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[54] **METHOD FOR IN-SITU UTILIZATION OF FUELS
 BY COMBUSTION**
15 Claims, 7 Drawing Figs.

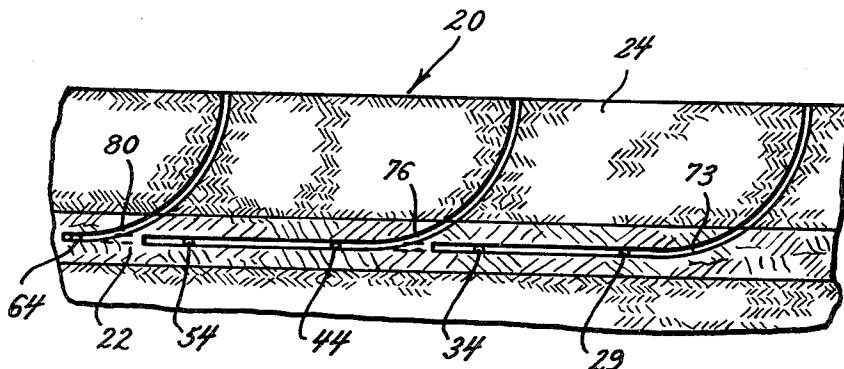
[52] U.S. Cl. 299/2;
 166/259; 175/12
 [51] Int. Cl. E21c 43/00
 [50] Field of Search 299/2, 4, 5;
 175/12; 166/256—259

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ABSTRACT: Subsurface combustible material, such as coal, can be burned in situ by providing a number of passages which extend downwardly from the surface and which extend to, and generally horizontally through, the combustible material, by forming a combustion chamber within said combustible material adjacent to and in communication with the ends of said passages, and by using one of said passages to supply air to said combustion chamber while using another of said passages to remove products of combustion from said combustion chamber. The wall of said combustion chamber, which is adjacent the inner ends of said passages, will progressively burn away, and thus cause said combustion chamber to "move" toward said passages; and the overburden adjacent said wall will provide a self-supporting overhang which will enable air to continue to enter said combustion chamber from said one passage and will enable products of combustion to move to and outwardly through said other of said passages — even though the overburden adjacent the opposite wall of said combustion chamber slumps down into said combustion chamber adjacent to said opposite wall, reach the area where that combustible material is being burned.



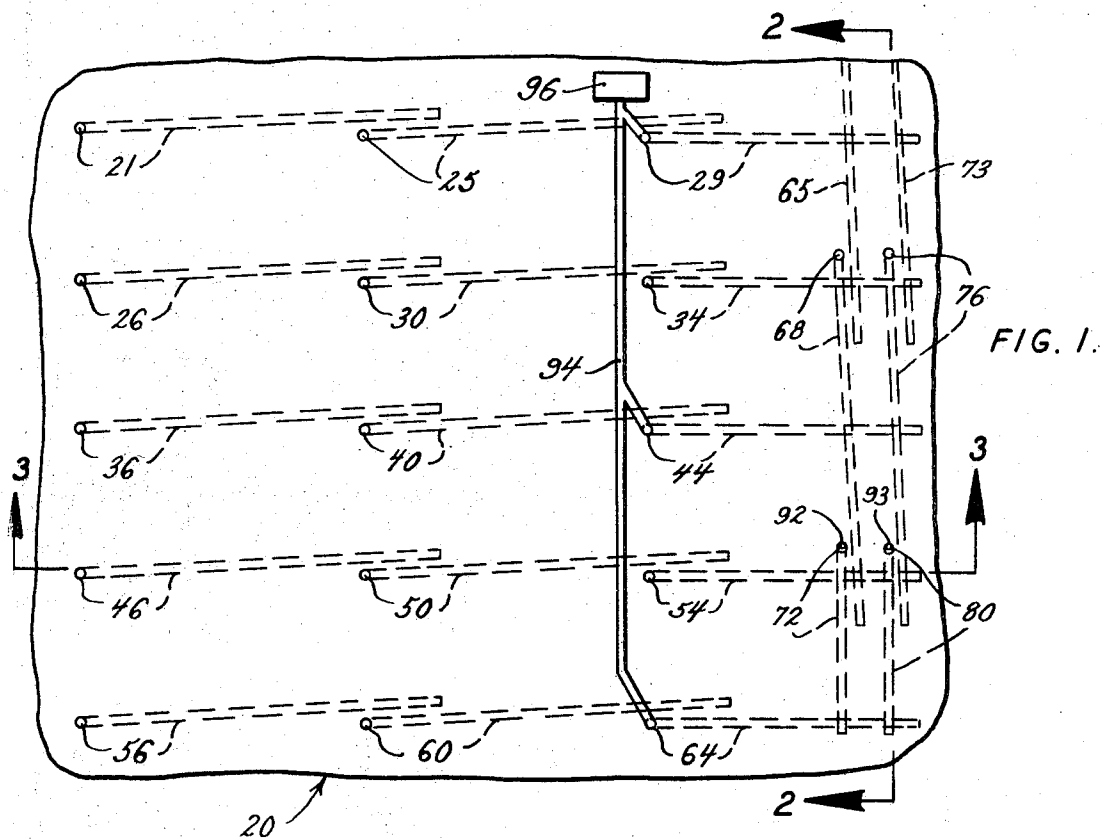
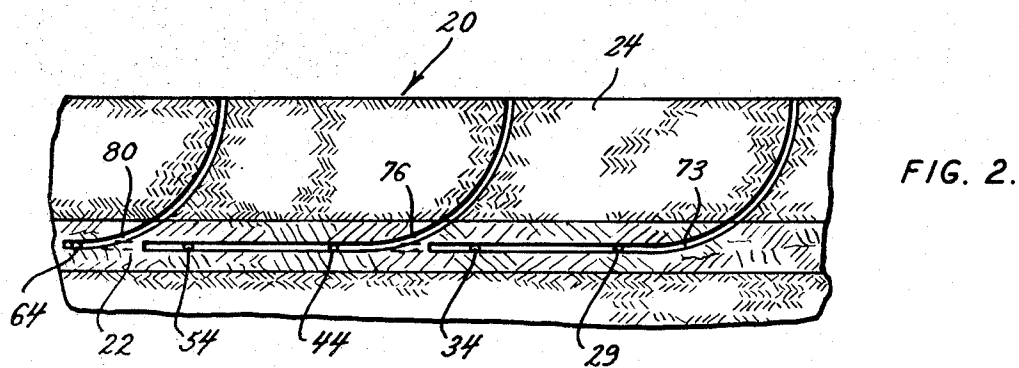
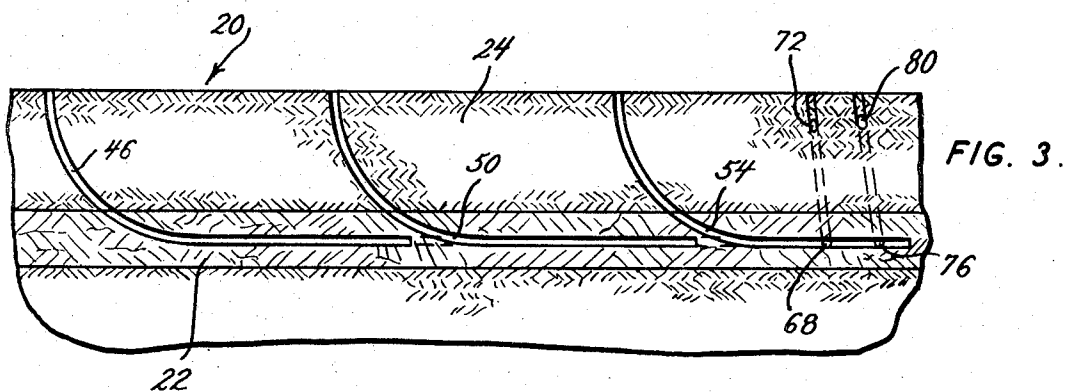


FIG. 4.

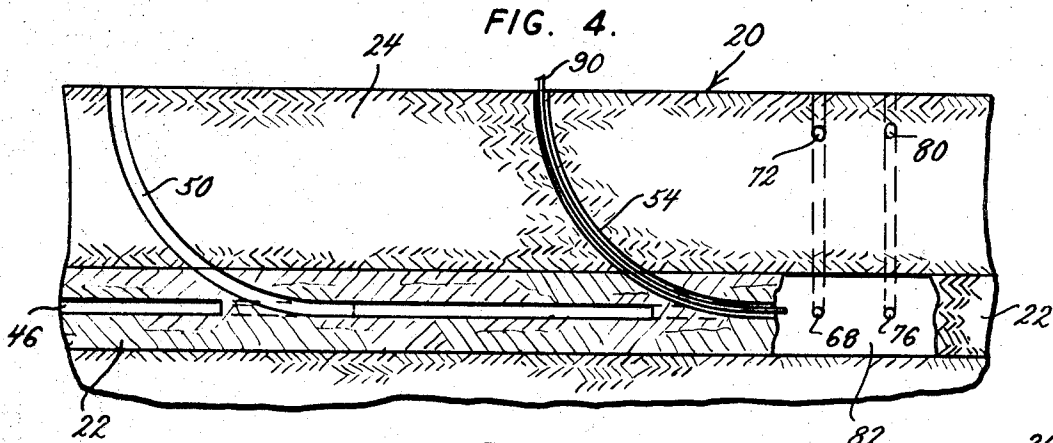


FIG. 5

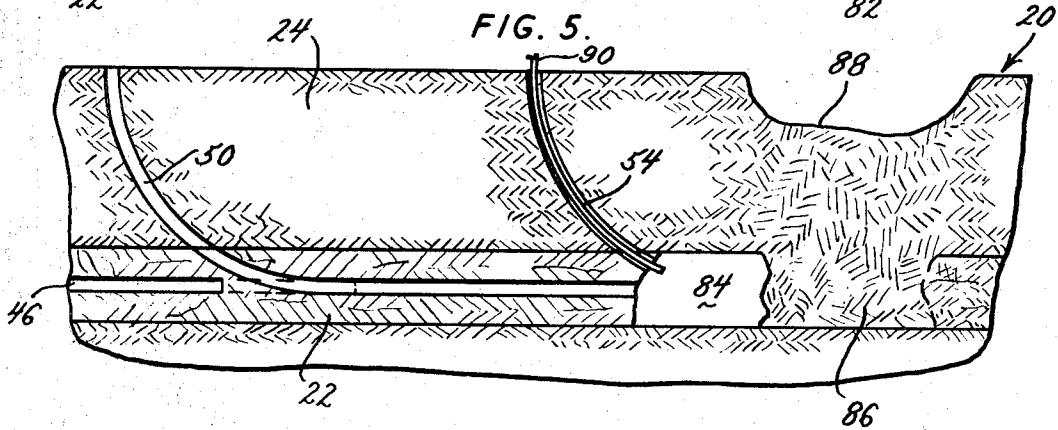


FIG. 6.

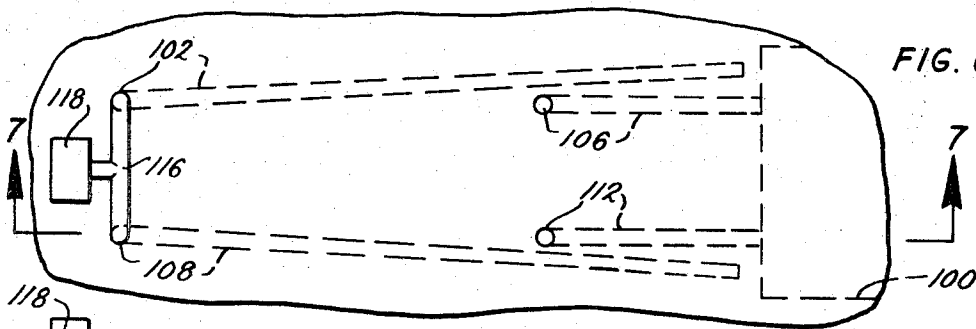
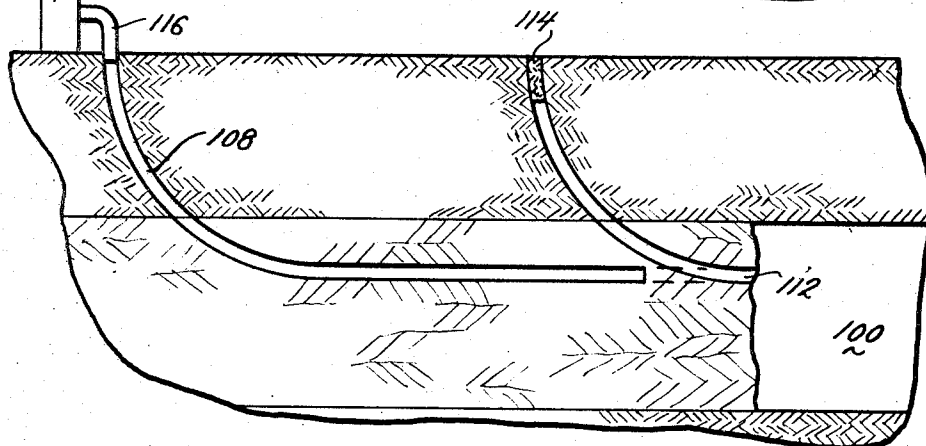


FIG. 7.



METHOD FOR IN-SITU UTILIZATION OF FUELS BY COMBUSTION

This invention relates to improvements in Mining. More particularly, this invention relates to improvements in methods of burning subsurface combustible material in situ.

It is, therefore, an object of the present invention to provide an improved method of burning subsurface combustible material in situ.

The cost of mining subsurface combustible material, such as coal, is high where that combustible material must be mined at the working faces of shafts. The strip mining of subsurface combustible material is expensive where that combustible material is located an appreciable distance below the surface, and it is expensive where governmental agencies require the mined area to be restored to a state approximating its original state. The expense and other disadvantages of mining subsurface combustible material by driving shafts and by stripping could be obviated if a commercially practical method of burning subsurface combustible material in situ could be developed. In recognition of this fact, very large sums of money have been expended in attempts to develop commercially practical methods of burning subsurface combustible material in situ; but those attempts have been unavailing. Consequently, it would be desirable to provide a commercially practical method of burning subsurface combustible material in situ. The present invention provides such a method; and it does by forming a number of passages so they extend downwardly from the surface to a seam of combustible material and then extend substantial distances through that seam in a generally horizontal direction. It is, therefore, an object of the present invention to form a number of passages so they extend downwardly from the surface to a seam of combustible material and then extend substantial distances through that seam in a generally horizontal direction.

Several prior attempts to develop commercially practical methods of burning subsurface combustible material in situ have utilized vertically directed passages which extended downwardly from the surface to the seams of combustible material; and the combustible material was caused to burn away from the lower ends of those passages. Unfortunately, after the combustible material burns away any appreciable distances from the lower end of a vertically directed passage, part of the overburden tends to fall into the space between that lower end and the unburned combustible material. The resulting rubble tends to, and frequently will, so impede the supplying of further air to the burning combustible material, and to so impede the removal of products of combustion, that effective combustion of the remaining combustible material can not be sustained. However, with the passages provided by the present invention, the combustible material will burn toward, as well as away from, the inner ends of those passages; and hence the rubble, that develops as part of the overburden falls into the space previously occupied by the combustible material, will fall behind the burning combustible material and will not fall between that burning combustible material and the inner ends of the passages. Because the overburden will usually have enough structural strength to provide a self-supporting overhang of several feet in width, after the combustible material beneath it has been burned, the rubble which develops as the overburden falls into the space previously occupied by the combustible material will usually be several feet away from the inner ends of the horizontally directed portions of the passageways. The resulting space between the rubble and the inner ends of the horizontally directed portions of the passageways will enable some of those passages to continue to supply air to, and will enable other of those passages to continue to withdraw products of combustion from, the combustible material; and hence the passages provided by the present invention make it practical to burn subsurface combustible material in situ.

Where subsurface mining is done by driving shafts, one serious hazard is the existence of pockets of noxious gases, such as carbon monoxide and methane, which can release those gases as the shafts approach those pockets. The present invention

makes subsurface mining, which is done by driving shafts, safer by forming passages which extend into the seams ahead of the shafts and by maintaining reduced pressures within those passages. If any pockets of noxious gases exist in the seams ahead of the shafts and if those pockets are intersected by the passages of the present invention, the reduced pressures within those passages will withdraw the noxious gases from those pockets, and thus will keep those noxious gases from entering the shafts as the shafts progress to the areas containing those pockets. Even where the passages of the present invention do not intersect the gas-filled pockets, the reduced pressures within those passages will tend to draw any noxious gases from those pockets through fissures, cracks or porous areas in the seams. In the event the seams are free of fissures, cracks and porous areas, the reduced pressures within the passages can still withdraw noxious gases from pockets within those seams where blasting charges at the working faces of the shafts develop cracks and fissures in those seams. As a result, the forming of passages which extend down into a seam ahead of a shaft driven into that seam, and the maintaining of reduced pressures within those passages, can minimize and even eliminate the hazards of noxious gases. It is, therefore, an object of the present invention to form passages which extend down into a seam ahead of a shaft driven into that seam and to maintain reduced pressures within those passages.

Other objects and advantages of the present invention should become apparent from an examination of the drawing and accompanying description.

In the drawing and accompanying description two preferred embodiments of the present invention are shown and described but it is to be understood that the drawing and accompanying description are for the purpose of illustration only and do not limit the invention and that the invention will be defined by the appended claims.

In the drawing

FIG. 1 is a diagrammatic plan view of an area which overlies a seam of subsurface combustible material, and it indicates by dotted lines a number of passages which extend downwardly from the surface to that seam;

FIG. 2 is a sectional view through the area shown in FIG. 1, and it is taken along the plane indicated by the line 2-2 in FIG. 1;

FIG. 3 is another sectional view through the area shown in FIG. 1, and it is taken along the plane indicated by the line 3-3 in FIG. 1;

FIG. 4 is a sectional view which is comparable to the right-hand portion of FIG. 3 after part of the combustible material of the seam has been burned away;

FIG. 5 is a sectional view which is similar to FIG. 4, but it shows how rubble has filled part of the area where combustible material of the seam has been burned away;

FIG. 6 is a diagrammatic view of a mine shaft and of passages formed ahead of that mine shaft; and

FIG. 7 is a sectional view that is taken along the plane indicated by the line 7-7 in FIG. 6.

Referring to the drawing in detail, the numeral 20 generally denotes an area which has a seam 22 of coal located beneath the surface. That seam of coal is overlain by an overburden 24 of rock, clay, top soil, or the like; and that seam of coal may be many thousands of feet long and may be many hundreds of feet wide. The numerals 21, 25 and 29 denote passages which extend downwardly from the surface of the area 20, through the overburden 24, and into the seam 22 of coal. Those openings extend downwardly from the surface of the area 20 to, and then extend horizontally through, the seam 22 of coal. The passages 21, 25 and 29 can be arcuate, in part, or they can incline downwardly to the seam 22. The inner end of the passage 25 laps part of the horizontally extending portion of the passage 29, and the inner end of the passage 21 laps part of the horizontally directed portion of the passage 25. In practice, the horizontally extending portion of each of the passages 21, 25 and 29 may be several hundred feet long. The lapped

portions of adjacent passages will preferably be coextensive for distances in the range of 20 to 50 feet. The lapped portions of adjacent passages can be spaced apart appreciable distances; but, preferably, those lapped portions will be located within a few feet of each other.

The numerals 26, 30 and 34 denote further passages which extend downwardly from the surface to the seam 22. The passages 21, 25 and 29 plus other passages, not shown, define a row of passages; and the passages 26, 30 and 34 plus other passages, not shown, define a second row of passages. The numerals 36, 40 and 44 denote further passages which extend downwardly from the surface to the seam 22; and those passages plus other passages, not shown, define a third row of passages. The numerals 46, 50 and 54 denote further passages which extend downwardly from the surface to the seam 22; and those passages plus other passages, not shown, define a fourth row of passages. The numerals 56, 60 and 64 denote further passages which extend downwardly from the surface to the seam 22; and those passages plus other passages not shown, define a fifth row of passages. The five rows of passages denoted by the hereinbefore-enumerated numerals are representative of many rows of passages which are formed in the overburden 24 and which extend into the seam 22; and those rows will extend throughout the entire portion of the area where the combustible material of the seam 22 is to be burned. The various rows of passages will preferably be spaced apart distances in the range of 30 to 50 feet.

The numerals 65, 68 and 72 denote additional passages which extend downwardly from the surface to the seam 22; and those passages plus other passages, not shown, define a row of passages which extends transversely of the previously described rows of passages in the area 20. The inner end of the passage 65, while crossing the inner ends of the passages 29 and 34, laps part of the horizontally directed portion of the passage 68; and the inner end of the passage 68, while crossing the inner ends of the passages 44 and 54, laps part of the horizontally directed portion of the passage 72. The numerals 73, 76 and 80 denote still further passages which extend downwardly from the surface to the seam 22; and those passages plus other passages, not shown, define a row of passages which is parallel to the row that includes the passages 65, 68 and 72. The row which includes the passages 73, 76 and 80 will preferably be spaced from the row which includes the passages 65, 68 and 72 by a distance in the range of 6 to 8 feet.

The various passages shown in the drawing will preferably be formed by using an in-the-hole drill. That drill can, if desired, be made in accordance with my U.S. Pat. No. 3,084,673 which was granted Apr. 9, 1963.

An air-supplying pipe 92, which has a diameter smaller than the diameter of the passage 72, will be passed downwardly through that passage until the lower end of that pipe is disposed just a short distance from the inner end of that passage. Similarly, an air-supplying pipe 93, which has a diameter smaller than the diameter of the passage 80, will be passed downwardly through that passage until the lower end of that pipe is disposed just a short distance from the inner end of that passage. Thereafter, suitable, readily ignitable, combustible material will be forced downwardly through the air-supplying pipes 92 and 93, and then cables with spark plugs at the ends thereof will be forced down through those pipes, and arcs will be developed across those spark plugs while quantities of oxygen are forced downwardly through those pipes. The readily ignited combustible material will respond to the oxygen and to the arcs to start burning; and that combustible material will be kept burning by forcing air downwardly through the pipes 92 and 93. The products of combustion, which form as the combustible material burns, will be drawn upwardly through the space between the air-supplying pipe 92 and the inner surface of the passage 72, and through the space between the air-supplying pipe 93 and the inner surface of the passage 80, by connecting the inlet of a heat-resistant blower to the upper ends of those passages. The burning of the combustible material adjacent the inner end of the passage 72 will

develop a combustion chamber which will tend to expand in all directions and to merge with the inner end of passage 64; and, similarly, the burning of the combustible material adjacent the inner end of the passage 80 will develop a combustion chamber which will tend to expand in all directions and to merge with the inner end of the passage 64. Those combustion chambers will quickly expand sufficiently to merge together to form a combined combustion chamber 82; and then the air-supplying pipe 93 can be withdrawn from the passage 80. Thereafter, the air needed to burn the combustible material adjacent the passages 72 and 80 will be supplied by the pipe 92; and the products of combustion from that combustible material will be withdrawn through the passages 80 and 64.

The continued supplying of air to the pipe 92, and the continued withdrawal of products of combustion from the passages 80 and 64, will cause the combustible material adjacent the inner ends of the passages 64, 72 and 80 to burn away. Very quickly, enough of the combustible material will burn away to permit part of the roof of the combustion chamber 82 to crack and crumble; and, thereupon, rubble will fall and partially fill that combustion chamber. Although that rubble will fill the portions of the combustion chamber 82 where the inner ends of the passages 64, 72 and 80 were initially located, the roof of that combustion chamber will be strong enough to overhang the portions of the combustible material which define the existing inner ends of the passages 64, 72 and 80. As a result, the pipe 92 within the passage 72 will be able to continue its air-supplying function, and the passages 64 and 80 will be able to continue to perform their functions as conduits for products of combustion. The air-supplying pipe 92 will gradually be withdrawn through the passage 72, as the portions of the seam 22 which define the inner end of that passage burn away; and hence that air-supplying pipe will not be crushed or deformed by the rubble which falls into the combustion chamber 82 as succeeding parts of the roof of that combustion chamber crumble and crack. This means that the air-supplying pipe 92, the inner end of the passage 72, and the inner ends of the passages 64 and 80 will underlie, and will be protected by, the overhanging portion of the roof of the combustion chamber 82. Further, it means that those portions of the seam 22 which are adjacent the existing inner ends of the passages 64, 72 and 80 will be able to continue to burn away.

The burning of the combustible material will continue; and it will extend the combustion chamber 82 along a line which is parallel to the two rows of passages which, respectively, include the passages 65, 68 and 72 and the passages 73, 76 and 80. That combustion chamber will be wider than the distance between those two rows; and it will merge with the inner ends of the passages 68 and 76 while it is receiving air from the air-supplying pipe 92 in the passage 72 and while products of combustion are being withdrawn from the passages 64 and 80. At that time, the air-supplying pipe 92 will be withdrawn from the passage 72 and will be passed downwardly through the passage 68 to supply the air needed to continue the burning of the combustible material. Also at that time, the inlet of the heat-resistant blower will be connected to the passage 76 to withdraw the products of combustion through that passage.

The burning of the combustible material, adjacent the two rows of passages which, respectively, include the passages 65, 68 and 72 and the passages 73, 76 and 80, will be continued until an elongated chamber has been formed which extends transversely of, and which merges with the right-hand passages of, the five rows of passages shown in the drawing plus the further rows of passages, not shown, that are parallel to those five rows of passages. As the inner end of each passage, in the row of passages which includes the passages 65, 68 and 72, is successively burned away, the air-supplying pipe 92 will gradually be withdrawn from that passage and inserted within the next-succeeding passage in that row. If desired, of course, a second air-supplying pipe could be introduced into the next-succeeding air-supplying passage be-

fore the air-supplying pipe 92 was withdrawn from the preceding airsupplying passage. As the inner end of each passage, in the row of passages which includes the passages 73, 76 and 80 is successively burned away, the inlet of the heat-resistant blower will be disconnected from that passage and connected to the next-succeeding passage in that row. If desired, of course, the inlet of the heat-resistant blowers could be connected to the next-succeeding passage while that inlet was still connected to the immediately preceding passage. In this way, the combustion chamber 82 will be elongated until it defines a combustion-supporting chamber that extends transversely of, and that merges with, the inner ends of all of the passages 29, 34, 44, 54, 64 and of similar passages in further rows of passages, not shown, within the seam 22 of combustible material. That elongated combustion-supporting chamber will act as a header; and, while the longitudinal center line of that elongated combustion-supporting chamber may be filled with rubble, the portions of that elongated combustion-supporting chamber which are immediately adjacent the inner ends of the passages 29, 34, 44, 54 and 64 will be overhung by the roof of that elongated combustion-supporting chamber and thus will be essentially free of rubble. This is important; because it will enable that elongated combustion-supporting chamber to permit air to be supplied through some of the rows of passages and for products of combustion to be withdrawn from further rows of passages.

As the elongated combustion-supporting chamber 82 is formed, an air-supplying pipe 90 will be passed downwardly through the passage 54, a further air-supplying pipe, not shown, will be passed downwardly through the passage 34, and additional air-supplying pipes, not shown, will be passed downwardly through the right-handmost passage of each even-numbered row of passages. The air which passes downwardly through those air-supplying pipes will support the burning of the combustible material adjacent the inner ends of the passages in the even-numbered rows of passages; and the resulting products of combustion will be withdrawn through the passages 29, 44 and 64 and the right-handmost passages of the other odd-numbered rows of passages.

The supplying of air through the air-supplying pipe 90 and through the other air-supplying pipes in the right-handmost passages of each of the even-numbered rows of passages and the removal of the products of combustion through the right-handmost passages of each of the odd numbered rows of passages will preferably be begun as the elongated combustion-supporting chamber 82 burns into the inner ends of those passages. Where that is done, combustion will promptly develop, and then will be maintained, along the left-hand face of the full length of the elongated combustion-supporting chamber 82. If, for any reason, it was desirable to initiate the burning of the combustible material at the inner ends of the right-hand passages of the various rows of passages only after the combustion which had formed the elongated combustion-supporting chamber 82 had been completely terminated, the combustion along the left-hand wall of that elongated combustion-supporting chamber could be initiated by passing readily ignitable, combustible material and a cable equipped with a spark plug down one or more of the even-numbered passages.

As the left-hand face of the elongated combustion-supporting chamber 82 burns, it will burn away the portions of the seam 22 which define the inner ends of the passages 29, 34, 44, 54 and 64 and of the right-hand passages, not shown, of the other rows of passages. Moreover, as the left-hand face burns, the elongated combustion-supporting chamber 82 will widen to include the space 84; and, at such time, the roof of the elongated combustion-supporting chamber 82 will tend to crack and crumble. Thereupon, rubble 86 will fall downwardly within the elongated combustion-supporting chamber 82, and the overburden 24 will slump downwardly to form a depression 88 in the surface of the area 20. The depression 88 may not be objectionable if it is not unsightly; and, except in low lying ground where it could present some drainage

problems, it need not preclude the resumption of a farm operation. The rubble 86 will not prevent continued burning of the right-hand face of the seam 22, will not prevent continued supplying of air to the elongated combustion-supporting chamber, and will not prevent continued withdrawal of products of combustion from that elongated combustion-supporting chamber; because the roof of the space 84 will be strong enough to overhand the combustion area by several feet.

As the burning of the right-hand face of the seam 22 continues, the portions of that seam which define the inner ends of the passages 29, 34, 44, 54 and 64 and of the right-hand passages, not shown, of the other rows of passages will burn away. At that time, the elongated combustion-supporting chamber 82 will merge with the inner ends of the passages 25, 30, 40, 50 and 60 and of the right-hand passages, not shown, of the other rows of passages. Thereupon, the air-supplying pipe 90 and the other air-supplying pipes will be withdrawn from the passages in which they were disposed and will be introduced into the next left-handmost passages to supply air to the elongated combustion-supporting chamber 82. The air supplied through those air-supplying pipes will enable the combustible material which defines the passages 25, 30, 40, 50 and 60 and the corresponding passages in the other rows of passages to burn; and, as that combustible material burns, further portions of the roof of the elongated combustion-supporting chamber 82 will crack and crumble. This means that the slump 88 will progressively shift to the left; but the overhanging portion of the roof of the elongated combustion-supporting chamber 82 will keep the rubble, within that chamber, far enough away from the burning face of the seam 22 to enable air to be supplied to, and to permit products of combustion to be withdrawn from, that burning face. As a result, the combustible material in the seam 22 can be progressively burned away, and the products of combustion can be passed upwardly through the odd-numbered passages to the surface.

The burning of the coal or other combustible material of the seam 22 will be incomplete — essentially producing a gaseous fuel such as carbon monoxide or hydrogen rather than an incombustible product of combustion such as carbon dioxide or water. The carbon monoxide, hydrogen and other products of incomplete combustion will be drawn upwardly to the surface by a heat-resistant blower 96 via a conduit 94 which is connected to the various odd-numbered passages. That heat-resistant blower will move those products of incomplete combustion to a utilization area, where those components which are desirable as fuels will be separated from the rest of the components of the products of incomplete combustion and will be used to heat water in a boiler. The rest of the components of the products of incomplete combustion will be suitably treated to separate out from them any marketable compounds or compositions.

The boiler could be the boiler of any electric generating plant; and that electric generating plant would be erected close to the middle of one of the long sides of the area 20. That electric generating plant would be displaced far enough from the portion of the area 20 which overlies the seam 22 so the slump 88 could not weaken the support for that electric generating plant; but that electric generating plant would be close enough to the area 20 to minimize the heat losses through the wall of the conduit 94. By locating the electric generating plant immediately adjacent the area 20, all of the shipping costs associated with combustible materials that are mined are avoided. Further, by locating the electric generating plant immediately adjacent the area 20, the gases which exhaust from that electric generating plant into the surrounding atmosphere are not immediately added to the air adjacent a large city. In addition, because the odor-producing and smoke-producing components developed by this process can be removed from the gaseous fuels before those gaseous fuels are burned under the boiler, the exhaust gases from the electric generating plant will contain fewer air pollutants than the exhaust gases from electric generating plants using solid fuels.

As soon as any of the passages in the area 20 has performed its function and its usefulness is ended, the upper end of that passage will be suitably plugged. This means that after the seam 22 has been burned away, the area 20 can largely be in the same condition it was before the combustible material was burned away, except for the slumping of the surface.

The rate at which the combustible material burns away can be controlled by controlling the rate at which air is introduced into the elongated combustion-supporting chamber at the right-hand face of the seam 22. To determine how rapidly the combustible material is being burned, small diameter observation holes can be drilled down to the seam 22 throughout the area 20 and then suitably capped. To ascertain how far the burning has progressed, it would only be necessary to remove some of the caps and see whether smoke rose out of those observation holes. The rate at which the combustible material burns away also could be determined by disposing thermocouples adjacent the outlet ends of the air-supplying pipes, and by connecting those thermocouples to a suitable circuit at the upper ends of those pipes.

Some fly ash will be formed as the combustible material of the seam 22 burns away; and that fly ash may tend to lodge within the passages of the odd-numbered rows of passages. If the fly ash within those passages tends to accumulate to an undesired degree, the air-supplying pipes can be removed from the passages of the even-numbered rows of passages and can be introduced into the passages of the odd-numbered rows of passages. At such time, the upper ends of the passages of the odd-numbered rows of passages will be disconnected from the conduit 94, and that conduit will be connected to the upper ends of the passages of the even-numbered rows of passages. In addition, air can be forced downwardly through the annular spaces between the air-supplying pipes and the passages of the odd-numbered rows of passages. The overall result is that ample air will be available to the burning combustible material, the products of combustion can be readily drawn to the surface, and some of the fly ash can be driven out of the annular spaces between the air-supplying pipes and the passages of the odd-numbered rows of passages. Similarly, if the portions of the right-hand face of the seam 22, which define the inner ends of the air-supplying passages, tend to burn away at a rate which is excessively greater than the rate of burning of those portions of the right-hand face of that seam, which define the inner ends of the exhaust passages, the air-supplying pipes can be removed from the air-supplying passages and introduced into the exhaust passages and the exhaust passages can be disconnected from the conduit 94 and that conduit can be connected to the passages of the even-numbered rows of passages. In this way the burning face of the seam 22 can be kept generally straight.

All of this means that the overall rate of burning of the combustible material can be controlled, that the rate of burning of individually different portions of that combustible material can be controlled, and that ready withdrawal of the products of incomplete combustion can be attained. This, despite the fact that the seam 22 is always concealed and overlain by the overburden 24.

The present invention makes it possible to utilize many subsurface combustible materials that otherwise would not be utilized. For example, the present invention makes it possible to utilize combustible materials that are found in the form of shallow seams that could not be mined economically by driving shafts or by strip mining. Further, that invention makes it possible to utilize combustible materials that have unduly high percentages of sulfur and of other elements; because several forms of those elements can be removed before the products of incomplete combustion are burned beneath the boiler. In addition the present invention makes it possible to utilize combustible materials that are overlain by overburdens which could not be stripped economically — because of unfavorable seam-to-overburden ratios or because of governmental restrictions against land disfigurement.

The present invention is particularly useful in mining subsurface coal; but it also is useful in recovering other solid fuels such as lignite and peat. In addition, the present invention is useful in recovering oil from oil wells, wherein the rate at which the oil is normally released from the oil-bearing sands or rocks is too low to make the pumping of the oil economic. Specifically, one or more passages can be formed which extend downwardly from the surface to the oil-bearing sands or rocks and then extend substantial distances through those oil-bearing sands or rocks in a generally horizontal direction; and combustion can be initiated and sustained at the inner end of that passage or at the inner ends of those passages to heat the oil and thereby reduce the viscosity of that oil to the point where that oil will be able to drain out of the oil-bearing sands or rocks. In some instances, the combustion can be sustained by air and by the oil which drains out of the oil-bearing sands or rocks; but, in other instances, the combustion will have to be sustained by air and by gaseous fuel which is forced downwardly to the inner end of a passage through a suitable pipe. In all instances, some of the oil will be vaporized and some of the oil will be incompletely burned to form combustible products of combustion; and the vaporized oil and the combustible products of combustion will be drawn to the surface for suitable treatment and use. The vaporized oil and the combustible products of combustion will heat the walls of the horizontally extending portions of the passage or passages; and hence substantial amounts of oil can be recovered. As the oil adjacent the inner end of the passage or adjacent the inner ends of the passages is recovered, the area of combustion will be moved toward the outer end of that passage or toward the outer ends of those passages. Consequently, it should be apparent that the present invention provides an important and useful method of mining or recovering various kinds of subsurface materials.

Referring particularly to FIGS. 6 and 7, the numeral 100 denotes a horizontally directed shaft in a subsurface seam of combustible material. The numerals 102 and 106 denote passages which are disposed ahead of that shaft and which extend downwardly from the surface and penetrate that seam. The passages 102 and 106 are representative of a number of passages which are generally aligned to constitute a row of passages ahead of the shaft 100. The numerals 108 and 112 denote further passages which are disposed ahead of the shaft 100 and which extend downwardly from the surface and penetrate the seam in which that shaft has been driven. The passages 108 and 112 are representative of a number of passages which are generally aligned to constitute a second row of passages ahead of the shaft 100. The passages 102 and 108 are disposed wholly forwardly of the shaft 100; and, initially, the passages 106 and 112 were disposed wholly forwardly of that shaft. However, as the working face of the shaft 100 was advanced, it merged with the inner ends of the passages 106 and 112.

The inner end of the passage 102 laps part of the horizontally directed portion of the passage 106. Similarly, the inner end of the passage 108 laps part of the horizontally directed portion of the passage 112. The inner ends of the passages 102, 106, 108 and 112 will pass through, or close to, any large pockets which are disposed forwardly of the shaft 100 and which contain noxious gases.

The numeral 118 denotes a gas-moving device; and a conduit 116 extends between the inlet of that gas-moving device and the upper ends of the passages 102 and 108. Initially that conduit connected the inlet of that gas-moving device to the upper ends of the passages 106 and 112; and it served to draw out of those passages any noxious gases that entered those passages from pockets which were intersected by, or were close to, those passages. However, after the working face of the shaft 100 merged with the passages 106 and 112, the conduit 116 was disconnected from the upper ends of those passages and was then connected to the upper ends of the passages 102 and 108. Also, plugs 114 were used to close the upper ends of the passages 106 and 112 after the working face of the shaft 100 merged with the inner ends of those passages.

The gas-moving device 118 will maintain reduced pressures within the passages 102 and 108, and thus will tend to withdraw from those passages, and from the seam ahead of the shaft 100, any noxious gases in large pockets ahead of the working face of that shaft. Those reduced pressures will, of course, withdraw any noxious gases from pockets which are directly intersected by the passages 102 and 108; but those reduced pressures also can withdraw noxious gases from large pockets which are close to those passages. Specifically, those reduced pressures will withdraw noxious gases from any large pockets which are spaced from the passages 102 and 108 but which are in communication with those passages via cracks or fissures in the seam or via porous material in that seam. Also, if the blasting at the working face of the shaft 100 tends to form cracks or fissures which communicate with the passages 102 and 108, those passages will be able to withdraw any noxious gases which entered those cracks and fissures. By maintaining reduced pressures ahead of the working face of the shaft 100, the present invention minimizes, and can even prevent, the likelihood of any noxious gases entering that shaft.

Whereas the drawing and accompanying description have shown and described two preferred embodiments of the present invention it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

I claim:

1. The method of burning subsurface combustible material in situ that comprises:

drilling a passage which extends downwardly from the surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;

drilling a second passage which extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;

said second passage being spaced from the first said passage but the generally horizontal portion of said second passage being generally at the same level as, and being generally parallel to, the generally horizontal portion of said first said passage;

igniting the combustible material adjacent the inner ends of said passages to cause a portion of said combustible material to burn away and thereby form a combustion chamber within said combustible material which extends transversely of said first said and said second passages and which interconnects said inner ends of said first said and said second passages;

removing products of combustion of said combustible material from said combustion chamber through said second passage;

said generally horizontal portions of said first said and said second passages being overlain by an overburden;

the portion of said overburden adjacent to the inner ends of said first said and said second passages providing a self-supporting overhang which enables air to enter said combustion chamber from said first said passage and which enables products of combustion to move to and outwardly through said second passage;

said air supplied to said combustion chamber by said first said passage causing that wall of said combustion chamber which is adjacent to said inner ends of said first said and said second passages to burn away and cause said combustion chamber to progressively "move" along the lengths of said generally horizontal portions of said first said and said second passages while continuing to interconnect said inner ends of said first said and said second passages; and

portions of said overburden adjacent to the opposite wall of said combustion chamber slumping down into said combustion chamber, but said portion of said overburden adjacent to said inner ends of said first said and said second passages enabling air to continue to enter said com-

bustion chamber from said first said passage and enabling products of combustion to move to and outwardly through said second passage.

2. The method of burning subsurface combustible material in situ as claimed in claim 1 wherein a reduced pressure is maintained at the upper end of said second passage to facilitate the removal of said products of combustion of said combustible material, from said combustion chamber, through said second passage.

3. The method of burning subsurface combustible material in situ that comprises:

drilling a passage which extends downwardly from the surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;

drilling a second passage which extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;

said second passage being spaced from the first said passage but the generally horizontal portion of said second passage being generally at the same level as, and being generally parallel to, the generally horizontal portion of said first said passage;

igniting the combustible material adjacent the inner ends of said passages to cause a portion of said combustible material to burn away and thereby form a combustion chamber within said combustible material which extends transversely of said first said and said second passages and which interconnects said inner ends of said first said and said second passages;

supplying air, to the combustible material defining the walls of said combustion chamber, through said first said passage;

removing products of combustion of said combustible material from said combustion chamber through said second passage;

said generally horizontal portions of said first said and said second passages being overlain by an overburden;

the portion of said overburden adjacent to the inner ends of said first said and said second passages providing a self-supporting overhang which enables air to enter said combustion chamber from said first said passage and which enables products of combustion to move to and outwardly through said second passage;

said air supplied to said combustion chamber by said first said passage causing that wall of said combustion chamber which is adjacent to said inner ends of said first said and said second passages to burn away and cause said combustion chamber to progressively "move" along the lengths of said generally horizontal portions of said first said and said second passages while continuing to interconnect said inner ends of said first said and said second passages;

portions of said overburden adjacent to the opposite wall of said combustion chamber slumping down into said combustion chamber, but said portion of said overburden adjacent to said inner ends of said first said and said second passages enabling air to continue to enter said combustion chamber from said first said passage and enabling products of combustion to move to and outwardly through said second passage;

subsequently supplying air to said combustible material, which defines said walls of said combustion chamber, through said second passage;

removing products of combustion of said combustible material, from said combustion chamber, through said first said passage; and

the resulting flow of air and products of combustion through said combustion chamber, from said inner end of said second passage to said inner end of said first said passage, increasing the rate of burning of the portion of the first said wall of said combustion chamber which is adjacent to said inner end of said second passage.

4. The method of burning subsurface combustible material in situ that comprises:

- drilling a passage which extends downwardly from the surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- drilling a second passage which extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- said second passage being spaced from the first said passage;
- igniting the combustible material adjacent the inner ends of said passages;
- supplying air to said combustible material through the first said passage;
- removing products of combustion of said combustible material through said second passage;
- drilling a third passage so it extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- said third passage having the inner end thereof lapping part of said first said passage so the burned out area in said combustible material will merge with said third passage before it moves wholly away from said first said passage;
- drilling a fourth passage so it extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction; and
- said fourth passage having the inner end thereof lapping part of said second passage so said burned out area will merge with said fourth passage before it moves wholly away from said second passage.

5. The method of burning subsurface combustible material in situ that comprises:

- drilling a passage which extends downwardly from the surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- drilling a second passage which extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- said second passage being spaced from the first said passage;
- igniting the combustible material adjacent the inner ends of said passages;
- supplying air to said combustible material through the first said passage;
- removing products of combustion of said combustible material through said second passage;
- drilling a third passage so it extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- said third passage having the inner end thereof lapping part of said first said passage so the burned out area in said combustible material will merge with said third passage before it moves wholly away from said first said passage;
- drilling a fourth passage so it extends downwardly from said surface to said combustible material and then extends a substantial distance through said combustible material in a generally horizontal direction;
- said fourth passage having the inner end thereof lapping part of said second passage so said burned out area will merge with said fourth passage before it moves wholly away from said second passage;
- said third passage being drilled so it coacts with said first said passage to define a row of passages; and
- said fourth passage being drilled so it coacts with said second passage to define a second row of passages which is spaced from, but generally parallel to, the first said row of passages.

6. The method of burning subsurface combustible material in situ which comprises:

- drilling a row of passages which extend downwardly from the surface to said combustible material and then extend substantial distances through said combustible material in a generally horizontal direction;
- drilling the passages of said row of passages so they overlap in part; drilling a second row of passages which extend downwardly from said surface to said combustible material and then extend substantial distances through said combustible material in a generally horizontal direction;
- drilling the passages of said second row of passages so they overlap in part;
- said second row of passages being formed so it is spaced from but generally parallel to the first said row of passages;
- drilling a further row of passages which extend downwardly from said surface to said combustible material and then extend substantial distances through said combustible material in a generally horizontal direction;
- said further row of passages being drilled so it is close to, but is directed transversely of, said first said and said second row of passages;
- using said further row of passages to burn out the combustible material adjacent the inner ends of the passages of said first and second row of passages and thereby form an elongated combustion-supporting chamber in said combustible material which is close to, but is directed transversely of, said first said and said second row of passages;
- supplying air to at least one passage of said first said row of passages and applying a reduced pressure to the upper end of at least one passage of said second row of passages to promote burning of the combustible material forming one face of said elongated combustion-supporting chamber; and
- subsequently supplying air to a further passage of said first said row of passages and applying a reduced pressure to the upper end of a further passage of said second row of passages to continue to promote burning of the combustible material forming one face of said elongated combustion-supporting chamber.

7. The combination of a small diameter drilled passage that curves downwardly from the surface of an area to a subsurface seam, said passage having an elongated portion that extends a substantial distance through said seam in a direction generally parallel to said seam, a gas-moving device at said surface of said area, and a conduit that extends between the upper end of said passage and the inlet of said gas-moving device, said gas-moving device maintaining a reduced pressure within said passage, said passage performing the dual functions of collecting gases withdrawn from said subsurface seam by said reduced pressure within said passage and of then conducting said gases to said surface of said area.

8. The combination claimed in claim 7 wherein the inner end of said passage extends toward a working driven into said seam, and wherein said reduced pressure within said passage will withdraw noxious gases from any large pockets that are within said seam and that are located ahead of said working and that are intersected by said passage.

9. The combination of a small diameter drilled passage that curves downwardly from the surface of an area to a subsurface seam, said passage having an elongated portion that extends a substantial distance through said seam in a direction generally parallel to said seam, a gas-moving device at said surface of said area, a second small diameter drilled passage that curves downwardly from said surface of said area to said subsurface seam, said second passage having an elongated portion that extends a substantial distance through said seam in a direction generally parallel to said seam, said elongated portion of said second passage being spaced from but being generally parallel to and being generally coextensive with said elongated portion of the first said passage, a combustion-supporting chamber within said seam which extends transversely of said first said

and said second passages and which interconnects the inner ends of said first said and said second passages, a source of pressurized air connected to the upper end of said second passage, and a conduit that extends between the upper end of said first said passage and the inlet of said gas-moving device, said source of pressurized air and said second passage supplying air to said combustion chamber, said gas-moving device maintaining a reduced pressure within said first said passage and products of combustion within said combustion-supporting chamber responding to said reduced pressure within said first said passage to pass upwardly from said combustion-supporting chamber to said gas-moving device

10. The method of maintaining a reduced pressure throughout a substantial area within a subsurface seam which comprises drilling a small diameter passage that curves downwardly from the surface to said seam, extending the inner end of said passage a substantial distance through said seam in a direction generally parallel to said seam, connecting the upper end of said passage to the inlet of a gas-moving device, and operating said gas-moving device to withdraw gas from said upper end of said passage and thereby maintain a reduced pressure within said passage, said passage performing the dual functions of collecting gases withdrawn from said subsurface seam by said reduced pressure within said passage and of then conducting said gases to said surface of said area.

11. The method of maintaining a reduced pressure throughout a substantial area within a subsurface seam as claimed in claim 10 wherein said passage is drilled so the inner end thereof extends toward a working driven into said seam, and wherein gases from pockets that are in said seam ahead of said working and that are intersected by said passage pass upwardly through said passage to said gas-moving device.

12. The method of maintaining a reduced pressure throughout a substantial area within a subsurface seam which comprises drilling a small diameter passage that curves downwardly from the surface to said seam, extending the inner end of said passage a substantial distance through said seam in a direction generally parallel to said seam, connecting the upper end of said passage to the inlet of a gas-moving device, drilling a second small diameter passage that curves downwardly from said surface to said seam, extending the inner end of said passage a substantial distance through said seam in a direction generally parallel to said seam, drilling said second passage so said inner end thereof is spaced from but is generally parallel to and is generally coextensive with said inner end of said first said passage, a combustion-supporting chamber within said seam, supplying air to the upper end of said second passage to cause said air to pass to said combustion-supporting chamber, and operating said gas-moving device to cause products of combustion from said combustion-supporting chamber to pass upwardly through said first said passage to said gas-moving device.

13. The method of recovering subsurface material in situ that comprises:

drilling a passage which extends downwardly from the surface to said material and then extends a substantial distance through said material in a generally horizontal direction;

initiating and sustaining combustion adjacent the inner end of said passage to vaporize part of said material and to incompletely burn part of said material;

the vaporizing of part of said material and incomplete burning of part of said material forming a combustion chamber within said material in communication with said inner end of said passage;

the horizontally extending portion of said passage being overlain by an overburden;

the portion of said overburden adjacent said inner end of said passage providing a self-supporting overhang which enables air to enter said combustion chamber and which enables said vaporized portion of said material and the products of incomplete combustion of said material to flow through and out of said combustion chamber;

supplying pressurized air to said combustion chamber to cause that wall of said combustion chamber which is adjacent said inner end of said passage to volatilize and to incompletely burn and thereby cause said combustion chamber to "move" along the length of said horizontally extending portion of said passage; and

withdrawing said vaporized portion of said material and the products of incomplete combustion of said material to the surface for utilization thereof; and

portions or said overburden adjacent the opposite wall of said combustion chamber slumping down into said combustion chamber, but said portion of said overburden adjacent said inner end of said passage enabling air to continue to enter said combustion chamber and enabling said vaporized portion of said material and the products of incomplete combustion of said material to flow through and out of said combustion chamber.

14. The method of recovering subsurface material in situ as claimed in claim 13 wherein said material is oil that normally has too high a viscosity to freely drain out of the oil-bearing sands or rocks in which it is held, and wherein said combustion warms said oil and reduces the viscosity thereof sufficiently to enable said oil to drain from said oil-bearing sands or rocks.

15. The method of recovering subsurface material in situ as claimed in claim 13 wherein said material is oil that normally has too high a viscosity to freely drain out of the oil-bearing sands or rocks in which it is held, and wherein said vaporized portion of said material and the products of incomplete combustion of said material warm the walls of said passage and thereby enable the oil held within said walls of said passage to drain away from said walls.