Fig. 1

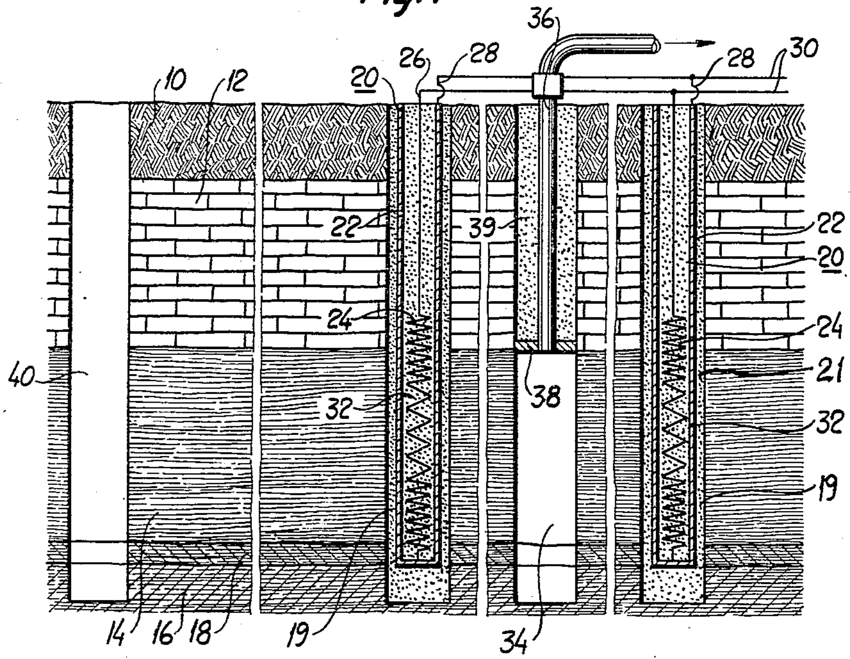

Fig. 2

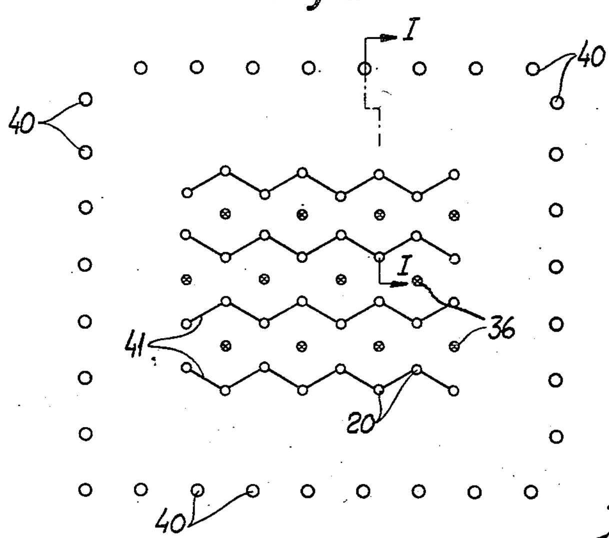

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Fig. 5

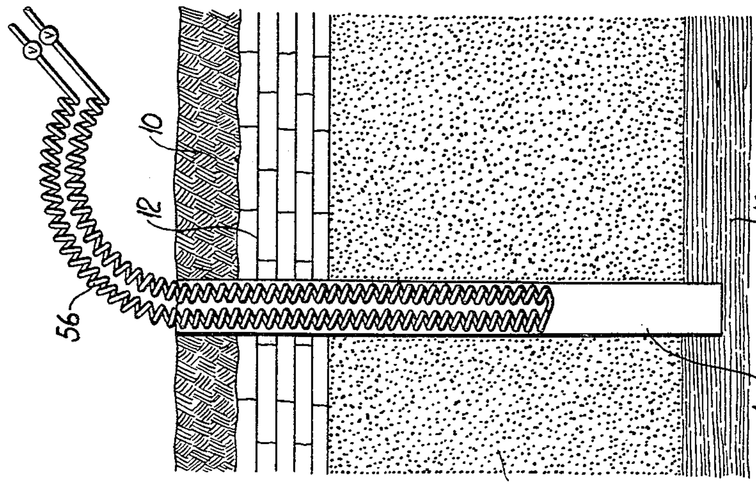

Fig. 4

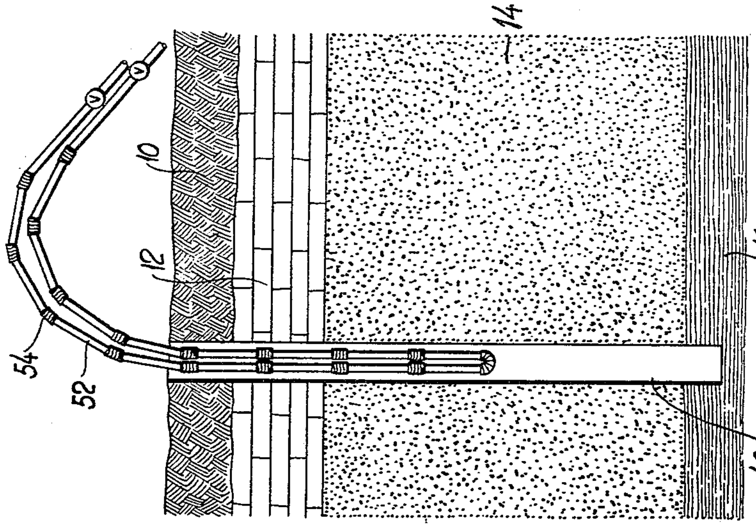

Fig. 3

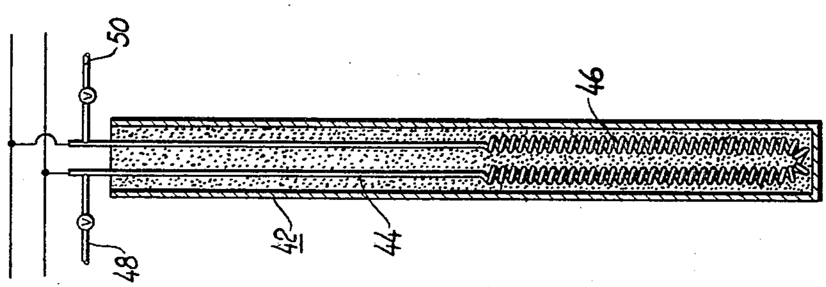

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Fig. 6

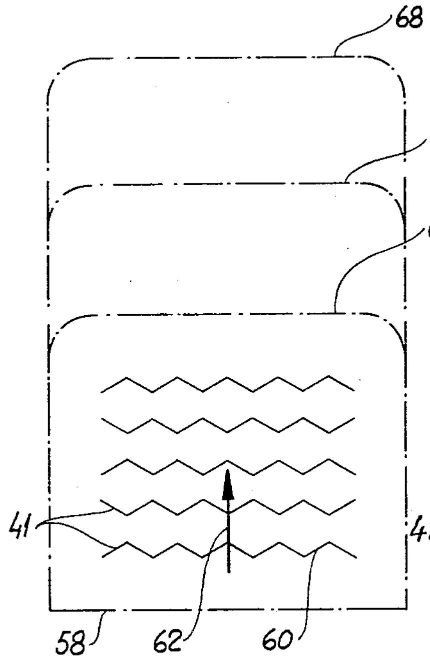

Fig. 7

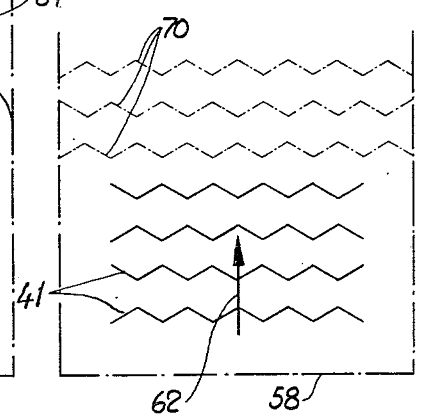

Fig. 8

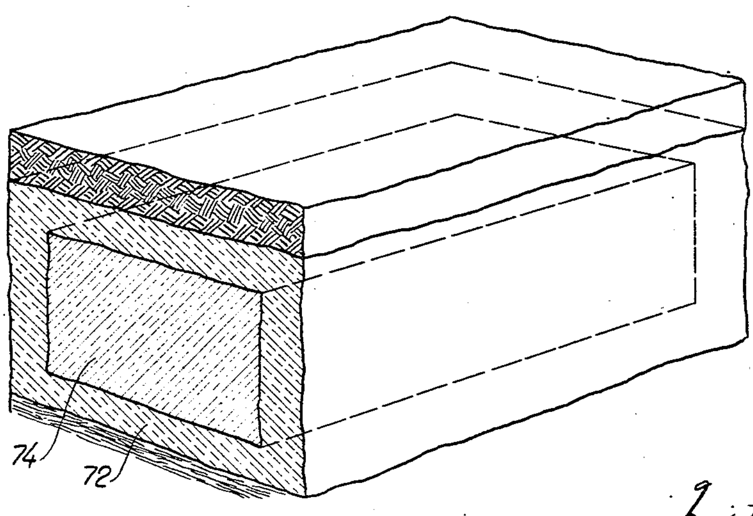

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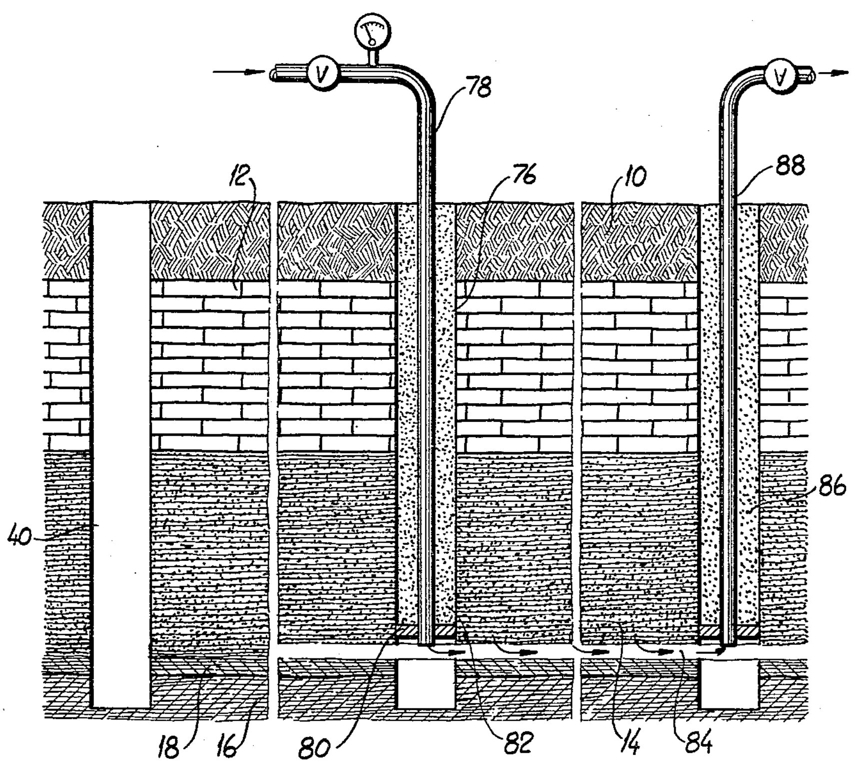
Fig. 9



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2,777,679

RECOVERING SUB-SURFACE BITUMINOUS DEPOSITS BY CREATING A FROZEN BARRIER AND HEATING IN SITU

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5 Claims. (Cl. 262—3)

My present invention relates to pyrolysis and gasifying of bituminous sub-surface deposits, such as oil shale, oil sand, tar sand and coal "in situ," i. e. in place in the earth. Sub-surface deposits are in this connection to be understood to mean also non-consolidated sub-terraneous strata such as fuel-containing sand. According to the method set forth oil and/or gases are produced by directly heating parts of the fuel-containing deposits or layers. The loss of heat entailed by a pyrolysis in situ has in the methods hitherto proposed or employed been much increased by the losses of heat caused by the inevitable evaporation of water leaking in or otherwise penetrating into the deposits or layers. This drawback is particularly disturbing when the fuel-containing deposits or layers are interposed by porous layers or strata consisting of sand, decomposed limestone or other such geological formations which are aquiferous in the horizontal plane and usually because of the existence of vertical splits or fissures in the layers facilitate the access of water from the sides or from above. In this connection the economy of the heating process has proved to be largely depending on the horizontal extent of the field exposed to heating, the efficiency increasing with the size of the field which is to be explained by the fact that the penetration into the field of water from the surroundings decreases in the same degree as the area of the field increases.

In order to reduce the leakage of water into the field to be worked a drainage of the surroundings may be performed prior to the heating for example by pumping off subsoil water by means of a larger or minor number of drilled wells. In this way the hydraulic pressure and consequently the quantity of leakage water are obviously reduced.

One object of my invention is effectively to counteract leakage of water from the surroundings into the body of bituminous deposit the fuel-content of which is to be extracted.

A further object of my invention is to counteract a communication in the opposite direction, i. e. from the body of the deposit toward the surrounding so as so much as possible to prevent gases developed by the pyrolysis to escape from the heated body otherwise than through pre-determined collecting places.

Still a further object of my invention is to ensure when proceeding with methods working in situ and using superatmospheric pressure that said pressure is maintained in the body of deposit which is the object of the gasifying process.

Further objects and advantages of my invention will be apparent from the following description considered in connection with the accompanying drawings, which forms part of this specification, and of which:

Fig. 1 is a vertical section through different layers of geological formations including one fuel-containing layer and having members introduced there into adapted to carry out the method according to the invention; said figure being a section along line I—I of Fig. 2 which in turn is a plan view of the surface of the area in question.

Fig. 3 is a longitudinal section through a combined freezing and heating element.

Figs. 4 and 5 are vertical sections through the geological formations with wells or holes penetrating the same and into which freezing elements constructed according to the invention are partly inserted.

Figs. 6 and 7 are diagrammatic plan views an area treated according to the method of the invention.

Fig. 8 is a perspective view of a geological formation under treatment according to the invention.

Fig. 9 is a vertical section through a series of geological layers in which a bituminous layer is being gasified by using a modification of the method according to the invention.

In the various figures corresponding parts are denoted by the same reference numerals.

Referring to the drawings, **10** designates a surface overburden consisting of earth and gravel sand which in the embodiment illustrated rests on a layer of limestone **12**. This latter is in turn located over a layer **14** of the bituminous geological formation such as oil-shale which is to be subjected to pyrolysis. Below the layer **14** is a layer **16** which is supposed to consist of non-aquiferous clay slate or clay. The transition between the layers **14** and **16** may be constituted by a thinner layer **18** comprising eroded or dismembered, for example sand-carrying clay slate. The sequence of layers just described is in general typical for alum slate formations at various places in the world because of their formation during the same geological periods. The sequence is, of course, given as an example only and may vary in each case in different ways, in particular if the bituminous deposit is of another type.

A pyrolysis of the shale layer **14** is in the embodiment presented in Fig. 1 performed by an electrothermal method. Holes or wells **19** are driven into the geological formation, and into said holes heating elements generally denoted by **20** are introduced. These elements comprise metal tubes **22** in which are placed one or a plurality of electric resistances **24**. The clearance between the walls of the wells or holes **19** and the tube **22** may be filled with a granular material **22** facilitating the heat transfer, such as sand. The resistance **24** is at its lower end in electrical connection with the tube **22** and by wires **26**, **28** joined in a circuit **30** for low tension alternating current of, for example, three-phase character. The clearance between the resistance **24** and the tube **22** is filled with quartz sand or a similar granular material in order partly to prevent the current from flashing over and partly to facilitate the transfer of the generated heat to the shale layer. By being constructed with coils having various pitches the resistance **24** may be given varying heat capacity, for example so as to supply more heat to the upper and lower portions of the bituminous layer **14** than to its intermediate portions. The gases developed by the supply of heat are collected by holes **34** from which tubes **36** extend to the surface. Between the lower end of the tube **36** and the wall of the hole **34** is a sealing flange **38** above which the tube is encased by a granular material **39**. As will be seen from Fig. 2 each gas-collecting tube **36** may be surrounded by a large number of electric elements **20**. This pyrolysis method is more fully described in co-pending patent application Serial No. 756,624, filed June 24, 1947, now Patent No. 2,732,915, to which reference is made for explanation of the method and the means required for carrying out the same.

One or a plurality of wells or holes **40** are drilled through the geological layers, said wells or holes encircling the area which is the object subjected to pyrolysis and which is designated in Fig. 2 by the zigzag-shaped lines **41**. According to the invention, freezing elements are introduced into the wells or holes **40**. Said elements may, as is illustrated in Fig. 3, consist of a tube **42** entered by a narrower tube **44** forming a loop and being wound to the shape of a coil over a major or a minor portion **46** of its length. The tube **42** extends beyond the shale layer **14** into the layer **16** which in the illustrated example is assumed to be non-aquiferous. A liquid or gaseous cooling medium is supplied to the one shank of the tube **44** through a pipe **48** and escapes through the other shank and a pipe **50**. The freezing elements **42** cause a reduction of the temperature in the geological formations or layers below the freezing point of the water present therein. In this way a kind of box or case of frozen mineral and ice is shaped around the area or body subjected to pyrolysis and preventing water from the surrounding areas to enter said area or body. At the same time also the escape of gas and oil generated under the pyrolysis of the area or body treated is obstructed. In the example illustrated the box or case has a bottom of water-tight material. The freezing elements should be located in such a spaced relation from the area of pyrolysis as to permit the completion of its exploitation prior to developing such transfer of heat to the frozen barrier as will melt the ice. In this connection it may be mentioned that geological formations usually have a low heat transfer capacity due to which the progress of the heat is relatively slow.

Preferably the freezing coil is flexible so as to permit its easy insertion into the well or hole. As is illustrated in Fig. 4 the loop is composed of tubular pieces **52** interconnected by flexible sleeves **54** made of rubber or similar material. The flexibility of the freezing coil may also be obtained by winding its two shanks helicoidally, as is indicated at **56** in Fig. 5. The heat transfer from the surroundings to the loop is supported by the fact that the well or hole **40** is filled with subsoil water which when starting the cooling operation is frozen to ice.

Referring to Fig. 6, **58** denotes the barrier of frozen minerals and ice surrounding and sealing the area subjected to pyrolysis and indicated by the zigzag-shaped full lines **41**. The pyrolysis is preferably performed so as to cause a front of heat to travel in the direction indicated by the arrow **62**, i. e. rows of heating elements **20** are switched in successively so as to reach the temperature of pyrolysis in the fuel-containing layer approximately simultaneously along the individual lines **41**. Ahead of the front of heat are successively one after the other sealing frozen barriers **64, 66, 68**, in a spaced relation such that the distance between each of them is larger than the distance between the heating elements. When the front of heat has reached the barrier **64** the next following barrier **66** takes over the task of encasing the field of pyrolysis ahead of the heat front.

In accordance with the modification illustrated in Fig. 7 in front of the area of pyrolysis there is provided a freezing front designated in the figure by the dot and dash zigzag-line **70** and travelling in the direction of the arrow **62** in the same manner as does the front of heat. In this way one is capable of initially forming a frozen body of the geological formations which subsequently is heated by starting the pyrolysis. The layers or strata to be subjected to pyrolysis and the layers existent above and below the same are thus initially cooled down to a temperature below the freezing point of the water contained therein, whereby a more or less coherent frozen body is obtained which subsequently is heated to gasification temperature, in the first instance by a travelling front of heat. In Figure 8, **72** denotes a tight box or case of the fuel-containing layer and adjacent layers, respectively, in which a body **74** forms the object of gasification. The heated body may both at the top and at the bottom as

well on all sides be bounded by bituminous, for example non-consolidated geological formations.

In order to create the travelling freezing and heating fronts, the same wells or holes may be employed. Further the same elements **42** may initially be used as freezing elements and subsequently as heating elements. The freezing elements illustrated in Figs. 4 and 5 will under their operation become surrounded by ice, as is mentioned above. In order to withdraw them a melting of the ice in the wells or holes **40** may be performed by electric heating or by means of a gaseous or liquid hot medium which is introduced into the coiled pipes, which medium may be the same as the cooling medium. The quicker the melting is performed, the minor transfer of heat to the surrounding portions of the geological formations will be encountered. A new freezing of water in the wells or holes will occur if the temperature around the well or hole is sufficiently low. The freezing element upon release and retraction out of the well or hole may be transferred to a well or hole of the next now. When the front of heat commences to approach the wells or holes **40** and the ice in them melts, they are used for the insertion of heating elements or as holes for the escape of developed gas. If desired, a thawing of the ice in the wells or holes may, however, be performed prior to the approach of the front of heat, for example in order to use them for the supply or escape of gas. For this purpose, a suitable salt may be introduced into the wells or holes from the surface of the soil.

Fig. 9 finally illustrates an embodiment, where the bituminous deposit, such as oil-shale, is gasified by introducing oxygen or air into the same. This may be done by driving a plurality of holes **76** down to the deposit and preferably to the vicinity of its bottom layer. Into the holes **76** are inserted tubes **78** which at their lower end portion are sealed against the wall of the hole by means of a packing **80** connected with the tubes. Further the clearance between the pipe and the wall of the hole is filled with a granular material **82** such as sand. Through a row of such holes the combustion-supporting gas such as oxygen is supplied under a pressure such that the geological formations resting thereupon are lifted and a substantially horizontal space **84** is created, in the illustrated embodiment in the lower portion of the bituminous deposit. Tests have established that within alum shale a space of the kind extends to a larger distance from the supply place, said distance amounting to 50 or 100 metres, for example. At a distance determined with respect hereto from the row of holes **76** a second row of holes **86** is made into which tubes **88** are introduced and tightened with the same means as above. The field or area to be exploited is surrounded with a sealing frozen barrier by means of cooling elements arranged in the holes **40** according to any of the alternatives described above. Upon ignition of the fuel-containing deposit in one or the other way, for example by means of electric heating elements or electric resistances located in the lower portion of the supply tubes **78**, the space **84** will cause a continuous gasification in the deposit. The ignition of the deposit may also be performed by means of only the oxygen gas supplied through the tubes **78**, for example by a rapid increase of its pressure and the heating effect resulting thereof, or by oxidation with the oxygen. The developed gases flow to the collecting tubes **86** in which a corresponding superatmospheric pressure is maintained. By heat transfer the zone of gasification is enlarged upwards so that larger and larger portions of the deposit will be brought to the temperature at which gases are developed and pyrolysis will take place. A method of this kind is described for example in the U. S. patent specification Serial No. 210,682, filed February 13, 1951, now forfeited, which is referred to for explanation of its details. In this case it is particularly important that the space **84** outside the remotest holes along the flanks of the front of heat travelling from one row of holes to the next one be prevented by the sealing barrier of ice from permitting the gases to escape otherwise than through the collecting pipes.

In this alternative embodiment, too, the holes **76** and **86** may be employed for the supply of the combustion-supporting gas and the collecting of the gases developed from the deposit as well as initially creating the frozen box or case and the freezing front.

The cooling and/or heating elements may be wound up helically with loops not larger than to permit convenient transportation to the place of installation to be successively introduced into the wells or holes through straightening, if desired by being passed between a pair or system of rolls.

While several more or less specific embodiments of my invention have been shown, it is to be understood that this is for purpose of illustration only, and my invention is not to be limited thereby, but its scope is to be determined by the appended claims.

What I claim is:

1. A method of gasifying in situ and recovering bituminous sub-surface deposits which includes the steps of cooling a zone down to a temperature at least as low as the freezing temperature of water to create a barrier zone for a selected area to be treated, heating the deposit in said selected area to produce gaseous products while maintaining the barrier zone, wherein the selected area is heated along a portion thereof to produce a heat front and said heat front is caused to travel generally parallel to itself within said area, and said barrier zone includes a cold front generally parallel with said heat front travelling in spaced relation thereto in advance thereof, and wherein the heat front is maintained by heat supplied to boreholes, the barrier zone is maintained by refrigerant supplied to boreholes, and the boreholes in the barrier zone are successively thawed to remove ice therein prior to the approach of the heat front to provide for gas movement in the thawed boreholes as the heat and cold fronts advance.

2. A method of gasifying in situ and recovering bituminous material in a sub-surface formation, comprising forming a barrier zone in said formation adjacent a selected area to prevent ingress of water from adjacent areas by cooling said formation at said zone to a temperature at least as low as the freezing point of water to create said barrier, heating said formation within said barrier zone to produce gaseous products in situ in the bituminous formation within the barrier zone while maintaining the barrier zone, and removing the gaseous products produced, to the surface.

3. A method of gasifying in situ and recovering bituminous material in a sub-surface bituminous formation, comprising forming a barrier zone in said formation between a selected area and a lateral area by introducing a cooling medium into said zone, cooling said barrier zone to a temperature at least as low as the freezing point of water to create said barrier which extends as a cold front between said selected area and the laterally adjacent area, heating said selected area along a portion thereof within said barrier zone to form a heat front to produce gaseous products from bituminous material in said formation, causing said heat front to travel generally parallel to itself within said selected area, and maintaining said cold front generally parallel to said heat front and travelling in spaced relation thereto in advance thereof, and removing gaseous products formed during heating to the surface.

4. The method as set forth in claim 2 in which the selected portion of the formation is a zone laterally spaced from the barrier zone, and the gaseous products are removed within the confines of said selected portion.

5. Temperature control apparatus for selectively supplying refrigeration and heat in situ in a geological bore in a sub-surface formation including bituminous material to be processed by heat-treatment, said apparatus including a hollow metallic element adapted to be inserted in said bore and to have refrigerant circulated therethrough when the formation adjacent said apparatus is to be refrigerated, and said element including a heat generating resistance adapted to be inserted into said bore for supplying heat thereto when energized, whereby the formation may be selectively cooled or heated from the same bore hole without removal of the temperature control apparatus.

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