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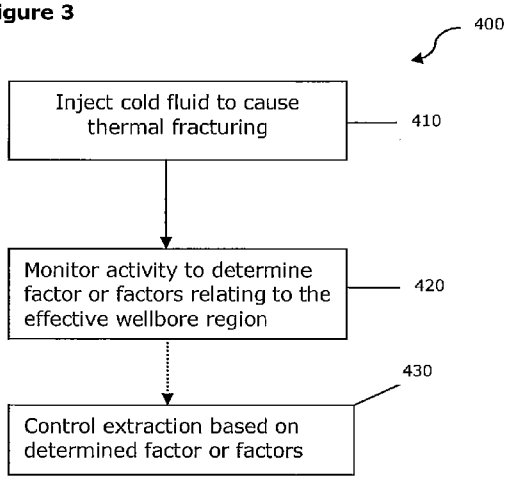
(54) Title: IMPROVED EFFECTIVE WELL-BORE DIAMETER FOR HEAT EXTRACTION

Figure 3



(57) Abstract: A method and system for determining or predicting a factor relating to an effective well-bore region, such as an effective wellbore diameter or other dimension, of an extraction well-bore of a geological or geothermal reservoir or other subsurface region, and controlling extraction of a natural resource, such as hot water from the subsurface region in accordance with the determined or predicted factor. Determination of such a factor includes analysis of the degree of permeability and/or fracture connectivity in a region surrounding the wellbore.

"IMPROVED EFFECTIVE WELL-BORE DIAMETER FOR HEAT EXTRACTION"

FIELD OF INVENTION

The invention comprises a method and system for extracting heat from a geothermal reservoir.

BACKGROUND

In the extraction of hot fluid from a geothermal reservoir, fluid from, and percolating to, the region around the wellbore enters the wellbore and is pumped to the surface where heat energy is extracted, for example in a steam turbine. If fluid or heat energy is extracted from the region around the wellbore faster than heat transfers to this region from the surrounding reservoir then the temperature of the extracted fluid will fall, which if it occurs significantly can 'take down' the well. In particular, if heat extraction from the wellbore exceeds the rate at which heat is thermally conducted from the surrounding rock to the wellbore vicinity, then the temperature of the extracted fluid will fall.

SUMMARY OF INVENTION

It is an object of the invention to provide an improved or at least alternative a method and/or system for conveying heat from the geothermal reservoir to a single wellbore in the reservoir.

In a first aspect the invention broadly comprises a method for extracting heat from a geothermal reservoir comprising the steps of:

introducing relatively cold fluid into a wellbore to cause thermal fracturing at least in a region (herein: the effective wellbore region) of the reservoir at or towards and around or adjacent an actual wellbore, and

controlling the extraction of relatively hot fluid based on a factor relating to the effective wellbore region.

In a second aspect the invention broadly comprises a method for controlling extraction of fluid from a geothermal reservoir, which comprises controlling the extraction of relatively hot fluid based on a factor relating to a larger effective wellbore region of the reservoir at or towards and around or adjacent an actual drilled bore head of the wellbore.

The factor relating to the effective wellbore region may be an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

Controlling extraction of fluid based on a factor relating to the effective wellbore region may comprise controlling the rate and/or temperature and/or pressure of fluid extraction from the well.

In accordance with the invention, the desired thermal fracturing to increase the effective wellbore region is fracture interconnectedness or connectivity throughout the rock in all directions, and/or between areas of relatively high fracture interconnectedness localised around separated defect sites in the rock, by increasing or maximising connected breakdown of cement bonds (typically silica) between harder rock particles or aggregates of particles of the rock, increasing bulk permeability through the rock. The invention in effect increases the reservoir volume from which heat can be sustainably extracted in comparison with the reservoir volume that can be sustainably supplied by thermal conduction alone.

In a third aspect the invention broadly comprises a system for extraction of geothermal energy from a geothermal reservoir, the system comprising:

a wellbore for extracting hot fluid from a reservoir, and

a geothermal plant arranged to extract hot fluid via the wellbore based on a factor relating to a larger effective wellbore region of the reservoir at or towards and around or adjacent an actual drilled bore head of the well-bore.

The factor relating to the effective wellbore region may be an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

Preferably the geothermal plant is arranged to extract hot fluid from the reservoir at a controlled rate and/or temperature and/or pressure of fluid recovery, such as a controlled rate based on a measure of the effective wellbore region to maintain a temperature or a temperature range of the extracted fluid.

In a fourth aspect the invention may broadly be said to consist of a method for extracting resource or energy from a subsurface region comprising the steps of:

determining a factor relating to an effective wellbore region, the effective wellbore region including an actual region of a wellbore and a surrounding region of fractured geological formations, and

controlling the extraction of the resource or energy based on the factor relating to the effective wellbore region.

Preferably the method further comprises the step of inducing fracturing in the surrounding wellbore region.

Preferably the step of inducing fracturing comprises introducing relatively cold fluid into the wellbore to cause thermal fracturing in the surrounding region.

Preferably the step of inducing fracturing comprises controlling any one or more of the temperature, rate and/or pressure of fluid during introduction into the wellbore.

Preferably the step of determining the factor relating to the effective wellbore region comprises estimating or assessing an effective diameter or other dimension of or relating to the effective wellbore region.

In a preferred embodiment the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

Preferably the step of controlling extraction comprises controlling extraction of fluid based on a factor relating to the effective wellbore region by controlling the rate and/or temperature and/or pressure of fluid extraction from the well.

In a fifth aspect the invention may broadly be said to consist of a system for extraction of a resource or energy from a subsurface region, the system comprising:

a wellbore for extracting a resource from a reservoir, and

a plant arranged to extract the resource via the wellbore based on a factor relating to an effective wellbore region of the reservoir, the effective wellbore region including an actual region of the wellbore and a surrounding region of fractured geological formations.

Preferably the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

Preferably the system further comprises an input wellbore for injection of relatively cold fluid into the wellbore to cause thermal fracturing in the surrounding region and wherein the plant is further configured to inject cold fluid into the input wellbore.

Preferably the plant is configured to inject the cold fluid into the input wellbore while controlling one or more of the temperature, rate and/or pressure of the cold fluid during injection.

In a preferred embodiment the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

Preferably the plant is arranged to extract hot fluid from the reservoir at a controlled rate and/or temperature and/or pressure of fluid recovery based on the factor of the effective wellbore region to maintain a property or properties of the extracted fluid.

In a sixth aspect the invention may broadly be said to consist of a control system for controlling extraction of a resource or energy through an extraction wellbore of a subsurface region comprising:

a processor configured to:

determine a factor relating to an effective wellbore region, the effective wellbore region including an actual region of the wellbore and a surrounding region of fractured geological formations, and

determine on or more control parameters for controlling the extraction of relatively hot fluid through the wellbore based on the factor relating to the effective wellbore region.

Preferably the processor is configured to receive input information relating to the fracture connectivity of the surrounding region for determining the factor relating to the effective wellbore region.

In a preferred embodiment the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

Preferably the one or more control parameters comprise any combination of one or more of the rate, temperature or pressure of fluid recovery.

Preferably the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

Typically the extraction of geothermal fluid is by pumping from the well the hot fluid which typically comprises hot liquid and/or steam, but alternatively may be by allowing and/or controlling escape of fluid under geothermal pressure.

In this specification and claims the phrase "fracture connectivity" and the term "fracture" includes both any separation or discontinuity or non-cohesiveness that divides previously cohesive geological formations such as rocks, caused by tectonics-induced tensile stress exceeding the rock strength for example, creating permeability and/or porosity, and also naturally occurring permeability and/or porosity or non-cohesiveness through rock, occurring at a grain scale for example in the rock or other geological formation.

The term "comprising" as used in this specification and claims means "consisting at least in part of". When interpreting each statement in this specification and claims that includes the term "comprising", features other than that or those prefaced by the term may also be present. Related terms such as "comprise" and "comprises" are to be interpreted in the same manner.

BRIEF DESCRIPTION OF THE FIGURES

The invention is further described with reference to the accompanying figures by way of example and without intending to be limiting, in which:

Figure 1 schematically shows a geothermal system,

Figure 2 schematically shows a wellbore indicating an actual wellbore diameter and a larger improved effective wellbore diameter, and

Figure 3 is a flow diagram of a preferred form resource extraction method of the invention.

DETAILED DESCRIPTION

In the following description, specific details are given to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, software modules, functions, circuits, etc., may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known modules, structures and techniques may not be shown in detail in order not to obscure the embodiments.

Aspects of the systems and methods described below may be operable on any type of general purpose computer system or computing device, including, but not limited to, a desktop, laptop, notebook, tablet or mobile device.

Referring to figure 1, a system 300 for extraction of natural resources from a subsurface region 200 is shown. The system 300 is, in the preferred embodiment, for extraction of hot water from a geothermal reservoir 200. It will be appreciated that in alternative embodiments, the system 300 may be utilised for extraction of other natural resources such as oil, gas or minerals from a geothermal, hydrocarbon or any other type reservoir. The system 300 comprises a plant 160 configured to at least extract a natural (hot water) resource from the (geothermal) reservoir 200 and at least an extraction wellbore extending from the surface of the earth through to the reservoir 200 and connecting to the plant 160. The plant 160 has an associated control system 170 for controlling extraction.

The region 131 of the reservoir 200 surrounding or adjacent the extraction wellbore 130 is fractured. The region 131 preferably has an increased fracture connectivity and/or permeability through induced fracturing. An effective wellbore region is defined as the combination of the actual region of the wellbore and the surrounding/adjacent region of fractured formations/rock which extends within the reservoir beyond the boundary or periphery of the wellbore 130. The control system 170 of the plant 160 is configured to control extraction of natural (hot water) resource from the reservoir 200 depending on a factor or factors relating to the effective wellbore region. Such a factor or factors may be determined by the control system 170 of the plant 160 or alternatively provided to the control system 170 prior to extraction. In the preferred embodiment, an effective diameter or other dimension associated with the effective wellbore region (different from the actual diameter or dimension defined by the physical boundary/periphery of the wellbore) is determined by the control system 170, and this effective diameter or other dimension is utilised to control extraction through the wellbore 130. The plant 160 may be arranged to extract a hot fluid from the reservoir at a controlled rate and/or temperature and/or pressure determined by the control system based on the factor relating to the effective wellbore region to maintain a parameter of the extracted fluid, such as the temperature or a temperature range of the extracted fluid or to substantially improve or maximise productivity of the plant 160.

In the preferred embodiment, the system 300 is configured to induce fracturing or increase fracture connectivity and/or permeability in the region surrounding the extraction wellbore 130 to thereby enlarge or increase the diameter or other dimension of the effective wellbore region. In particular, the system 300 is configured to induce fracturing thermally however, in alternative embodiments other fracturing techniques may be used instead. An input or injection wellbore 100 is drilled to the subterranean location of the geothermal reservoir 200. In the preferred embodiment input wellbore 100 is separate from the extraction wellbore 130, but in some

embodiments a single wellbore may be used as the input and extraction wellbore. Cold fluid 110 such as water is injected through this well-bore 100 and into the reservoir 200. The temperature of the fluid is sufficiently cool to cause thermal fracturing (as is further described) of the geological formations within the reservoir. The cold fluid injected into the wellbore 100 exits at the wellbore 100 and may propagate through geological formations and/or the crustal rock volume surrounding/around and/or adjacent the wellbore. The temperature differential between the cool fluid and the hot geological formations, optionally combined with high pressure at which the fluid is pumped into the well-bore, causes thermal fracturing of the formations and rubblising at least a region of the reservoir adjacent and/or around/surrounding the wellbores 100 and 130. Rubblising increases fracture connectivity and enhances the permeability of the reservoir region around the drilled wellbores 100/130. Increased fracture connectivity and permeabilityenlarges, such as by increasing the effective diameter of, the effective wellbore region, and in particular enlarges the effective diameter of the effective wellbore region relative to the actual diameter of drilled wellbore 130. Fluid flow into the wellbore 100 may be axial as well as radial. The control system 170 is preferably configured to control fluid injection to cause thermal fracturing in the above described manner. The control system 170 may control one or more parameters of the fluid injection process, including rate, temperature and pressure based on one or more physical properties associated with the reservoir to achieve thermal fracturing.

Figure 2 schematically shows a wellbore 130 indicating an actual drilled wellbore diameter ABD (shown as still larger than actual) and a larger effective wellbore diameter EBD (referred to as n in figure 2) across a rubblised/thermally fractured region 131 around the actual wellbore. Because the effective wellbore EBD is larger, fluid can be extracted from the well at a higher rate without reduction, or reduction below a predetermined level, of temperature (and/or pressure). Advected heat is proportional to the fluid velocity, and wellbore inflow velocity is inversely proportional to radius. Therefore advection temperatures at a larger wellbore are less than advection temperatures at a smaller wellbore for the same axial wellbore flow rate. Fluid extracting heat at a fixed rate via a wellbore can cool the surrounding rock at rates that decrease with increasing wellbore radius. At a larger effective wellbore radius/diameter, the velocity of fluid into the wellbore decreases which in turn slows down the cooling of local geological formations meaning heat can be extracted for longer periods for the same fixed rate of extraction. This provides a more efficient geothermal system.

In some embodiments the determination of a factor or factors relating to the effective wellbore region is based on an estimation or calculation of the level of fracturing or fracture connectivity or permeability surrounding the extraction wellbore. The control system 170 (an in particular a

processing component 171 of the system) may be configured to determine on or more parameters relating to the level of fracture connectivity using one or more physical properties of the geological formations surrounding the wellbore, such as rock volume porosity and rock volume permeability for example. In some embodiments, the level of fracture connectivity is estimated based on one or more properties of seismic activity, such as the spatial distribution of the seismic activity, experienced within the region surrounding the extraction wellbore 130 in response to induced (preferably thermal) fracturing. An empirical formula relating fracture connectivity to the one or more factors of the effective wellbore region may be established from test data obtained. Such a formula may relative an effective diameter or other dimension of the wellbore region with the state or level of fracture connectivity surrounding the extraction wellbore for example. This formula may be stored in a memory component 172 of the control system 170 for use by the processing component 171 to determine the diameter or other dimension of the wellbore region prior to control of extraction. The one or more factors relating to the effective wellbore region can be stored in memory 172 once estimated or calculated by the processor 171.

Other formulas and/or look up tables may be pre-established from test data and stored in memory 172 to further determine one or more parameters or properties for controlling extraction, such as the rate, temperature and/or pressure of extracted fluid based on the one or more factors of the effective wellbore region. The formulas and/or look up tables stored in memory 172 allow the determination of the one or more properties or parameters for controlling extraction by the processor 171 to maximise or improve the production efficiency and/or yield of the reservoir based on a given effective wellbore region.

The extraction of fluid such as the pumping rate may be controlled by the control system 170 based on a diameter or other estimated or assessed factor, such as effective wellbore volume, relating to the effective wellbore region extending beyond the periphery of the actual drilled wellbore (rather than the actual drilled wellbore).

Also, the cold fluid injection can be controlled by the control system 170 to achieve a predetermined degree of estimated thermal fracturing and/or increase in the effective wellbore factor such as effective wellbore diameter. In particular, by controlling one or more properties of the injected fluid, such as temperature and/or pressure for example, the extent or rubblising and the resulting effective wellbore diameter can also be controlled. Thus advection temperatures can

also be controlled by customising one or properties of the injection fluid to thereby control the overall efficiency of the system.

The invention therefore further relates to a method or system for extracting heat from a geothermal reservoir which requires the control of one or more operational properties of the fluid injection process to thereby control heat advection during the extraction process. The step of controlling fluid injection properties can be automatically implemented by the system/method based on predetermined information or it may be manually controlled by an operator of the system. The system and/or an operator may subject the system and reservoir to a process of pre-injection calibration/customisation where information for setting the fluid injection property or properties is/are determined. The resulting injection/extraction processes would then be operated in accordance with the customised injection properties to enhance the efficiency of heat extraction from the geothermal reservoir.

Referring to figure 3, a flow diagram of the preferred form method 400 for resource extraction from a subsurface region is shown. The method 400 is initiated by controlling fluid injection (or other fracturing process) to induce thermal fracturing about an input wellbore (step 410). At step 420, a factor relating to the effective wellbore region associated with an extraction wellbore is calculated or estimated. This may be achieved through sampling of one or more physical parameters relating to the wellbore region such as the spatial distribution of seismic activity as mentioned above. After determination of the factor relating to the effective wellbore region, one or more properties of extraction are set and used to control the extraction process to improve production efficiency and/or yield accordingly (step 430).

It is noted that the embodiments may be described as a process that is depicted as a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be rearranged. A process is terminated when its operations are completed. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc., in a computer program. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or a main function.

Embodiments may be implemented by hardware, software, firmware, middleware, microcode, or any combination thereof. The methods or algorithms described in connection with the examples

disclosed herein may be embodied directly in hardware, in a software module executable by a processor, or in a combination of both, in the form of processing unit, programming instructions, or other directions, and may be contained in a single device or distributed across multiple devices. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD- ROM, or any other form of storage medium known in the art. A storage medium may be coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor.

In the foregoing, a storage medium may represent one or more devices for storing data, including read-only memory (ROM), random access memory (RAM), magnetic disk storage mediums, optical storage mediums, flash memory devices and/or other machine readable mediums for storing information. The terms "machine readable medium" and "computer readable medium" include, but are not limited to portable or fixed storage devices, optical storage devices, and/or various other mediums capable of storing, containing or carrying instruction(s) and/or data.

The various illustrative logical blocks, modules, circuits, elements, and/or components described in connection with the examples disclosed herein may be implemented or performed with any combination of one or more of the following implementation mediums: general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic component, discrete gate or transistor logic, discrete hardware components, designed to perform the one or more functions described herein. To perform the various functions and transfer information between the blocks, modules, circuits, elements and/or components described, the implementation mediums may be communicatively coupled either directly or via any suitable communications network as is well known in the arts of electrical and software engineering. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, circuit, and/or state machine. A processor may also be implemented as a combination of computing components, e.g., a combination of a DSP and a microprocessor, a number of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

One or more of the components and functions illustrated the figures may be rearranged and/or combined into a single component or embodied in several components without departing from the invention. Additional elements or components may also be added without departing from the invention.

In its various aspects, the invention can be embodied in a computer-implemented process, a machine (such as an electronic device, or a general purpose computer or other device that provides a platform on which computer programs can be executed), processes performed by these machines, or an article of manufacture. Such articles can include a computer program product or digital information product in which a computer readable storage medium containing computer program instructions or computer readable data stored thereon, and processes and machines that create and use these articles of manufacture.

The foregoing describes the invention including preferred forms thereof and alterations and modifications as will be obvious to one skilled in the art are intended to be incorporated in the scope thereof as defined by the accompanying claims.

CLAIMS

1. A method for extracting heat from a geothermal reservoir comprising the steps of:

introducing relatively cold fluid into a wellbore to cause thermal fracturing at least in a region (herein: the effective wellbore region) of the reservoir at or towards and around or adjacent an actual wellbore, and

controlling the extraction of relatively hot fluid based on a factor relating to the effective wellbore region.

2. A method for controlling extraction of fluid from a geothermal reservoir, which comprises controlling the extraction of relatively hot fluid based on a factor relating to a larger effective wellbore region of the reservoir at or towards and around or adjacent an actual drilled bore head of the wellbore.

4. A method according to either claim 1 or claim 2 wherein the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

5. A method according to any one of claims 1 to 3 wherein controlling extraction of fluid based on a factor relating to the effective wellbore region comprises controlling the rate and/or temperature and/or pressure of fluid extraction from the well.

6. A system for extraction of geothermal energy from a geothermal reservoir, the system comprising:

a wellbore for extracting hot fluid from a reservoir, and

a geothermal plant arranged to extract hot fluid via the wellbore based on a factor relating to a larger effective wellbore region of the reservoir at or towards and around or adjacent an actual drilled bore head of the well-bore.

7. A system according to claim 6 wherein the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

8. A system according to either claim 6 or claim 7 wherein the geothermal plant is arranged to extract hot fluid from the reservoir at a controlled rate and/or temperature and/or pressure of

fluid recovery, such as a controlled rate based on a measure of the effective wellbore region to maintain a temperature or a temperature range of the extracted fluid.

9. A method for extracting resource or energy from a subsurface region comprising the steps of:

determining a factor relating to an effective wellbore region, the effective wellbore region including an actual region of a wellbore and a surrounding region of fractured geological formations, and

controlling the extraction of the resource or energy based on the factor relating to the effective wellbore region.

10. A method according to claim 9 further comprising the step of inducing fracturing in the surrounding wellbore region.

11. A method according to claim 10 where the step of inducing fracturing comprises introducing relatively cold fluid into the wellbore to cause thermal fracturing in the surrounding region.

12. A method according to claim 11 further comprising the step of controlling any one or more of the temperature, rate and/or pressure of fluid during introduction into the wellbore.

13. A method according to any one of claim 9 to claim 12 wherein the step of determining the factor relating to the effective wellbore region comprises estimating or assessing an effective diameter or other dimension of or relating to the effective wellbore region.

14. A method according to any one of claim 9 to claim 13 wherein the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

15. A method according to claim 14 wherein the step of controlling extraction comprises controlling extraction of fluid based on a factor relating to the effective wellbore region by controlling the rate and/or temperature and/or pressure of fluid extraction from the well.

16. A system for extraction of a resource or energy from a subsurface region, the system comprising:

a wellbore for extracting a resource from a reservoir, and

a plant arranged to extract the resource via the wellbore based on a factor relating to an effective wellbore region of the reservoir, the effective wellbore region including an actual region of the wellbore and a surrounding region of fractured geological formations.

17. A system according to claim 16 wherein the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

18. A system according to either one of claim 16 or claim 17 further comprising an input wellbore for injection of relatively cold fluid into the wellbore to cause thermal fracturing in the surrounding region and wherein the plant is further configured to inject cold fluid into the input wellbore.

19. A system according to claim 18 wherein the plant is configured to inject the cold fluid into the input wellbore while controlling one or more of the temperature, rate and/or pressure of the cold fluid during injection.

20. A system according to any one of claim 16 to claim 19 wherein the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

21. A system according to claim 20 wherein the geothermal plant is arranged to extract hot fluid from the reservoir at a controlled rate and/or temperature and/or pressure of fluid recovery based on the factor of the effective wellbore region to maintain a property or properties of the extracted fluid.

22. A control system for controlling extraction of a resource or energy through an extraction wellbore of a subsurface region comprising:

a processor configured to:

determine a factor relating to an effective wellbore region, the effective wellbore region including an actual region of the wellbore and a surrounding region of fractured geological formations, and

determine on or more control parameters for controlling the extraction of relatively hot fluid through the wellbore based on the factor relating to the effective wellbore region.

23. A control system according to claim 22 wherein the processor is configured to receive input information relating to the fracture connectivity of the surrounding region for determining the factor relating to the effective wellbore region.

24. A control system according to either one of claim 22 to claim 23 wherein the subsurface region is a geothermal reservoir and the extracted resource or energy is hot fluid or heat from hot fluid.

25. A control system according to claim 24 wherein the one or more control parameters comprise any combination of one or more of the rate, temperature or pressure of fluid recovery.

26. A control system according to any one of claim 22 to claim 25 wherein the factor relating to the effective wellbore region is an estimated or assessed diameter or other estimated or assessed dimension or measure of or relating to the effective wellbore region.

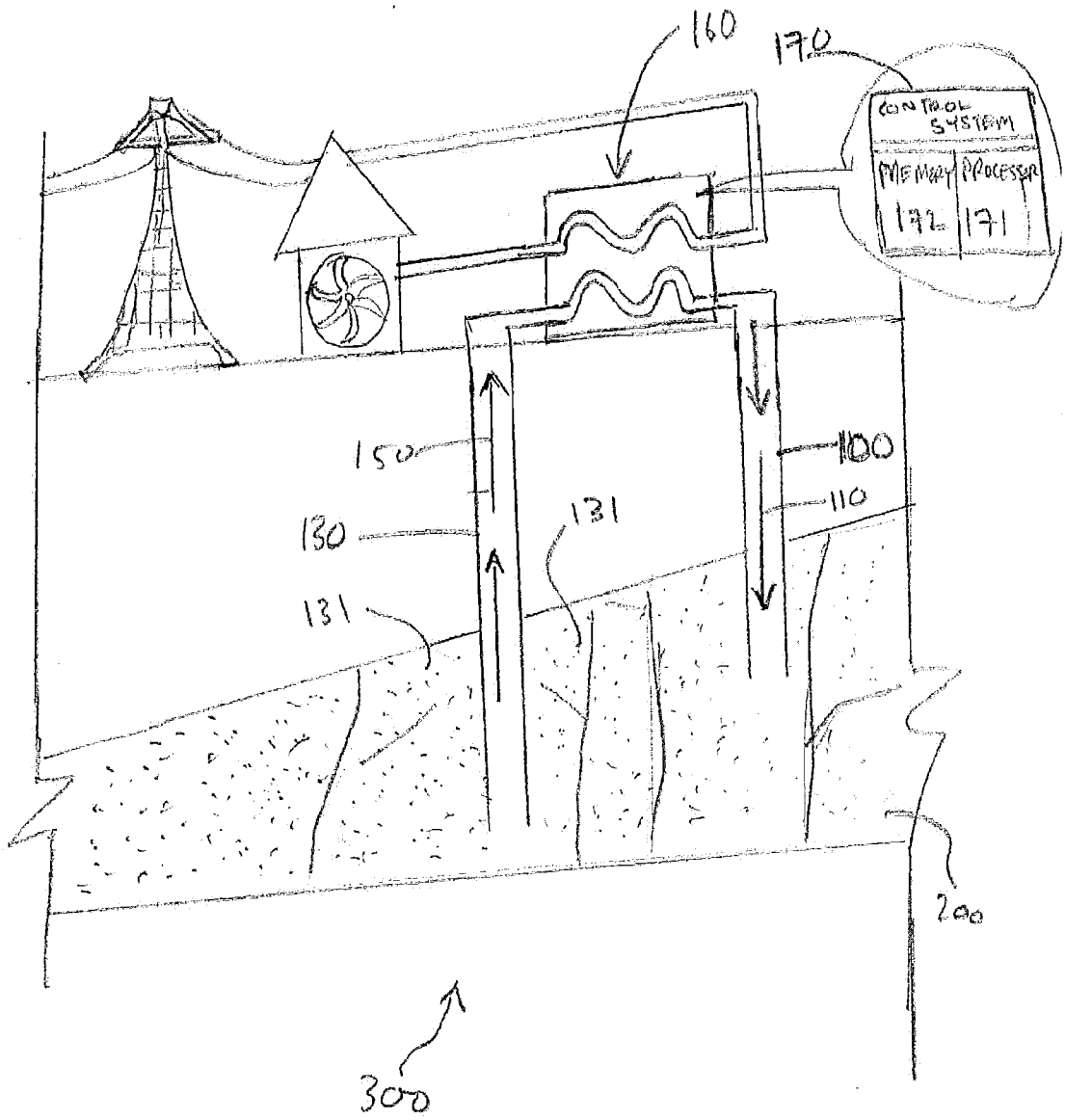

160
170
CONTROL SYSTEM
MEMORY
PROCESSOR
172
171
150
100
110
130
131
131
200
300

Figure 1

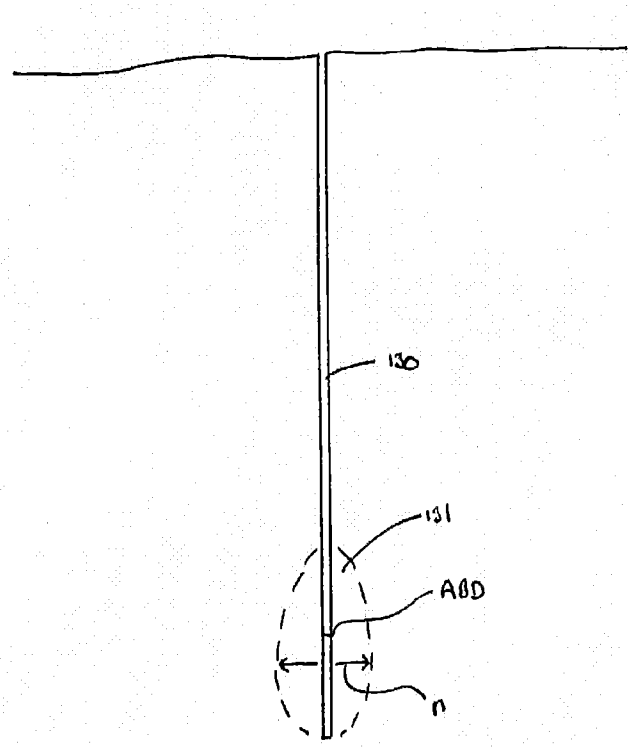


Figure 2

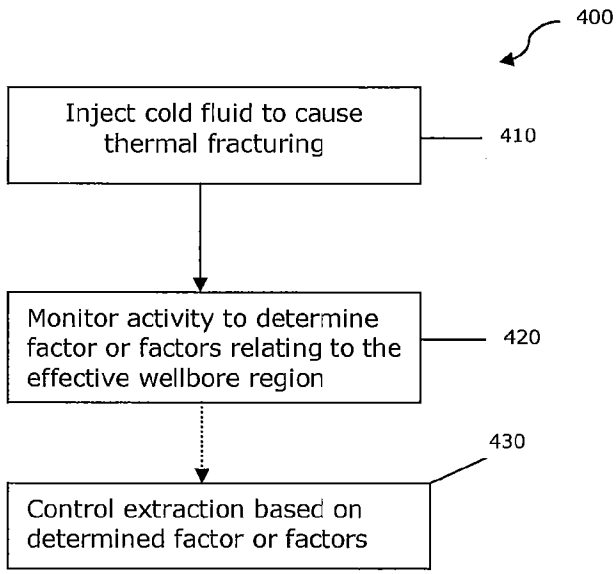


Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ2014/000049

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/12 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DATABASE: EPODOC, WPI: IPC/CPC Marks E21B43/12, E21B43/26, E21B43/14, E21B04/325, F24J3/08, Y02E10/10 & Keywords: Geothermal, Control, Optimise, Fracture, Diameter, Size, Dimension, Velocity, Flow, Speed, Control, Vary, Alter, Change, Evaluate, Geology and the like terms.

DATABASE: TXTE & Keywords: Control, Optimise, Evaluate, Extract, Recover, Analyse, Derive, Determine, Calculate, Compute, Predict, Factor, Parameter, Wellbore, Region, Effective, Permeable Facture, Connectivity, Cohesion, Diameter, Size, Dimension, Velocity, Flow, Speed, Control, Vary, Alter, Change, Optimise, Evaluate and the like terms.

DATABASE: EPODOC & Cited and Citing on most relevant prior art.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2014	02 May 2014

Name and mailing address of the ISA/AU	**Authorised officer**
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INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/NZ2014/000049**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0272515 A1 (CURLETT) 28 October 2010 Abstract, Fig 4, Paragraph 0003, 0050	1-26
A	O'SULLIVAN, M. et al, 'State of the Art of Geothermal Reservoir Simulation', Geothermics, Volume 30, Issue 4, Pages 395-429, 2001. Whole Document	1-26
A	KJETIL, M.D. et al, 'Thermal Fracturing of Geothermal Wells and the Effects of Borehole Orientation', [online], [retrieved on 29/04/2014]. Retrieved from the Internet <URL: http://arxiv.org/pdf/1212.2763v1.pdf > published 12 December 2012. Whole Document	1-26

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/NZ2014/000049**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2010/0272515 A1	28 Oct 2010	AU 2005258224 A1	05 Jan 2006
		BR PI0512499 A	11 Mar 2008
		CA 2560331 A1	05 Jan 2006
		CN 101027480 A	29 Aug 2007
		EA 200700100 A1	26 Oct 2007
		EP 1966489 A2	10 Sep 2008
		JP 2008504470 A	14 Feb 2008
		KR 20070050041 A	14 May 2007
		LT 2007004 A	27 Dec 2007
		LT 5472 B	25 Feb 2008
		MX PA06014998 A	18 May 2007
		US 2007223999 A1	27 Sep 2007
		US 7753122 B2	13 Jul 2010
		WO 2006002325 A2	05 Jan 2006

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.