THERMAL OIL RECOVERY

Filed April 13, 1964 3 Sheets-Sheet 1

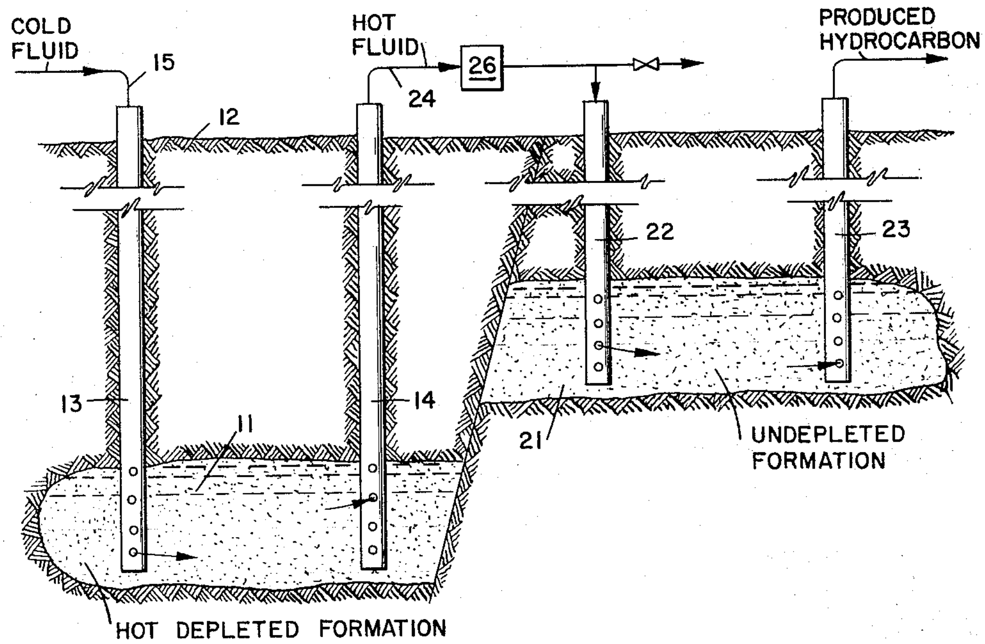

FIG. 1

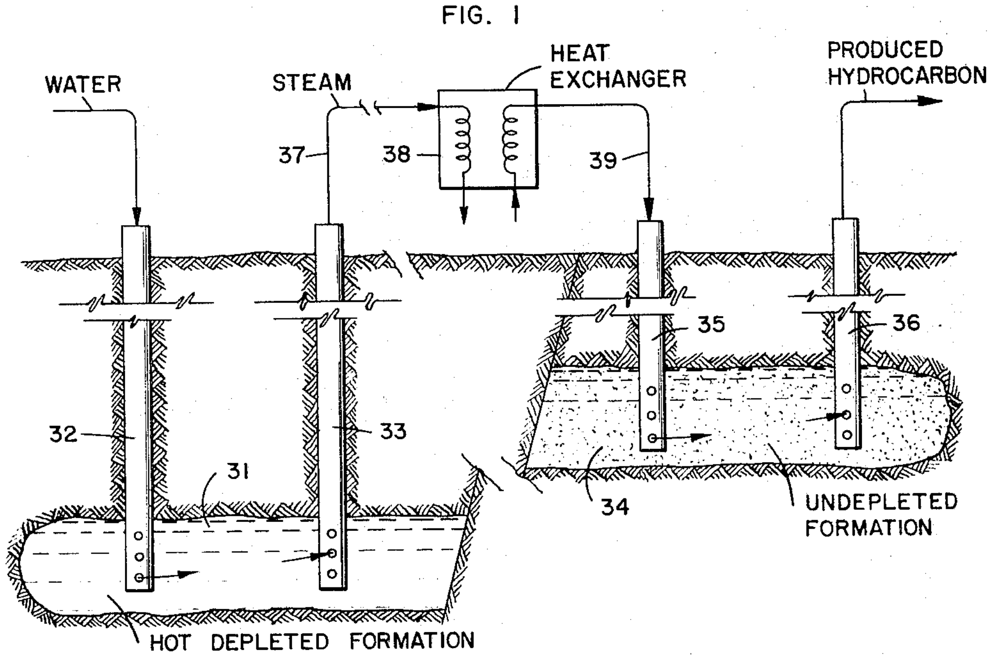

FIG. 2

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Dec. 27, 1966 J. V. VOGEL 3,294,167

THERMAL OIL RECOVERY

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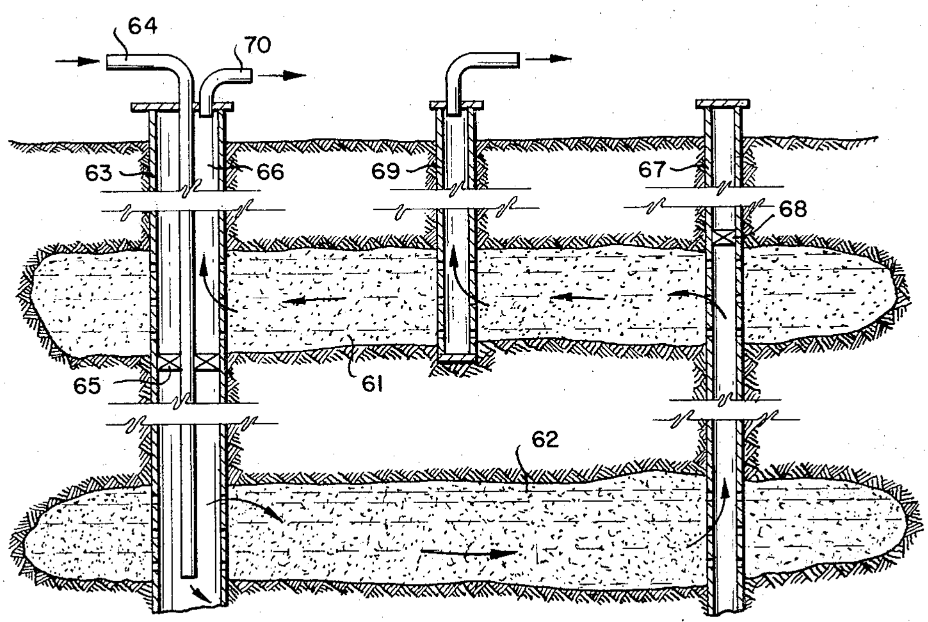

FIG. 3

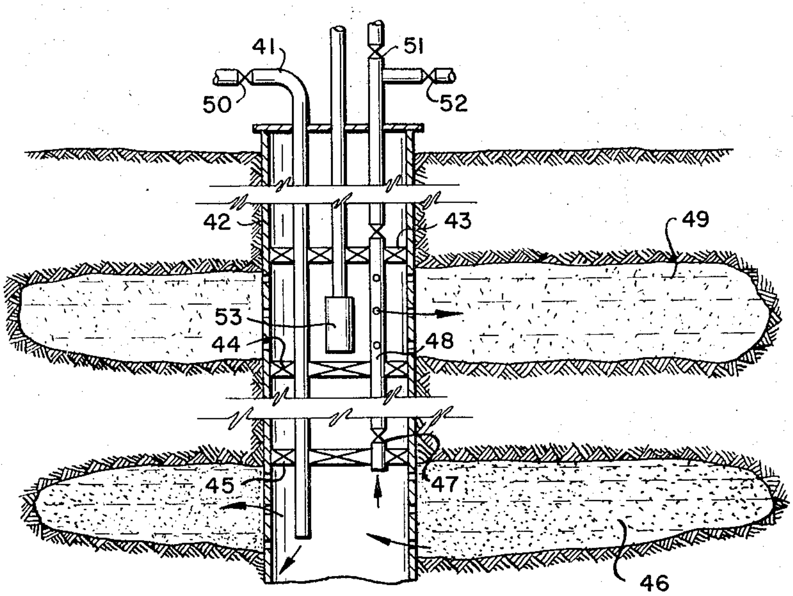

FIG. 4

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THERMAL OIL RECOVERY

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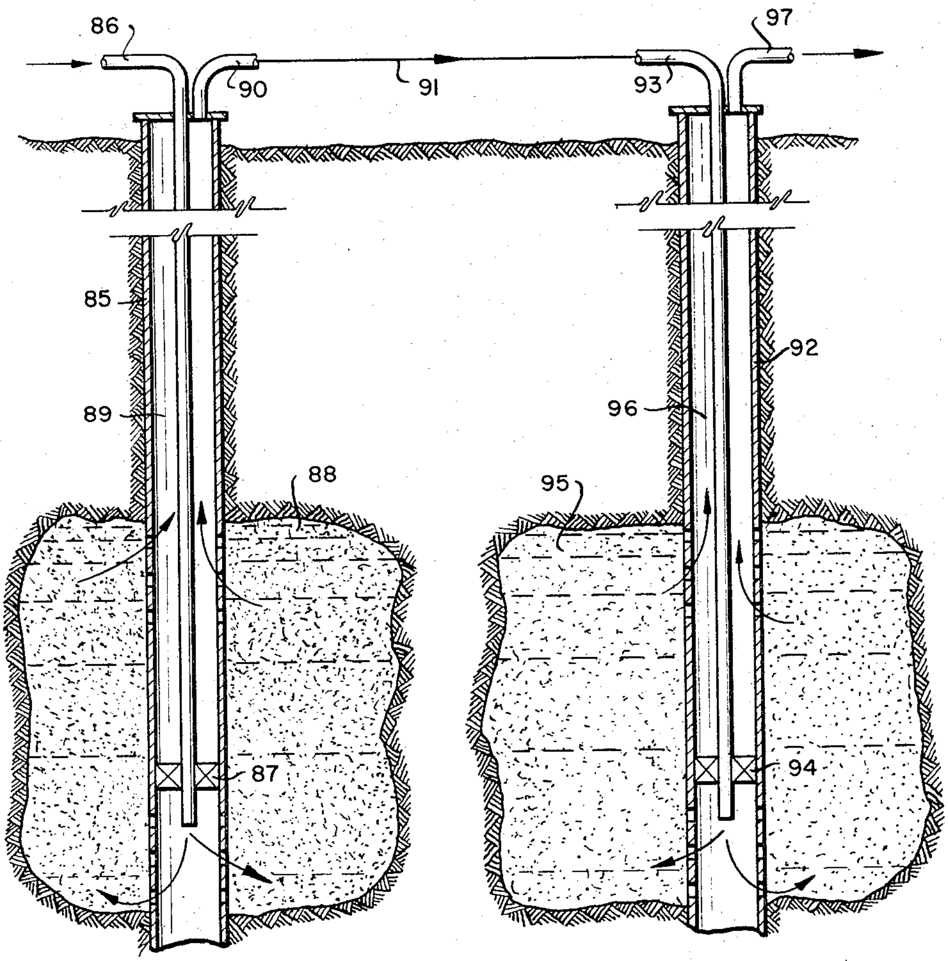

FIG. 5

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3,294,167
THERMAL OIL RECOVERY

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This invention relates to a method of recovering oil from underground formations and pertains more particularly to a method of driving oil from a first formation by thermal means, said first formation being positioned adjacent a second formation from which oil had been previously recovered by thermal means or methods.

It is well known that heat can be employed to recover hydrocarbons from underground formations through wells drilled in the underground petroleum deposits. Various methods have been developed over the years for the primary or secondary recovery of oil from underground formations by thermal means. The manner in which the hydrocarbons are recovered often depends upon the temperature to which they are heated and/or whether or not combustion takes place. Thus, hydrocarbons can be removed from an underground formation by heating the formation to a temperature sufficient to reduce the viscosity of the hydrocarbon to a mobile condition whereby, upon reduction of pressure, the heated oil may flow back into the heat injection well, or alternatively may be driven to a second well, commonly known as a production well, by thermal drive means. At higher temperatures of heating, pyrolysis of the hydrocarbons may take place with the resulting products being driven through the formation and collected at the production well. Such action may take place during in situ combustion wherein the air and the fuel are injected in a formation and burned to heat the formation, or where merely air is injected into the formation at a temperature sufficient to promote underground combustion within the formation. Pyrolysis can also be caused to occur without in situ combustion by heating the underground formation with a hot heat-carrying medium such as steam, water, hydrocarbon liquids or vapors, and other liquids, gases or vapors.

In any of the well-known thermal production methods of underground formations, a substantial amount of heat is retained in the now depleted or substantially depleted underground hydrocarbon-bearing formations. In addition, those formations forming the cap and base rocks, that is, the formations above and below the former oil-bearing formation, absorb significant amounts of heat and stay hot for many months.

In some oil fields, especially those containing low grade and low viscosity oils which must be heated before it is possible to recover them from an underground formation, a primary consideration of the economic feasibility of recovering such an oil would be the cost of heating the oil-bearing formation.

It is therefore a primary object of the present invention to provide a method of recovering hydrocarbons from an underground formation by use of the thermal recovery method.

A further object of the present invention is to provide a method of recovering oil from an underground formation wherein a thermal recovery method is employed utilizing a hot fluid which has been heated by previously forcing it through a heat-bearing underground formation from which hydrocarbons, sulfur or other materials have previously been extracted.

Another object of the present invention is to produce two adjacent oil-bearing underground formations by thermal recovery means wherein first one formation is heated and the oil therein recovered therefrom and subsequently the second formation is heated by heat retained in the first formation so that the oil can subsequently be recovered from the second formation.

These and other objects of the invention will be understood from the following description taken with reference to the drawing, wherein

FIGURE 1 is a diagrammatic view showing two adjacent oil fields or oil-bearing formations taken in longitudinal section and provided with a pair of wells each for carrying out the method of the present invention; and

FIGURES 2, 3, 4 and 5 are diagrammatic views showing other arrangements of heating equipment for carrying out the method of the present invention in adjacent oil-bearing formations which are shown in longitudinal section.

In accordance with the method of the present invention, hydrocarbons may be recovered from a subsurface formation by providing communication through a well between the surface of the earth and a first subsurface formation containing hydrocarbons, recovering hydrocarbons from said first subsurface formation by a thermal recovery method, completing the thermal recovery method in the first formation in a manner whereby a substantial amount of heat remains in the first formation, providing communication between the heated first subsurface formation and a second subsurface formation containing hydrocarbons, forcing fluid into and out of the heated first subsurface formation whereby the temperature of the fluid is increased, conveying the fluid from out of the heated first subsurface formation and into a second subsurface formation to heat the hydrocarbons therein, and producing the hydrocarbons from the second subsurface formation.

As shown in FIGURE 1, a first subsurface formation **11**, originally containing hydrocarbons, is in communication with the surface **12** of the earth through a pair of wells **13** and **14** which are preferably lined by well casing closed at the top and open or perforated at the bottom whereby a fluid may be forced down well **13**, through the formation **11** and up well **14**.

In the vicinity of the first subsurface formation **11**, a second subsurface formation **21** containing hydrocarbons exists. This second subsurface hydrocarbon-containing formation **21** is also in communication with the surface o fthe earth through one or more wells **22** and **23** which are open or perforated at the bottom so that fluid may enter the hydrocarbon formation **21**. In FIGURE 1 the wells **13** and **22** may be considered input wells while the wells **14** and **23** may be considered output wells. The output well **14** of the first subsurface formation **11** is in fluid communication with the input well **22** of the second subsurface formation **21** which contains hydrocarbons. If the two subsurface formations are relatively close to each other, the output well **14** may be connected to the input well **22** by a pipeline **24** which may be provided, if desired, with pumps (not shown) in order to convey any fluid in the pipeline a considerable distance.

FIGURE 1 of the drawing illustrates the method of the present invention wherein hydrocarbons have been recovered to a substantial degree from the first subsurface formation **11** by any suitable thermal recovery method wherein a substantial amount of heat is left in the first formation **11**. Thus, with the pipeline **24** not being connected to well **22**, air or a combination of air and fuel may be injected down well **13** to carry out an in situ combustion within the formation **11** so as to drive the hydrocarbon products therein out of the formation through the output well **14**. Instead of carrying out an underground combustion in the first formation **11**, a thermal fluid drive may be carried out wherein steam or hot water or a combination of both, or any other heat-carrying fluid, is injected down well **13** to reduce the viscosity of the hydrocarbons in the formation **11** and/or to pyrolyze them and cause them to be produced from output well **14**.

After the thermal recovery method in the subsurface formation **11** has been completed, the output well **14** is connected by means of pipeline **24** or any other suitable means to the input well **22** in communication with the second subsurface hydrocarbon-bearing formation **21** which represents an oil field independent of formation **11** and located some distance therefrom in which thermal recovery of the hydrocarbons is to be carried out. In carrying out the method of the present invention, a cold heat-absorbing medium is pumped through pipe **15** and down injection well **13** into the hot depleted formation **11**. The injected medium or fluid may flow either through naturally permeable rock or through artificially induced fractures in the formation **11**. It is not necessary that the injected fluid or medium contact all portions of the hot rock of the formation in order to recover heat therefrom. Heat will flow by conduction from the hot rock to cooler portions of the formation in immediate contact with the heat-absorbing medium. After absorbing heat from the rock in the first formation **11**, the hot medium is led back to the surface through output well **14** and then transported through pipe **24** to input well **22** of the undepleted hydrocarbon-bearing formation **21**. In some oil fields the depleted hot first formation furnishes all the heat required to heat the fluid sufficiently to carry out the thermal recovery method of the second undepleted formation **21**. If more heat is required within the second formation **21**, additional heat may be supplied to the fluid in pipeline **24** by any suitable means, as by a heater **26** positioned in the line. Alternatively, heat may be supplied to the underground formation **21** as necessary from other suitable sources well known to the art. If desired, partial combustion of the material in the second subsurface formation **21** may be carried out.

It is not necessary that the depleted first underground formation **11** and the second undepleted underground formation **21** be in different fields, formations or strata, or that they be separated by faults or impermeable structures, such as a salt dome. The two fields or formations **11** and **21** may, in fact, simply be portions of one continuous large deposit.

Any of several fluids may be employed as the heat-absorbing medium for use in accordance with the present invention. Various media may include, but are not limited to liquids, gases, and vapors, such as water, steam, hydrocarbon liquids, hydrocarbon gases or vapors, air, nitrogen, carbon dioxide, carbon monoxide, and other gases.

It is not essential to the basic invention that the same fluid or medium be injected into the hydrocarbon-bearing or undepleted formation as was used to absorb heat from the hot depleted formation. Thus, one fluid or medium could be used to absorb heat from the hot depleted formation and the heat picked up by the fluid could then be transferred by means of well-known heat-exchanged devices to another heat-carrying medium for injection into the undepleted or hydrocarbon-bearing formation. This modification of the method is illustrated in FIGURE 2 of the drawing showing a hot depleted formation **31** in the vicinity of a hydrocarbon-bearing undepleted formation **34**. Input and output wells **32** and **33**, respectively, are in communication between the earth surface and the hot depleted formation **31** while input and output wells **35** and **36**, respectively, are in communication with the oil-bearing formation **34** to be depleted. The output well **33** of the first formation **31** is connected by pipeline **37** to a heat-exchange device **38** while a second fluid in the heat exchange device **38** is led therefrom through pipe **39** down the input well **35** into the second formation **34** to be subjected to thermal recovery methods for hydrocarbons. For example, water could be injected through input well **32** into the hot depleted deposit **31** where it absorbs heat and is vaporized to steam which is led to the surface through discharge well **33** and thence into the heat exchanger **38**. In the heat exchanger **38**, the steam gives up its heat to evaporate or heat a second fluid, for example a hydrocarbon liquid, which is then injected through pipeline **39** into the input well **35** and thence into the oil-bearing formation **34**. The heated oil in the formation **34** is then driven out the discharge well **36**.

The method of the present invention may be carried out in either a continuous or intermittent manner. In either case it is not essential to the process that two wells be used for conveying a fluid into and out of a hot depleted formation in order to absorb the heat therefrom.

FIGURE 5 illustrates an example where only one well is used in the hot depleted formation and another in the formation to be depleted. A cold heat-absorbing medium is pumped into well **85** down through insulated pipe **86** past a packer **87** and into a hot depleted formation **88**. The injected medium or fluid may flow either through naturally permeable rock or through artificially induced fractures up through formation **88** from which it absorbs heat. It is led back to the surface through annulus **89** and brought out outlet **90**. The hot medium or fluid is then led or pumped through line **91** to well **92** in a second formation **95**, which is to be depleted. The hot fluid is led down insulated pipe **93** past packer **94** and into formation **95** from which it causes the thermal recovery of products which are carried up to the surface through annulus **96** and through outlet **97**.

FIGURE 4 illustrates an intermittent operation in which a cold fluid could be injected down pipe **41** of well **42** past packers **43**, **44** and **45** and into a hot depleted formation **46**. During this period a valve **47** in a conduit **48**, which is in communication between the lower hot depleted formation **46** and an upper oil-bearing undepleted formation **49**, is closed. After the fluid injected into the hot formation **46** is at the desired pressure and temperature, valve **50** in line **41** would be closed and valve **47** in conduit **48** would be opened to allow the hot fluid from formation **46** to flow up conduit **48** into the oil-bearing formation **49** to be heated. At this time valves **51** and **52** at the wellhead would be closed. After the hydrocarbons in the upper formation **49** had been heated to a temperature sufficient to reduce their viscosity, they would flow into the well **42** above the packer **44** and be removed therefrom, as by a pump **53** of any type well known to the art. While the oil-bearing formation **49** is illustrated as being above the hot depleted formation **46** in FIGURE 4, it is readily apparent that it could just as well be below the hot depleted formation **46** and a suitable piping arrangement made to heat the oil-bearing formation.

The method of the present invention may be employed in various arrangements of wells which are in communication with one or more or the formations needed in carrying out the method of the present invention. In FIGURE 3 an oil-bearing undepleted formation is illustrated as being positioned above a hot depleted formation **62**. One well **63** is in communication between the surface of the earth with both of the formations **61** and **62** whereby a cold fluid is injected through pipe **64** past a casing packer **65** and into the lower hot formation **62** while at the same time hot oil may be produced up the annulus **66** between the pipe **64** and the casing **63**. A second well **67** passes through both formations **61** and **62** and is in communication with both so that hot fluid from the lower formation **62** may be led upwardly to the upper oil-bearing formation **61** to heat the formation and drive oil therefrom. The second well **67** is either closed at the top or is provided with a packer **68** just above the upper oil-bearing formation **61**.

If desired, an intermediate well **69** may be provided in communication between the upper oil-bearing zone **61** and the earth surface. Thus, a cold fluid would be injected through pipe **64** down into the hot depleted formation **62** and thence along the formation to the output well **67** which would lead the heated fluid into the upper oil-bearing formation **61**. The oil in the formation **61** would be driven therefrom through the intermediate production well **69**, or would be driven into well **63** above the packer **65** and thence upwardly through the annulus **66** to be discharged through pipe **70** at the top of the well.

The method of the present invention of using the heat in a depleted formation may be used in any other method which requires the injection of a hot heat-carrying medium or fluid into a formation. These methods may be continuous or intermittent. They may be one well or multiwell methods and may include, but are not limited to, steam soak, steam drive, hot water flood, hot solvent drive, underground pyrolysis, etc. The method may also be used to pre-heat a formation before utilizing an in situ combustion recovery method.

By using the method of the present invention a high overall efficiency of heating formations and recovering hydrocarbons therefrom by thermal recovery method is achieved with savings of up to 60% in the cost of heating and depleting an oil-bearing reservoir. Where water is used as the heat absorbing medium, another advantage is enjoyed by eliminating any need for treating the water used in the drive or flood. Thus, impure water can be injected into a hot depleted formation where it is vaporized with the impurities carried by the water being left underground where they do not contaminate the oil-bearing formation to be treated.

I claim as my invention:

1. A method of recovering hydrocarbons from a subsurface formation which comprises the steps of

providing communication through a well between the surface of the earth and a first subsurface formation containing hydrocarbons,

recovering hydrocarbons from said first subsurface formation by a thermal recovery method,

completing said thermal recovery method in said first formation in a manner whereby a substantial amount of heat remains in said first formation,

providing communication between said heated first subsurface formation and a second subsurface formation containing hydrocarbons, at least a portion of said communication being provided through a well,

forcing fluid into and out of said heated first subsurface formation from which hydrocarbons have been recovered, said fluid having a temperature less than that of said heated formation at the time it is forced into said heated formation,

conveying said fluid from out of said heated first subsurface formation and into said second subsurface formation to heat the hydrocarbons therein, and

producing said hydrocarbons from said second subsurface formation.

2. The method of claim **1** including the steps of adjusting the temperature of said fluid coming out of said heated first subsurface formation prior to conveying it to said second subsurface formation, and injecting it into said second subsurface formation to recover the hydrocarbons therefrom by thermal drive.

3. The method of claim **1** wherein the communication provided between surface of the earth and the heated first subsurface formation and between said heated first subsurface formation and said second hydrocarbon-bearing formation is through a common well.

4. The method of claim **1** wherein said first and second subsurface formations are vertically displaced substantially one above the other.

5. The method of claim **1** wherein said first and second subsurface formations are laterally displaced one from the other and includes the step of conveying to the surface of the earth, said fluid coming out of said heated first subsurface formation is conveyed to the surface of the earth and thence laterally to a point above said second hydrocarbon-bearing formation and thence down to and into said second formation.

6. A method of recovering hydrocarbons from a subsurface formation which comprises the steps of

providing communication through a well between the surface of the earth and a first subsurface formation containing hydrocarbons,

recovering hydrocarbons from said first subsurface formation by a thermal recovery method,

completing said thermal recovery method in said first formation in a manner whereby a substantial amount of heat remains in said first formation,

providing communication between said heated first subsurface formation and a second subsurface formation containing hydrocarbons, at least a portion of said communication being provided through a well,

forcing fluid into and out of said heated first subsurface formation from which hydrocarbons have been recovered, said fluid having a temperature less than that of said heated formation at the time it is forced into said heated formation,

conveying said fluid from out of said heated first subsurface formation and into heat-transfer communication with a second fluid to heat said second fluid,

injecting said second heated fluid into said second subsurface formation to heat the hydrocarbons therein and form a fluid drive to force said hydrocarbons from said second subsurface formation, and

producing said hydrocarbons from said second subsurface formation to said surface of the earth.

7. A method of recovering hydrocarbons from a subsurface formation which comprises the steps of

providing communication through a well between the surface of the earth and a first subsurface formation from which hydrocarbons have been recently recovered by a completed thermal recovery method whereby said formation retains a substantial amount of heat,

providing communication between said heat-containing first subsurface formation and a second subsurface formation containing hydrocarbons at least a portion of said communication being provided through a well,

forcing fluid from the surface of the earth down to, into and out of said heat-containing first subsurface formation, said fluid having a temperature less than that of said heat-containing formation at the time it is forced thereinto,

conveying said fluid from out of said heat-containing formation and into said second subsurface formation to heat the hydrocarbons therein, and

producing said hydrocarbons from said second subsurface formation.

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