A thermal recovery method employing an electrical pre-heating method to condition the hydrocarbon-bearing formation as a means of improving recovery when steam injection is later applied. In addition, a method of comparing the applied electrical flux and resulting temperature profile to determine the heat transfer properties of each of a plurality of reservoir regions along the length of a horizontal well is disclosed. Advantageously, the heat flux supplied to each of the regions may be varied relative to each other region to compensate for different thermal transfer properties which may exist in the formation within each of the regions. Such controlled variation in thermal energy transfer, compensating for variances in fluid mobility and thermal properties in the reservoir allows for a more even steam chamber development and therefore optimized oil recovery.
FIG. 14
drilling a first horizontal wellbore in hydrocarbon-containing formation

drillin a first horizontal wellbore in hydrocarbon-containing formation

positioning electric heating elements proximate said horizontal wellbore, wherein
the heating elements are capable of providing adjustably-variable quantities of heat
to a corresponding plurality of distinct regions within the formation

positioning temperature sensing means at a location within each of the distinct
regions proximate a corresponding heating element

applying electric current to the heating elements

monitoring sensed temperatures of each of the distinct regions

upon a maximum upper temperature limit first being reached in a given region,
adjusting electric power to the corresponding heating element for said given region
to maintain a sensed temperature at said maximum upper temperature limit over a
period of time

adjusting electric power supplied to the other heating elements to a value less than
the value of electric power being supplied to the heating element corresponding to
the given region, for said period of time

FIG. 18
drilling a first horizontal wellbore in hydrocarbon-containing formation

positioning electric heating elements proximate said horizontal wellbore, wherein the heating elements are capable of providing adjustably-variable quantities of heat to a corresponding plurality of distinct regions within the formation

applying electric current to the heating elements

monitoring sensed temperatures of each of the distinct regions

controlling electric power supplied to each of said heating elements to ensure that said sensed temperatures at any of said locations do not exceed a maximum upper temperature limit

maintaining, via control of electric power supplied to an associated heating element, said maximum upper temperature limit as said location in at least one distinct region, for a period of time

after expiry of said period of time, injecting pressurized steam into the plurality of distinct regions; and

recoverying heated oil which drains downwardly from said plurality of regions

FIG. 19
ELECTRICAL HEATING METHOD FOR A HYDROCARBON FORMATION, AND IMPROVED THERMAL RECOVERY METHOD USING ELECTRICAL PRE-HEATING METHOD

FIELD OF THE INVENTION

The invention relates to an improved thermal recovery method employing an electrical pre-heating method to condition a hydrocarbon-bearing formation as a means of improving recovery when steam injection is later applied. The invention also relates to an improved (optimized) method per se of electrically heating oil in a formation.

BACKGROUND OF THE INVENTION AND DESCRIPTION OF THE PRIOR ART

Each of U.S. Pat. No. 6,612,808 and similar corresponding PCT application WO 1998/058156, each to Isted, R.E., entitled “Method and Apparatus for Subterranean Thermal Conditioning” and “Method and Apparatus for Subterranean Magnetic Induction Heating”, respectively, teach a method and apparatus for heating oil in a hydrocarbon-containing formation using magnetic induction heating elements to thereby mobilize oil within the formation for subsequent gravity drainage. No subsequent steam heating is disclosed.

Moreover, with regard to the manner of electrical heating, each teaching transducers at selected positions along a magnetic heating induction apparatus, so that temperature may be sensed and the output and waveform supplied to such induction heating apparatus may be adjusted “in accordance with control programs contained within the PCU computer and micro controllers.” No particular manner, however, of heating (i.e. controlling the induction heating elements to differently heat different parts of the hydrocarbon-containing formation) is disclosed or taught, nor any advantages suggested for any particular heating regime.

In this regard, PCT WO 1998/058156, at page 17, teaches that “temperatures and pressures and such other signals as may be connected . . . may be sensed . . . . One or more pressure transducers may be sensed to indicate pressure at selected locations and said instrument outputs a sequential series of signals which travel on the power supply wire(s) to the PCU wherein the signal is received and interpreted. Said information may then be used to provide operational control and adjust the output and wave shape to affect the desired output [of the magnetic induction heaters] in accordance with control programs contained within the PCU computer and micro controllers”.

To similar effect, U.S. Pat. No. 6,612,808 at col. 8, lines 48-52, and at col. 9, lines 47-63 similarly teaches, respectively, that:

“magnetic induction assembly 26 works in conjunction with a Power Conditioning Unit (PCU) 80 located at surface. PCU 80 utilizes single and multiphase electrical energy either as supplied from electrical systems or portable generators to provide modified output waves for magnetic induction assembly 26. The output wave selected is dependent upon the intended application. Square wave forms have been found to be most beneficial in producing heat. Maximum inductive heating is realized from waves having rapid current changes (at a given frequency) such that the generation of square or sharp crested waves are desirable for heating purposes.”

PCU 80, commences to sense, in a sequential manner, the electrical values of a multiplicity of transducers 102 located at selected positions along magnetic induction apparatus 20 such that temperatures and pressures and such other signals as may be connected at those locations may be sensed and as part of the same sequence. One or more pressure transducers may be sensed to indicate pressure at selected locations and said instrument outputs a sequential series of signals which travel on the power supply wire(s) to the PCU wherein the signal is received and interpreted. Said information may then be used to provide operational control and adjust the output and wave shape to affect the desired output in accordance with control programs contained within the PCU computer and micro controllers.

Notably, however, such prior art apparatus and methods when practically employed do in fact utilize a particular heating regime, namely a heating regime which applies electrical energy to the induction heating elements located along a well in the formation in a manner so as to maintain a constant temperature at each of the temperature-sensing locations. Such is further confirmed in a subsequently published article co-authored by Isted, R. E. (see footnote 2 herein, infra), wherein at page 3 thereof it is stated that: “The principal control strategy used to-date is to maintain a constant temperature at the wellbore annulus (in the vicinity of the inductors as measured by several temperature sensors deployed within the inductor assembly”.

As further explained below, the inventor has discovered that such prior art heating method of heating to constant temperature at the magnetic induction heating elements fails to optimize heating (and thus conform subsequent steam chamber development) throughout the formation, and instead applies excessive heat to areas which may not need it and/or insufficient heat to regions which do need such heat to fully condition the reservoir for optimal steam chamber development in such particular region.

SUMMARY OF THE INVENTION

As noted above under “Field of the Invention” herein, the invention in one aspect thereof relates to an electrical pre-heating step for heating oil within a formation as a way of improving mobility of oil and thus oil recovery when thermal recovery methods such as SAGD (Steam Assisted Gravity Drainage) are subsequently applied.

In this regard, it has been surprisingly discovered that by heating oil in a formation using electrical heating in a particular manner before applying thermal recovery methods such as SAGD (Steam Assisted Gravity Drainage) an improvement in the profile of the steam chamber development can be obtained as compared to thermal methods without electrical pre-heating.

The invention advantageously allows for application of different amounts of heat flux and different temperatures to different regions of the formation, alone or in combination with application of heat at temperatures above the saturated temperature of steam for a given pressure thereby allowing supply of superheated steam, by applying greater
electrical power, or greater temperature gradient, to regions of the formation having lower heat transfer properties, so as to initially better conform the mobility of the totality of fluids (oil and water) in the formation, and then subsequently subjecting the formation to steam injection or circulation.

Specifically, it is generally known that electrical heating of the wellbore relies solely on thermal conduction and natural convection to transfer heat to the surrounding reservoir, whereas steam injection, whether in a direct injection mode ("bullheading") or in a circulation mode, wherein the condensed steam may return to the surface, relies not only in the ability to transfer heat through thermal conduction and natural convection but, due to pressure difference between the wellbore and formation, penetrates into the formation by forced convection which is of a greater heat transfer rate than conduction and natural convection alone.

Due to this generally higher heat transfer rate, steam injection is usually acknowledged as being in most instances preferable to electrical heating methods for heating oil in underground formations for subsequent recovery.

Surprisingly, however, and very counter-intuitively, in one aspect of the invention of initially pre-heating a formation by electrical heating methods, by heating the well to temperatures above those attainable with steam due to pressure limitations, and by applying more electric power to zones with less potential for forced convection, largely due to less water in those reservoir region, and subsequently applying steam, produces better heat and temperature penetration throughout all regions of the formation than thermal methods which merely use steam injection without any electrical pre-heating treatment of the formation.

Accordingly, in a broad aspect of the present invention, such invention comprises a method for better conforming the total fluid mobility and therefore the steam chamber development within a plurality of distinct regions within a hydrocarbon-containing formation using electric pre-heating and thereafter injecting steam or water which turns to steam into said regions and recovering oil therefrom, comprising the steps of:

(i) drilling a first horizontal wellbore in said hydrocarbon-containing formation;

(ii) positioning electric heating means within or above said first horizontal wellbore, said electric heating means comprising a plurality of heating elements capable of providing adjustable-variable quantities of heat to a corresponding distinct region of said plurality of distinct regions within said formation;

(iii) positioning temperature sensing means at a location within each of said distinct regions proximate, or at a spaced distance from, a corresponding heating element for each distinct region;

(iv) providing electrical current to said heating elements;

(v) monitoring, via said temperature sensing means, sensed temperatures of said distinct regions at said locations;

(vi) maintaining, via control of electric power supplied to said associated heating element, said maximum upper temperature limit at said location in said associated region, for a period of time;

(vii) after expiry of said period of time, injecting steam or water which turns to steam into said plurality of distinct regions; and

(viii) recovering heated oil from said plurality of regions.

In a further preferred refinement, the advantages of which are further explained below, such above method further comprises the steps of:

(a) upon said maximum upper temperature limit first being reached in a given region or regions, adjusting said electric power to said heating element for said given region or regions to maintain said maximum upper temperature limit at said location in said region or regions over said period of time; and

(b) adjusting electric power supplied to said other heating elements to a value less than said value of electric power then being supplied to said heating element associated with said given region or regions.

In an alternative refinement to the above method, the advantages of which are likewise explained below, such method further comprises the steps of:

(a) upon said maximum upper temperature limit first being reached in a given region or regions, adjusting said electric power to said heating element for said given region or regions to maintain said maximum upper temperature limit in said given region or regions over period of time; and

(b) adjusting electric power supplied to said other heating elements to provide a temperature as sensed by said temperature sensing means less than said maximum upper temperature limit.

As suggested by the above two refinements, the invention also relates to a specific improvement to prior art electrical heating methods per se, which employs an optimized manner of distributing electrical power to the heating elements and thus for applying optimum temperature gradient for sufficiently heating all oil in a hydrocarbon-containing formation, as opposed to prior art electrical heating methods which typically only regulate electrical power so as to maintain a constant maximum temperature to all electrical heating elements. Disadvantageously with such prior art methods, due to a heavier "heating load" being sensed by the inductive heating elements in regions having higher heat transfer properties (due to the lower temperature of such heating elements due to heat being more rapidly drawn away therefrom), by such prior art methods keeping the temperatures of all inductive elements constant (i.e. equal) such prior art methods and systems actually supply more electrical power to such regions of the formation having higher heat transfer properties (largely due to higher water saturation) than to regions of the formation which have lower heat transfer properties (largely due to lower water saturation), which is precisely the opposite of what is needed to achieve sufficient heat penetration in regions of low heat transfer properties which require a higher temperature gradient to achieve the temperature penetration, whereas other areas having higher heat transfer properties do not need as much thermal energy supplied to them.

Accordingly, and in addition, the present invention relates to a new optimized electrical method per se for heating oil in a hydrocarbon formation and when so heating doing so in a manner so as to obtain better thermal penetration in
regions having poor heat transfer properties (where temperatures at locations within such regions proximate the heating elements in such region rise rapidly to high values due to poor heat transfer of heat away from such locations) so as to more uniformly conform the mobility of the totality of fluids within all regions of the formation along a horizontal wellbore. Such improved electrical heating method makes use of unique capabilities of electrical heating methods, namely the ability to apply heat at temperatures above the saturated steam conditions at the pressure of the well, the ability to vary heat applied to different regions of a formation, and in particular the ability to vary the temperature gradient applied to different regions of the formation.

[0035] In this regard, most hydrocarbon-containing formations tend to some degree to be non-homogeneous and accordingly typically have varying degrees of heat transfer properties throughout the formation. Specifically, geological factors such as different water saturation levels, different density, different rock composition and porosity, all produce non-homogeneity within a formation and all to greater or lesser extent directly affect the heat transfer properties of individual regions within a formation. Accordingly, due to differences in heat transfer properties of the various regions in a formation, the heat flux necessary to be supplied so as to cause heat to be transferred through a region of the formation during a given time interval to thereby raise the temperature throughout such region so as to mobilize all fluids in such region will vary from region to region within the formation.

[0036] Accordingly, by adjusting, using electrical heating methods, the heat flux and in particular the temperature gradient supplied to each region in a formation in accordance with the specific methods of the present invention, namely in a manner that applies the maximum electrical power and thus maximum temperature gradient at locations where temperatures in a region near an induction heating element rise the quickest (indicating poor heat transfer in the region), and reducing the thermal gradient at other regions having lower sensed temperatures (indicating higher heat transfer rates) the invention optimizes the heat applied to the formation and is able to thereby take advantage of the ability of electrical heating to apply greater temperatures (and thus temperature gradients) to regions of the formation where heat transfer is poor, to thus ensure similar extent of heat penetration occurs in such regions as compared to other regions of the formation which may, due to better heat transfer properties, merely require lower temperature gradients to achieve the same degree of temperature penetration. This variable allocation of heat cannot be achieved by steam injection, which injects at a single temperature and which by virtue of being a flowing fluid will penetrate directly into the regions which have the higher water mobility and by the resultant added forced convection exacerbate the problem of uneven heating of the reservoir regions with higher heat transfer properties.

[0037] Such method thus allows supplying greater heat flux to regions having poor heat transfer properties to obtain sufficient penetration to raise temperatures in such regions to the minimum temperature to achieve fluid mobility, and conversely avoids supplying excess quantities of heat to regions of high heat transfer properties which do not need as high a temperature gradient to achieve sufficient temperature penetration and mobility of all oil in such regions. Thus the total amount of electrical energy supplied to the regions in the formation is most efficiently allocated and optimized to achieve the necessary mobilization of all oil throughout the formation, thus avoiding problems of prior art methods of either oversupplying heat to areas having high heat transfer properties where such quantity of heat is not needed and/or the further problem of failing to supply adequate temperature gradient to regions of the formation having low heat transfer properties to mobilize all the oil in such regions.

[0038] Thus in the electrical method of heating of the present invention the electrical heat energy supplied to the formation is optimized to achieve conformed thermal conditioning for subsequent thermal recovery throughout the formation, but without excess application resulting in a savings of heat energy as compared to prior art methods which oversupply certain regions and/or undersupply other regions.

[0039] Accordingly, in an additional second aspect of the present invention, such invention comprises a method for conforming thermal conditioning within a plurality of distinct regions within a hydrocarbon-containing formation using electric heating, comprising the steps of:

[0040] (i) drilling a first horizontal wellbore in said hydrocarbon-containing formation;

[0041] (ii) positioning electric heating means within, above, or proximate said first horizontal wellbore, said electric heating means comprising a plurality of heating elements, each of said plurality of heating elements capable of providing an adjustable-variable quantity of heat to a corresponding distinct region of said plurality of distinct regions within said formation;

[0042] (iii) applying electrical power to said heating elements;

[0043] (iv) monitoring, via temperature sensing means positioned at a location within each of said distinct regions proximate, or at, a corresponding heating element for each distinct region, sensed temperatures at each said distinct region at said locations;

[0044] (v) upon a maximum upper temperature limit first being reached in a given region, adjusting electric power to said heating element for said given region to maintain a sensed temperature from said given region at said maximum upper temperature limit over a period of time; and

[0045] (vi) adjusting electric power supplied to said other heating elements to a value less than said value of electric power being supplied to said heating element corresponding to said given region, for said period of time.

[0046] In a further refinement of either the first or second aspects of the invention, the electric heating means (typically resistive heating element or inductive heating elements) are positioned above the first horizontal wellbore, and such methods further comprise the steps of:

[0047] (a) drilling a second horizontal wellbore in said hydrocarbon-containing formation, vertically spaced above and parallel to said first horizontal wellbore and extending through or proximate each of said distinct regions;

[0048] (b) positioning said electric heating elements within or proximate the second horizontal wellbore, each of the distinct regions located proximate to and along said second horizontal wellbore, and

[0049] (c) recovering heated oil from the plurality of regions in said first horizontal wellbore.

[0050] In a further refinement of the second aspect of the present invention, such method further comprises the subsequent steps of:
[0051] injecting steam or water which turns to steam into said plurality of distinct regions; and

[0052] recovering heated oil from said regions, such as oil which drains downwardly.

[0053] The electrical heating elements of the electrical heating means may comprise an electrically resistive heating element or elements, microwave heating elements, electrodes which use the resistance of the formation for heating, tubular magnetic induction apparatus, or other electrical heating means well known to persons of skill in the art. However, in a preferred embodiment, the electrical heating means used in the methods of the present invention comprises magnetic induction heating elements such as the type disclosed in U.S. Pat. No. 6,112,808, and the electrical energy being supplied thereto comprises an alternating electrical current.

[0054] Specifically, in a preferred embodiment, the electrical heating means comprises magnetic induction elements such as Triflux™ magnetic induction heating apparatus as supplied by Tesla Industries Inc. of Calgary, Alberta, which are joined together as part of a magnetic induction assembly and inserted within or adjacent to a ferromagnetic well casing, wherein the magnetic induction apparatus, when single phase or 3-phase electrical current is applied thereto, which induces a current in the adjacent ferromagnetic well casing of a wellbore and through electrical resistance and hysteresis such casing is caused to be heated thereby heating oil within surrounding regions of the formation.

[0055] The individual magnetic induction elements contained in a magnetic induction assembly are all capable of having the current supplied to each induction element separately controlled and regulated, so that different heat flux (output) can be obtained from one heating element to supply different heat to an associated region as compared to another heating element in the magnetic induction assembly supplying heat to another associated region. Alternatively, a single magnetic induction heating assembly may be used to heat each region, with the current, waveform, frequency and the like supplied to each magnetic induction assembly being capable of being independently controlled so that the electrical energy supplied to each magnetic induction element may be individually controlled so as to allow different amounts of heat to be applied to one region in the formation as compared to another or other regions in the formation.

[0056] In a preferred embodiment of the methods of the present invention, the electrical heating elements each comprise a magnetic induction heating element, wherein electrical energy being supplied thereto comprises an alternating electrical current, and wherein the plurality of induction heating elements are positioned proximate, and along, portions of a horizonal wellbore, and wherein the electrical energy, frequency, and/or waveform supplied to each individual magnetic induction apparatus can be individually controlled so as to adjust the heat output or temperature supplied to one region in the formation relative to other regions of the formation.

[0057] Electrical regulating apparatus for controlling the electrical power supplied to the magnetic heating elements may comprise a Power Conditioning Unit ("PCU") of the type known in the art for controlling such variables as the amplitude, phase, wave form, frequency, voltage, and amperage of the electrical current supplied to the electrical heating means, and may include such electrical regulating apparatus such as a Silicon Controlled Rectifier (SCR) and/or Insulated Gate Bipolar Transistor (IGBT) which are controlled by a PC computer-based control system to permit individual control of quantum and form of electrical energy supplied to the various heating elements situated downhole in proximity to (i.e. within or closely associated with) each region, as known in the art.

[0058] As mentioned in above in the “Background of the Invention and Description of the Prior Art”, PCU control devices disclosed in U.S. Pat. No. 6,112,808 and WO 1998/0518156 each to Isted, R. E. have been used as part of a system, mounted external to the well at surface, to vary the quantum and form of electrical power being supplied to heating elements downhole, based on a control strategy programmed into a PC computer comprising a part of the PCU. Such heating elements have only been controlled in the prior art, however, for maintaining maximum temperature, and no more, at each of the heating elements, and have not been controlled in the manner of the present invention to optimize the total fluid mobility in the formation in the above-described manners. Specifically, with respect to such prior art systems, the principal control strategy used by such prior art PCU control units has been to supply electrical energy to the induction heating elements so as to maintain a constant temperature in the vicinity of each of the heating elements as measured by temperature sensors deployed within the magnetic inductor assembly.²


[0059] Importantly, however, for non-homogenous formations, the temperature of an induction heating element associated with a particular region tends to be lower for regions which, due to high water saturation, are highly thermally transmissive and which rapidly transfer heat away from the associated inductive heating element, thus lowering the temperature at the inductive heating element. In contrast, the temperature of inductive heating elements remains higher for regions of low water saturation, namely regions which have low thermal convectivity, as the loss of heat from the inductive heating element is less and thus the temperature proximate such heating element remains higher. Accordingly, and disadvantageously, such prior art methods and PCU controllers by endeavoring to maintain inductive heating elements each at a constant temperature inadvertently end up supplying greater electrical power and thus heat to thermally conductive regions in a formation resulting in unintended oversupply of heat to such regions. Such heat may be transferred by conduction and/or convection to areas outside the “pay zone” which bear little or no oil. Conversely, they fail to supplying relatively more electrical energy to regions of lesser thermal transmissivity, and thus insufficiently heat all areas of such regions to a temperature sufficient to mobilize all oil in such regions and properly condition the region for thermal recovery methods.

[0060] The within inventor has realized that the aforesaid prior art system and method typically causes areas of low heat transfer properties receiving less heat than is necessary to raise the temperature within an associated region to a temperature sufficient to cause mobility and flow of oil therein, and conversely supply an excess of heat to regions of high thermal convectivity. Such methods are thus wasteful of the heat supplied and do not optimally condition the reservoir for subsequent thermal recovery techniques such as SAGD.
Accordingly, in the methods of the present invention for use in non-homogenous formations (which is nearly all hydrocarbon-containing formations to a greater or lesser extent), the inventor has advantageously provided, as noted above, a method to correct for heat wastage and avoid non-mobility of oil in one or more regions of a formation under development.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and permutations and combinations of the invention will now appear from the above and from the following detailed description of the various particular embodiments of the invention taken together with the accompanying drawings, each of which are intended to be non-limiting, in which:

FIG. 1 is a schematic representation of the prior art electrical heating method for heating oil within a formation having, for illustration purposes, three (3) discrete areas of different heat transfer properties, by locating magnetic induction heating elements within a wellbore and applying electric power to attain equal temperature at each of the magnetic induction heating elements [arbiterary values of 385° F. (196° C.) illustrated];

FIG. 2 is a schematic representation of an electrical heating method of the present invention, using heating elements located within or proximate to a wellbore, and applying the greatest heat to regions in which temperature proximate the heating elements is greatest, or the temperature rise is greatest;

FIG. 3 is a schematic representation of a further aspect of an electrical heating method of the present invention, using a plurality of vertical wells along which electrical heating elements are positioned, wherein oil is collected by a horizontal collector well;

FIG. 4 is a schematic representation of a further aspect of an electrical heating method of the invention, using a pair of horizontal wells, and a plurality of heating elements positioned in a first upper horizontal well;

FIG. 5 is a schematic representation of a further aspect of an electrical heating method of the invention, namely using a SAGD well pair, and inserting electrical heating elements in each of said well pair and pre-heating the formation by applying more heat to areas which have a high rate of temperature increase, and subsequently injecting steam in the upper of the well pair and collecting heated oil which drains into the lower horizontal well of the well pair; and

FIG. 6 is a schematic representation of the SAGD well pair shown in FIG. 5, during the step of subsequently injecting steam in the upper of the well pair and collecting heated oil which drains into the lower horizontal well of the well pair;

FIG. 7 shows a cross-sectional view through a modelled hydrocarbon formation of 850 m length with two horizontal wells, prior to steam heating, having three separate areas of different water saturation (see legend, right hand side), namely 7%, 22%, 15%, progressing from left to right;

FIG. 8 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 7, overlaid on a temperature grid (see legend, right hand side), after 1 month of steam heating via each of the two wells shown, using steam injection at a rate of 95 m³/day/well, showing temperatures in each of the three segments of the formation;

FIG. 9 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 8, after 2 months of steam heating via each of the two wells shown, using steam injection at a rate of 95 m³/day/well, showing temperatures in each of the three segments of the formation;

FIG. 10 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 9, after 3 months of steam heating via each of the two wells shown, using steam injection at a rate of 95 m³/day/well, showing temperatures in each of the three segments of the formation;

FIG. 11 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 10, after 3 months of steam heating via each of the two wells shown, using steam injection at a rate of 95 m³/day/well, and after 2.5 months of production from the bottom of the two wells; showing temperatures in each of the three segments of the formation, with operating pressure of 1750 kPa;

FIG. 12 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 7, showing two well each having therein 3 segment electrical heaters; each segment heater operating at a temperature of 350° C, after 1 month;

FIG. 13 shows the modelled hydrocarbon formation of FIG. 12, after each segment has been operating at a temperature of 350° C, after 2 months;

FIG. 14 shows the modelled hydrocarbon formation of FIG. 13, after each segment has been operating at a temperature of 350° C, after 3 months;

FIG. 15 shows the modelled hydrocarbon formation of FIG. 14, after 3 months electrical heating at 350° C, and after 2.5 months of production from the bottom of the two wells; showing temperatures in each of the three segments of the formation, with operating pressure of 1750 kPa;

FIG. 16 shows a similar cross-sectional view through the modelled hydrocarbon formation of FIG. 7, showing two well each having therein 3 segment electrical heaters; each segment heater operating at an optimized temperature as per the method of the present invention, namely 400° C, 50° C, and 300° C. (left to right), after 3 months;

FIG. 17 shows the modelled hydrocarbon formation of FIG. 16, after a further 2.5 months of steam injection through the top well, and production through the bottom well, again with an operating pressure of 1750 kPa;

FIG. 18 is a flow diagram showing the optimized electrical pre-heating method of the present invention, using optimized allocating of electrical heating, for conforming mobility of oil within regions of a hydrocarbon formation for subsequent recovery using gravity drainage; and

FIG. 19 is a further flow diagram showing another embodiment of the method of the present invention, teaching steps for electrical pre-heating followed by steam injection.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Identical reference numerals appearing in the various drawings figures herein are intended to denote identical features/elements.

FIG. 1 shows a prior art electrical heating method of the prior art applied to an underground hydrocarbon-containing formation 10, which method employs a plurality of electrical heating elements namely induction heating elements 12 for heating oil within various regions 13, 15, and 17 of a hydrocarbon containing formation 10, for subsequent collect-
tion in a collector well 20. The heating elements 12 are typically arranged along or in close proximity to wellbore liner 30 of collector well 20.

[0084] Electrical power supply cord, such as an ESP electrical supply cable 40, extends from an electrical power source 50 to provide electrical power to each of the heating elements 12. Electrical power is supplied via supply cable 40 to each of heating elements 12, and heat emanating therefrom heats oil in each of various regions 11, 13, and 15 of underground hydrocarbon formation 10, which heated oil is then collected in collector well 20.

[0085] In the specific example shown in FIG. 1, such depicts, for illustrative purposes, a non-homogeneous formation 10 wherein various regions 11, 13, and 15 thereof formation are cross-hatched in different manners to indicate different geologic formations and composition of rock therein, and thus different thermal heat transfer properties for each of regions 11, 13, and 15, with region 11 having the lowest heat transfer properties of the three regions, region 13 having the highest heat transfer properties, and region 15 having an intermediate value.

[0086] A plurality of temperature sensors 25, 25", 25", 25", 25", typically high temperature thermocouples, are situated in the inductive heating elements 12 or along wellbore liner 30, to allow temperatures at such locations to be sensed and such temperature values transmitted via a sensor cable 42 to a Power Control Unit ("PCU") 52, which senses such temperatures and individually controls electrical power source 50 (via cable 45) to regulate electrical power being individually supplied via power source 50 to each of heating elements 12.

[0087] The above electrical method of heating of the prior art tended to apply power to each heating element 12 to allow such heating elements 12 to reach a maximum permitted temperature, namely a temperature which would not exceed a certain value which otherwise cause damage by over-temperature to electrical wiring and insulation surrounding such electrical cables 40 and 42.

[0088] Disadvantageously with the prior art method of FIG. 1, the inventor has realized that for regions within formation 10 of high heat transfer properties, such as region 13, the corresponding temperature sensor 25" for region 13 will, due to high heat loss through region 13, indicate a lower temperature than, for example temperature sensor 25" for associated region 11, which due to lower heat transfer properties of the surrounding region 11 will thus typically have a higher value and a more rapid rate of temperature increase. Accordingly, as a result of temperature of sensor 25" indicating such higher temperature and rate of increase and being sensed by PCU 52, PCU 52 will then cause electrical power supply 50 to limit electrical power to corresponding heating element 12 for region 11, to prevent the maximum temperature limit being exceeded at such location. Conversely, because regions 13 & 15 have higher heat transfer properties and due to heat being more rapidly transferred away, the corresponding temperature sensors 25" and 25" for such regions will typically indicate a lower temperature, and thus high amounts of electrical power will continuously be supplied by PCU 52 and power supply 50. Such therefore results in greater heat flux being supplied to regions 13, 15 as compared to region 11, if temperatures at each element are to be constant, to raise temperatures of regions 13, 15 to the constant maximum temperature, which for illustrative purposes was assumed to be 385° F. (196° C.) as shown in FIG. 1. Thus for constant temperature of 385° F. (196° C.) being maintained by heating elements 12 at all locations, due to the highest amount of heat flux being supplied to region 13, and the lowest amount of heat flux being supplied to region 11, temperatures at extremities of each of the respective regions 11, 13, and 15 will differ, and for illustrative purposes, are shown in FIG. 1 to be 75° F., 250° F., and 225° F. (24° C., 121° C., and 107° C. respectively) in each of respective regions 11, 13, and 15.

[0089] Thus, in such method of FIG. 1, if oil is required to be heated to a temperature of 230° F. (110° C.) to become mobile, oil will have no mobility in certain areas of region 11 resulting in poor recovery of oil from region 11, and will be excessively overheated in region 13, resulting in inefficient allocation of heat.

[0090] FIG. 2 shows an electric heating method of the present invention for heating oil in a formation 10, having similar components to the schematic arrangement shown in FIG. 1. Such method is graphically depicted in FIG. 18, in steps 103-113 thereof.

[0091] For ensuring adequate temperature penetration to all areas within regions 11, 13, and 15 of formation 10, including to all areas within region 11 which has low thermal heat transfer properties, the method of the present invention provides in one aspect as follows. Specifically, when temperature sensors 25, 25", 25", and 25" at a point in time (during transfer of heat from heating elements 12 when provided with equal power from power source 50) indicate that a maximum temperature limit [say 400° F. (204° C.)] is first reached in region 11, it can thus then be recognized that such region 11 is a region of low heat transfer properties, and the highest maximum temperature need be retained in such region 11 by PCU 52 in order to obtain the greatest temperature gradient in such region. Thus, for example, as shown for illustrative purposes in FIG. 2, if when equal power is initially supplied over a period of time to regions 11, 13, and 15 and a maximum temperature of 400° F. (204° C.) is first reached at location of temperature sensor 25 in region 11, provided such maximum temperature produces a temperature gradient sufficient to cause temperature penetration to an extent that oil will be heated to a sufficient temperature [say 250° F. (121° C.)] within all areas of region 11, then penetration to a distance greater than such fixed distance of such temperature will have resulted at such point in time in other regions 13, 15 having greater thermal conductivity. Thus from such point in time onward less electrical energy can be supplied to areas 13 and 15 than originally supplied to such regions, if it is not desired to achieve any greater degree of temperature penetration in such regions greater than that which will be obtained in region 11. In other words, for illustrative purposes as shown in FIG. 2, if a maximum temperature is first reached in region 11 of 400° F. (204° C.) when applying equal amounts of power to regions 11, 13, and 15, from such point in time the lesser temperatures as reached at such point in time in other regions 13 and 15 may be thereafter maintained [say 350° F. (176° C.)] and 385° F. (196° C.), respectively, and thermal penetration in such regions will be approximately equal to the depth of thermal penetration as reached in region 11.

[0092] FIG. 3 shows an alternative configuration of a gravity drainage system for practising the method of electrically heating of the present invention, where heating elements 12 are vertically disposed within juxtaposed vertical wellbores 50, 50", and 50", and respective PCU’s 52, 52", and 52" sense temperatures from respective temperature sensors 25", 25", 26", 26", 27", and 27", & 27", and regulate electrical power to such elements being supplied by electrical
power supply 50 in accordance with the above method of the present invention. Collector well 20 collects heated oil which drains and into such well 20 through wellbore liners 30.

FIG. 4 shows an electrical pre-heating step in accordance with the method of the present invention being applied to a SAGD pair of wells, such SAGD well pair comprising a first lower horizontal collector well 20 and a second upper horizontal injector well 70, which extend through regions 11, 13, and 15 of a hydrocarbon-containing formation 10. Such method is graphically depicted in FIG. 19, in steps 201-215 thereof.

Each well 20, 70 preferentially has a corresponding porous well liner 30a, 30b, respectively.

In accordance with the electrical pre-heating method for a SAGD recovery, a first lower horizontal well 20 and a second upper horizontal well 70 are drilled. Electric magnetic induction heating elements 12 are uniformly spaced along, and within or proximate to, said second horizontal well 70.

Temperature sensing means, such as thermocouple temperature sensors 25', 25'', and 25'''', are positioned at locations proximate to or at a spaced distance from a corresponding heating element 12 for each associated region 11, 13, and 15 through which well 70 traverses.

For example, equal electrical power is provided individually to elements 12 via power supply 50. Temperatures at the various locations of sensors 25', 25'', and 25''' are monitored by PCU 52.

Upon a maximum upper temperature limit first being reached in a given region 12 and being sensed by PCU 52, PCU 52 via line 45 controls power supply 50 to regulate electrical power to associated heating element 12 for region 11 to maintain said maximum upper temperature limit [for illustrative purposes 400°F (204°C)] in said given region 11 over a period of time. PCU at such time further regulates electric power supply 50 via cable 45 to regulate power being supplied to remaining heating elements 12 associated with remaining regions 13, 15 to provide and maintain temperatures as sensed by associated sensors 25', 25'', and 25'''', respectively, at values less than the maximum upper temperature limit reached in respect of region 11, for said period of time.

Thereafter, namely after such electrical pre-heating step has been carried out for the above period of time, electrical heating elements 12 and sensors 25', 25'', 25''', and 25''' are thereafter withdrawn from well 70 (although they need not be) and steam 100 is then injected into the second well 70 and thereafter into pre-heated regions 11, 13, 15 which steam will, due to initial electrical pre-heating of regions 11, 13, and 15, more uniformly be able to conform the temperature of all oil in the regions to the minimum necessary value for oil mobility [for illustrative purposes as shown at 250°F (121°C)], and thereafter collect such oil which drains, via the direction of the arrows shown in FIG. 5, into lower horizontal collector well 20, and thereafter produced to surface.

FIG. 6 shows a further refinement to the electrical pre-heating step and subsequent SAGD steam injection method shown jointly in FIG. 4 & FIG. 5 as described above, wherein electrical magnetic induction heating elements 12 are inserted along, and proximate to or in, each of respective wells 20 and 70, along with associated temperature sensors 25', 25'', 25''', and 25'''', and the above electrical pre-heating method is carried out from each of wells 20 and 70. In this regard PCU 52 controls, via cable 45, power supply 50 to regulate electrical power supplied to heating elements 12 situated in well 70, and additional PCU 52', which senses temperatures from sensors 25', 25'', 25''', and 25''' within well 20, then controls electrical power via cable 47 the electrical power supplied individually by power supply 50 to various heating elements 12 in and along well 20, so as to electrically pre-heat more of regions 11, 13, and 15, and more uniformly conform the total mobility of the fluids in all of regions 11, 13, and 15 to a minimum temperature for mobility [shown, for illustrative purposes as 250°F (121°C)]. After a given pre-heating time, all heating elements 12 are subsequently removed from within wells 20 and 70, and thereafter steam 100 is injected in upper injection well 70 and collecting oil in well 20 which drains into well 20 is collected, as shown in FIG. 5.

Example 1

In order to confirm the positive impact of the method of the present invention, and in particular the more extensive temperature conformity throughout various regions of a non-homogenous formation for SAGD operations for which an electrical pre-heating step has been conducted, a sample formation was modelled, using the computer numerical simulation of the STARS™ Thermal Simulator 2010.12 provided by the Computer Modelling Group, Calgary, Alberta, Canada.

The modelling reservoir used in Examples 1 & 2 herein contained bitumen at 7°C, with uniform porosity (30%), but comprising three (3) distinct and separate areas 11, 13, and 15 as shown in FIGS. 1-6 herein, such regions and formation 10 having properties as shown in Table 1 below, and in particular containing, as shown in Table 1 below, initial water saturation at the heel of 7% (i.e. region 11), mid-well initial water saturation of 22% (i.e. in region 13), and initial water saturation at the toe of 15% (i.e. in region 15). Initial water saturation (from top to mid of reservoir) was modelled as being consistent at 15%.

| Table 1 |
|------------------|------------------|
| Reservoir Properties | Unit | Value |
| Pay Thickness | m | 30 |
| TVD to Reservoir TOP | m | 132 |
| Permeability | φ | 30 |
| Critical Water Saturation | % | 7 |
| Initial Water Saturation (Heel) | % | 7 |
| Initial Water Saturation (Mid-well) | % | 22 |
| Initial Water Saturation (Toe) | % | 15 |
| Initial Water Saturation (From top to mid of reservoir) | % | 15 |
| Initial Gas Saturation | % | 0 |
| Gas Mole Fraction | fraction | 0.01 |
| Horizontal Permeability | mD | 3500 |
| Vertical Permeability | mD | 2100 |
| Reservoir Temperature | °C | 7 |
| Initial Reservoir Pressure | kPa | 600 |
| Rock Compressibility | 1/kPa | 8.00E-06 |
| Rock Thermal Conductivity | J/(m·°C) | 6.00E+05 |
| Well Length | m | 850 |
| SAGD Spacing | m | 100 |
| Rock Heat Capacity | J/(m³·°C) | 2.33E+06 |
| Oil Properties | | |
| Molar Density | g/mol/m³ | 1762 |
| Viscosity, Dead Oil @ 10°C | cp | 3433933 |
| Viscosity @ 210°C | cp | 8.298 |
| MW | | 579 |
TABLE 1-continued

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mole Fraction fraction</td>
<td>0.99</td>
</tr>
<tr>
<td>Compressibility 1/kPa</td>
<td>6.84E-07</td>
</tr>
<tr>
<td>Well Control during Start-up</td>
<td></td>
</tr>
<tr>
<td>Steam Rate (CWE) per Well</td>
<td>m3/day</td>
</tr>
<tr>
<td>Steam Quality %</td>
<td></td>
</tr>
<tr>
<td>Operating Pressure kPa</td>
<td></td>
</tr>
<tr>
<td>Start-up duration month</td>
<td></td>
</tr>
<tr>
<td>Well Control during SAGD</td>
<td></td>
</tr>
<tr>
<td>Steam Quality %</td>
<td></td>
</tr>
<tr>
<td>Injection (Operating) Pressure kPa</td>
<td>1750</td>
</tr>
<tr>
<td>Producer Maximum Steam Rate (CWE) m3/day</td>
<td>1</td>
</tr>
</tbody>
</table>

In this first example, a SAGD well pair as shown in FIG. 5 was modelled, using formation properties as shown in Table 1 above. Temperature penetration was modelled for each of the three distinct regions 11, 13, and 15 after injection of steam into each of the three regions 11, 13, and 15 via the upper injector well 70 and lower horizontal collector well 20 of FIG. 5, for periods of 1 month, 2 months, and 3 months respectively, using a steam injection rate of 95 m³/day/well at 1750 kPa pressure.

Importantly, during this first example, pre-heat circulation was carried out with steam injection, with no initial electrical pre-heating, and SAGD subsequently carried out.

FIG. 7, with reference to the chart on the right hand side, shows initial water saturation in each of the 3 regions 11, 13, and 15 of 7%, 22%, and 15% respectively, thereby bestowing on each of such regions different heat transfer properties, with the region having 7% saturation having the lowest overall heat transfer character because of the lower amount of mobile water and hence less convective heat transfer component, with the mid-well region having a water saturation of 22% and thus the highest heat transfer character, and the toe region (right-hand side) having an intermediate water saturation of 15% and thus a mid-range level of heat transfer capacity.

FIG. 8 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation, after one (1) month initial steam circulation.

FIG. 9 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation after two (2) months of initial steam circulation.

FIG. 10 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation after three (3) months of initial steam circulation.

FIG. 11 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation after three (3) months of initial steam circulation, and a further 2.5 months of SAGD production where steam is continued to be injected into well 70, but production of oil is carried out from the lower production well 20.

Example 2

The same formation was modelled with two similar wells 20, 70, but with electrical heating instead of steam circulation. Such electrical heating was carried out in accordance with the prior art methods of maintaining constant temperature along the wellbores.

In this regard, the same well pair 20 and 70 were used, with three electrical heating elements 12 inserted in each of wells 20 and 70 as shown in FIG. 6, for heating respectively the three distinct regions 11, 13, and 15.

FIG. 12 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation having electrical heating within both of wells 20, 70, after 1 month.

FIG. 13 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation having electrical heating of such 3 regions from both of wells 20, 70, after 2 months.

FIG. 14 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation having electrical heating of such 3 regions within both of wells 20, 70, after 3 months.

FIG. 15 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation after three (3) months of initial steam circulation, and after a further 2.5 months of SAGD production where steam is injected into well 70 and production of oil is carried out from the lower production well 20.

Example 3

In this example the same formation was modelled with two similar wells 20, 70, but with optimized electrical pre-heating of each of the three regions 11, 13, and 15 in accordance with the method of the present invention.

Specifically, electrical heating was carried out with a maximum target temperature of 400°C in respect of region 11, a temperature of 50°C in respect of region 13 (i.e. no heating), and a target temperature of 300°C in respect of region 15.

FIG. 16 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation having such optimized electrical heating of such 3 regions within both of wells 20, 70, after 3 months.

FIG. 17 shows, with reference to the temperature correlation grid on the right hand side, the temperature distribution within the 3 regions of the modelled formation after three (3) months of optimized electrical pre-heating, and after a further 2.5 months of SAGD production where steam is injected into well 70 and production of oil is carried out from the lower production well 20.

As may be seen from FIG. 17, compared with FIG. 11 (3 months steam injection, followed by 2.5 months SAGD production) and FIG. 15 (3 months non-optimized electrical heating followed by 2.5 months of SAGD production, the temperature profile throughout regions 11, 13, and 15 is more uniform, and temperature penetration is more uniform using the method of the present invention.

The foregoing description of the disclosed embodiments is provided to enable any person skilled in the art to use the present invention. The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole. Thus, the present
invention is not intended to be limited to the embodiments shown herein, but is to be accorded the full scope consistent with the claims. Where reference is made in the claims to an element in the singular, such as by use of the article “a” or “an”, such is not intended to mean “one and only one” unless specifically so stated, but rather “one or more”.

For a complete definition of the invention and its intended scope, reference is to be made to the summary of the invention and the appended claims read together with and considered with the disclosure and drawings herein.

I claim:

1. A method for conforming the total fluid mobility within a plurality of distinct regions within a hydrocarbon-containing formation using electric pre-heating and thereafter injecting steam or water which turns to steam into said regions and recovering oil therefrom, comprising the steps of:
   (i) drilling a first horizontal wellbore in said hydrocarbon-containing formation;
   (ii) positioning electric heating means within or above said first horizontal wellbore, said electric heating means comprising a plurality of heating elements capable of providing adjustable-variable quantities of heat to a corresponding distinct region of said plurality of distinct regions within said formation;
   (iii) positioning temperature sensing means at a location within each of said distinct regions proximate to, or at a spaced distance from, a corresponding heating element for each distinct region;
   (iv) providing electrical current to said heating elements;
   (v) monitoring, via said temperature sensing means, sensed temperatures of said distinct regions at said locations;
   (vi) providing electric power to each of said heating elements so that at least one temperature sensing means indicates a maximum upper temperature limit reached for an associated region, and further controlling said electric power to ensure that said sensed temperatures at any of said locations do not exceed said maximum upper temperature limit;
   (vii) maintaining, via control of electric power supplied to said associated heating element, said maximum upper temperature limit at said location in said associated region, for a period of time;
   (viii) after expiry of said period of time, injecting steam or water which turns to steam into said plurality of distinct regions; and
   (ix) recovering heated oil from said plurality of regions.

2. The method as claimed in claim 1, further comprising the step of:
   (a) upon said maximum upper temperature limit first being reached in a given region or regions, adjusting said electric power to said heating element for said given region or regions to maintain said maximum upper temperature limit at said location in said region or regions over said period of time; and
   (b) adjusting electric power supplied to said other heating elements to a value less than said value of electric power then being supplied to said heating element associated with said given region or regions.

3. The method as claimed in claim 2, wherein up until said maximum upper temperature is first being reached in a given region or regions, all heating elements are initially supplied with equal amounts of electrical power.

4. The method as claimed in claim 1, further comprising the step of:
   (a) upon said maximum upper temperature limit first being reached in a given region or regions, adjusting said electric power to said heating element for said given region or regions to maintain said maximum upper temperature limit in said given region or regions over said period of time; and
   (b) adjusting electric power supplied to said other heating elements to provide a temperature as sensed by said temperature sensing means less than said maximum upper temperature limit.

5. The method as claimed in claim 2, wherein said electric heating means are positioned above said first horizontal wellbore; further comprising the steps of:
   (a) drilling a second horizontal wellbore in said hydrocarbon-containing formation, vertically spaced above said first horizontal wellbore and extending through or proximate each of said distinct regions;
   (b) positioning said electric heating means within or proximate said second horizontal wellbore, each of said distinct regions located proximate to and along said second horizontal wellbore;
   wherein said step of injecting said steam or water which turns to steam into said plurality of regions comprises injecting steam into said second wellbore and thereby into said distinct regions; and
   wherein said step of recovering heated oil comprises recovering heated oil from said first horizontal wellbore which drains from said plurality of regions into said first horizontal wellbore.

6. The method as claimed in claim 2, wherein said electric heating means are positioned above said first horizontal wellbore; further comprising the steps of:
   (a) drilling a second horizontal wellbore in said hydrocarbon-containing formation, vertically spaced above and parallel to said first horizontal wellbore and extending through or proximate each of said distinct regions;
   (b) positioning said electric heating means within or proximate said second horizontal wellbore, each of said distinct regions located proximate to and along said second horizontal wellbore;
   wherein said step of injecting said steam into said plurality of regions comprises injecting steam into said second wellbore and thereby into said distinct regions; and
   wherein said step of recovering heated oil comprises recovering heated oil from said first horizontal wellbore which drains from said plurality of regions into said first horizontal wellbore.

7. The method as claimed in claim 5 or 6, further comprising the steps of:
   (a) after expiry of said period of time, and prior to said step of (vii) of injecting steam into said second wellbore, withdrawing said electrical heating means from said second wellbore.

8. A method for conforming mobility of oil within a plurality of distinct regions within a hydrocarbon-containing formation using electric heating, comprising the steps of:
   (i) drilling a first horizontal wellbore in said hydrocarbon-containing formation;
   (ii) positioning electric heating means within, above, or proximate said first horizontal wellbore, said electric
heating means comprising a plurality of heating elements, each of said plurality of heating elements capable of providing adjustably-variable quantities of heat to a corresponding distinct region of said plurality of distinct regions within said formation;

(iii) positioning temperature sensing means at a location within each of said distinct regions proximate, or at, a corresponding heating element for each distinct region,

(iv) monitoring sensed temperatures of each of said distinct regions at said locations;

(v) upon a maximum upper temperature limit first being reached in a given region, adjusting electric power to said heating element for said given region to maintain a sensed temperature from said given region at said maximum upper temperature limit over a period of time; and

(vi) adjusting electric power supplied to said other heating elements to a value less than said value of electric power being supplied to said heating element corresponding to said given region, for said period of time.

9. The method as claimed in claim 8, wherein said electric heating means are positioned above said first horizontal wellbore; further comprising the steps of:

(a) drilling a second horizontal wellbore in said hydrocarbon-containing formation, vertically spaced above and parallel to said first horizontal wellbore and extending through or proximate each of said distinct regions;

(b) positioning said electric heating means within or proximate said second horizontal wellbore, each of said distinct regions located proximate to and along said second horizontal wellbore; and

(c) recovering heated oil from said first horizontal wellbore which drains from said plurality of regions into said first horizontal wellbore.

10. The method as claimed in 8 or 9, further comprising the subsequent steps of:

injecting steam into said plurality of distinct regions; and

recovering heated oil which drains to the well.

11. The method as claimed in any one of claims 2, 4 or 8, wherein:

said electrical heating means comprises magnetic induction heating means; and

said induction heating means is located in, and along, at least said portions of said first horizontal wellbore.

12. The method as claimed in any one of claims 2, 4 or 8 wherein:

said electrical heating elements each comprise a magnetic induction heating element;

each element is situated proximate, and along, a portion of said first horizontal wellbore; and

electrical power supplied to each magnetic induction element can be individually controlled so as to allow variation of adjust the heat output supplied to one region relative to heat supplied to other regions.

* * * * *