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METHOD OF DEGASSING AND FRACTURING
COAL SEAMS

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ABSTRACT OF THE DISCLOSURE

The fracturing and degassing of coal seams is carried out by pressing a volatile liquid consisting of at least one non-combustible halogenated hydrocarbon having at atmospheric pressure a boiling point of between -100° C. and $+50^{\circ}$ C., into a mine gas-containing rock zone including a coal seam, at an elevated pressure sufficient to fracture said coal seam, so as to fracture said zone, the latter being at an elevated temperature above the boiling point of the volatile liquid at atmospheric pressure; and releasing said elevated pressure so that said volatile liquid in contact with said fractured zone at said elevated temperature will be volatilized, thereby forming a gaseous mixture of volatilized liquid and mine gas, and withdrawing the thus formed gaseous mixture from the thus fractured zone, thereby relieving the latter of mine gas.

The present invention relates to a method of degassing and fracturing coal seams.

Hydraulic fracturing, sometimes referred to as the "frac method" is utilized for hydraulically breaking or fracturing oil or gas-holding rock formations in order to improve by such hydraulic fracturing, in one or more stages, the conditions of fluid flow in the oil or gas holding formation. For this purpose, viscous liquids, so called fracturing liquids, are used, for instance, jellified crude oils, water or acids which are pressed into the deposit at high pressure, the so-called formation breakdown pressure. The cracks formed thereby in the thus fractured rock are maintained opened by supporting materials, such as special sand, aluminum spheres, granulated walnut shells or glass beads which are introduced together with the fracturing liquid.

Due to mechanization of underground coal mining, particularly hard coal mining, the rate of advance per unit of time in working up coal seams has been greatly increased and probably will be further increased in the future. With a more rapidly progressing working face, and particularly long-wall faces, the release of methane gas, or mine gas, from the coal seam and the surrounding rock increases constantly due to release of rock pressure and crack formations connected therewith. For this reason, in order to maintain adequate safety standards, the operation of mechanized coal mines must be interrupted from time to time since it is not possible to eliminate by ventilation the large quantities of mine gas, or to maintain the concentration thereof below the permissible maximum. Such interruption of the mining operation, quite obviously, is undesirable for technical and economical reasons.

In view of these problems, the suggestion has been developed to degas the as yet unmined rock and coal seam portions by hydraulic fracturing and thereby to remove a major portion of the mine gas before the respective coal

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seam portion comes within the range of the actual mining operation.

However, the problems involved in the hydraulic fracturing of coal seams are different from those encountered in the hydraulic fracturing of oil or gas bearing rock, inasmuch as due to the low pressure of mine gas, the fracturing liquid, after having accomplished fracturing of the rock and/or coal seam, in contrast to conditions prevailing in the fracturing of oil or gas bearing rock, will not be automatically, eruptively removed. Thus, it would become necessary to pump out fracturing liquid after the same has accomplished the fracturing of the coal seam or surrounding rock. Such pumping over very considerable vertical distances is an expensive procedure and sometimes technically impossible, particularly if the direction of fracturing planes is downwardly followed the pitch of the fractured layers.

It is therefore an object of the present invention to provide a method for the fracturing and degassing of coal seams and surrounding rock which can be carried out in an effective, simple and economical manner.

It is a further object of the present invention to provide a method for the fracturing and degassing of coal seams and surrounding rock which will not require the pumping out of the spent fracturing liquid.

Other objects and advantages of the present invention will become apparent from a further reading of the description and of the appended claims.

With the above and other objects in view, the present invention contemplates a method of fracturing and degassing coal seams, which comprises the steps of pressing a volatile liquid into a mine gas-containing coal seam under a pressure sufficient to fracture such coal seam, so as to fracture the coal seam, the latter being at an elevated temperature above the boiling point of the volatile liquid at atmospheric pressure, releasing the pressure so that the volatile liquid in contact with the fractured coal seam at the elevated temperature will be volatilized, thereby forming a gaseous mixture of volatilized liquid and mine gas, and withdrawing the gaseous mixture from the thus fractured coal seam, thereby relieving the latter of mine gas.

Thus, according to the present invention, the liquids which are used for fracturing the coal seam and surrounding rock will be such that the same can be applied during pressing or pumping into the coal seam area in liquid condition and will be liquid while causing the fracturing of the coal seam and rock, which, however, after completion of fracturing of the coal seam or rock will be volatilized due to the higher temperature of the coal seam and rock and due to the release of the pressure under which the volatile liquid had been introduced. The thus-formed gas will mix with the mine gas and the thus-formed gaseous mixture can be withdrawn, for instance sucked out or pumped out through the bore hole through which the volatile liquid had been introduced. The removal of such gaseous mixtures does not cause the difficulties experienced in pumping out of a fracturing liquid.

It is thus essential according to the present invention that fracturing of the coal seams and the like is carried out by means of low boiling liquids.

Suitable liquids are primarily those which are known as refrigerants, such as halogenated hydrocarbons, for instance monofluorodichloromethane, monofluorotrichloromethane, as well as liquified ammonia, carbon dioxide, sulfur dioxide, liquified petroleum gas, etc. Prefer-

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ably such liquids will be utilized which are noncombustible, because they can be manipulated without danger and will reduce the risk of explosions in the mine area. It is also possible to utilize a mixture of several liquids instead of a single fracturing liquid.

Generally, all liquids may be used as fracturing liquids which have at atmospheric pressure a boiling point between about -100°C. and $+50^{\circ}\text{C.}$ Preferred are liquids having boiling points of between -10°C. and $+30^{\circ}\text{C.}$ and being noncombustible.

Economic considerations are of great importance in choosing a suitable refrigerant or fracturing liquid, in view of the fact that for individual application frequently several hundred cubic meters of such liquids are utilized.

The following list of suitable fracturing liquids is given as illustrative only without limiting the invention to the specific liquids mentioned therein:

Ammonia, carbon dioxide, sulfur dioxide, methylchloride, methylbromide, methylenechloride, monofluorotrichloromethane, difluoromethane, trifluoromonochloromethane, tetrafluoromethane, ethane and fluorine-free ethane derivatives such as ethyl chloride, ethyl bromide, fluorine-containing ethane derivatives such as trifluorodichloro-ethane, tetrafluorodichloro-ethane and its symmetric and asymmetric isomers, pentafluoromonochloro-ethane, trifluoromonochloro-ethane, difluoromonochloro-ethane, trifluoro ethane, difluoro ethane, propane and derivatives thereof such as fluorochloro derivatives of propane, for instance hexafluorodichloropropane, butane and butane derivatives such as isobutane, fluorochloro derivatives of butane, perfluoro butane, ethylene, halogenated ethylene derivatives, vinyl chloride, vinyl bromide, dichloro ethylene, trichloro ethylene, difluoro ethylene, difluoromonochloro ethylene, propylene, cyclic hydrocarbons and their halides, for instance cyclopropane and octafluorocyclobutane, ethers such as dimethyl ether or diethyl ether, aliphatic amines such as methylamine, dimethylamine, ethylamine, methylformiate; nitrous oxide, thionylfluoride, sulfurylfluoride, sulfur hexafluoride, boron trichloride, certain mixed refrigerants such as mixtures with variable evaporation temperatures and azeotropic mixtures, butylene, methylfluoride, pentane, carbon disulfide, trimethylamine and trifluoro-acetone.

Generally, the method of the present invention is carried out by first drilling a bore down to the underground area which is to be fractured, introducing a pipe through the bore and cementing the pipe. The pipe is then perforated at the depth or level at which fracturing is to be carried out, or it is opened at this level by a sand blast. Thereafter, the refrigerant, preferably combined with supporting material such as aluminum spheres or special fracturing sand is pressed by means of high pressure pumps into the bore hole so as to enter the coal seam or surrounding rock at the level at which fracturing should be carried out. The pressure must be at least equal to the formation breakdown pressure at this point. After introduction under pressure of the volatile liquid has been completed (up to several hundred cubic meters thereof may have to be introduced) the overpressure at the bore hole is released, so that the volatile liquid which is in contact with the coal seam or surrounding rock of higher temperature and which has now been volatilized can escape together with the mine gas present in the fractured area, or can be removed therefrom by pumping or sucking.

The following example is given as illustrative only without limiting the invention to the specific details thereof.

Example

After lowering a bore into the unfractured rock containing the coal seam, for instance, a 6 inch tube is cemented into the lower portion thereof. In the area of the coal seam which is to be fractured, for instance 1000 meters below ground, the tubes are opened within one

plane by means of a sand blast. It is assumed that the coal seam has a thickness of 1.5 meters and a permeability of 1 md., that the pressure at the deposit will be of the magnitude of a few atmospheres and the temperature at about 35°C. The petrostatic pressure at this depth will be about 220 atmospheres and consequently it can be expected that crack formation will be in horizontal direction. In order to obtain a sufficient withdrawal area for methane, a fractured area of about 300 meters diameter is to be produced which, by using German standard fracturing sand of between 8 and 28 mesh should have a permeability of 150 D. The treatment is now carried out by pressing 150 cubic meters of the low boiling liquid into the previously slitted coal seam. Frac sand is added to the low boiling liquid in increasing concentration of from about 90 to about 300 grams per liter. At an injection rate of between 3 and 4 cubic meters per minute, the maximum pressure at the head of the bore will be about 200 atmospheres. Thereafter an additional 12 cubic meters of the low boiling liquid, however free of sand, is pumped into the coal seam. After completion of pressing of the volatile liquid into the coal seam, the overpressure at the bore is released, and the introduced volatile liquid which now under the influence of the somewhat elevated temperature of the coal seam and surrounding rock will be in gaseous condition, will either escape through the bore under its own pressure or may be sucked out of the bore with the help of conventional ventilation or pumping arrangements. The gas removed at first, corresponding to up to about 50 percent of the amount of volatile liquid which had been pumped into the bore, will consist practically exclusively of the volatilized liquid, and thereafter, i.e. after about 50% have been removed, will include increasing proportions of mine gas. The concentration and type of the supporting material such as aluminum spheres or glass spheres or frac sand will have to be determined in a manner well known to those skilled in the art, depending on the specific conditions in each given case. The amount of volatile liquid which is to be used depends on the desired dimensions of the fractured area which again will have to be determined based on the specific conditions in each case.

The fracturing liquid, or at least a considerable portion thereof is then recovered from the gaseous mixture in conventional manner.

The fracturing liquid which is used in this example is methyl chloride.

The abbreviations "md." and "D." in this example mean "millidarcy" and "darcy," respectively. Darcy is the unit of permeability.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. A method of fracturing and degassing coal seams, comprising the steps of pressing a volatile liquid consisting of at least one non-combustible halogenated hydrocarbon having at atmospheric pressure a boiling point of between -100°C. and $+50^{\circ}\text{C.}$, into a mine gas-containing rock zone including a coal seam, at an elevated pressure sufficient to fracture said coal seam, so as to fracture said zone, the latter being at an elevated temperature above the boiling point of the volatile liquid at atmospheric pressure; and releasing said elevated pressure so that said volatile liquid in contact with said fractured zone at said elevated temperature will be volatilized, thereby forming a gaseous mixture of volatilized liquid and

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mine gas; and withdrawing said gaseous mixture from the thus fractured zone, thereby relieving the latter of mine gas.

2. A method of fracturing and degassing coal seams as defined in claim 1, wherein said gaseous mixture is withdrawn from said fractured coal seam by pumping. 5

3. A method of fracturing and degassing coal seams as defined in claim 1, wherein at least a portion of said volatile liquid is recovered from said withdrawn gaseous mixture.

4. A method of fracturing and degassing coal seams as defined in claim 1, wherein said volatile liquid has a boiling point of between about -10° C. and 30° C.

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