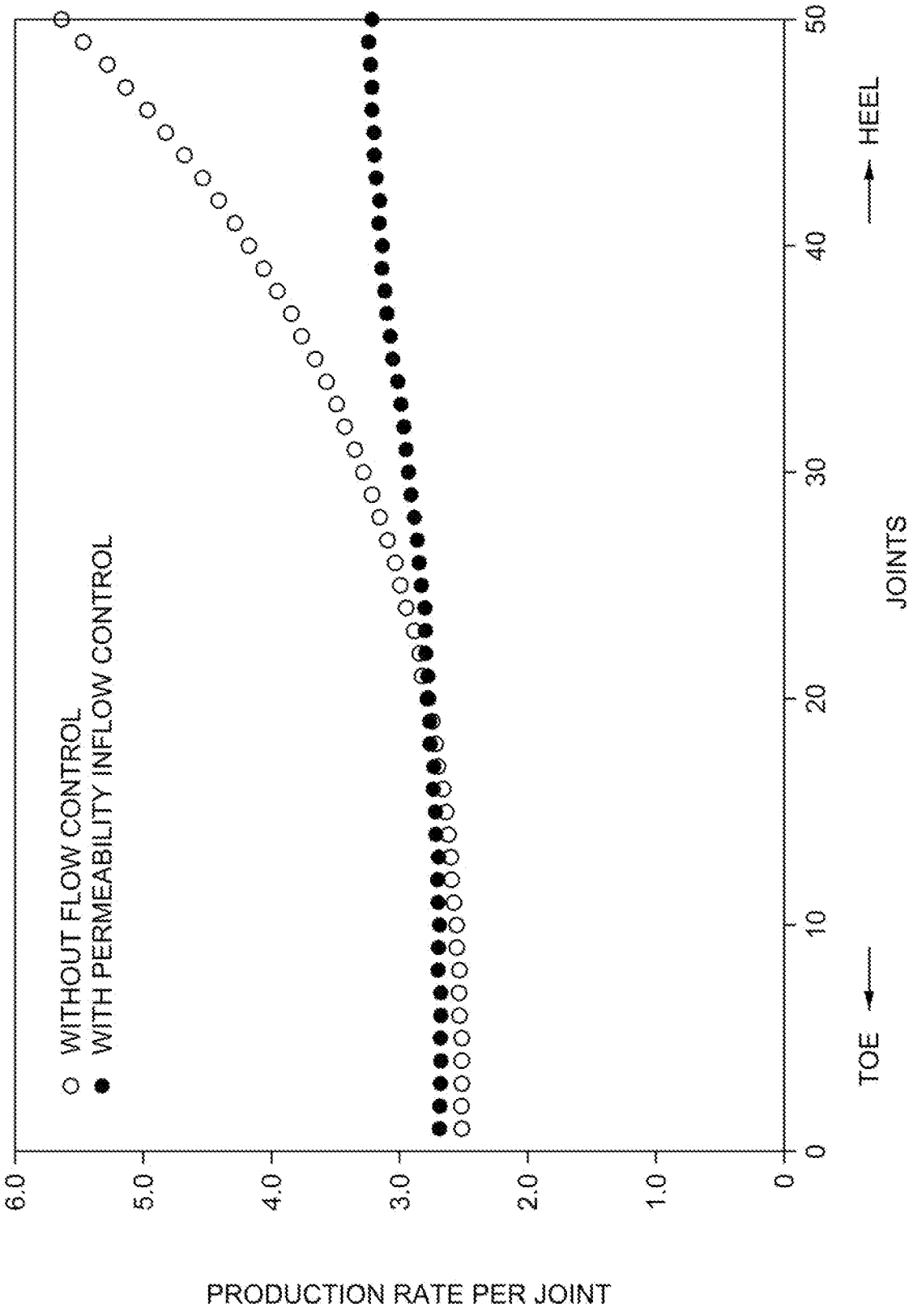

WITHOUT FLOW CONTROL
WITH PERMEABILITY INFLOW CONTROL
PRODUCTION RATE PER JOINT
6.0
5.0
4.0
3.0
2.0
1.0
0
0
10
20
30
40
50
JOINTS
TOE
HEEL

Fig. 2