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COLLECTION AND REMOVAL OF MINE GAS

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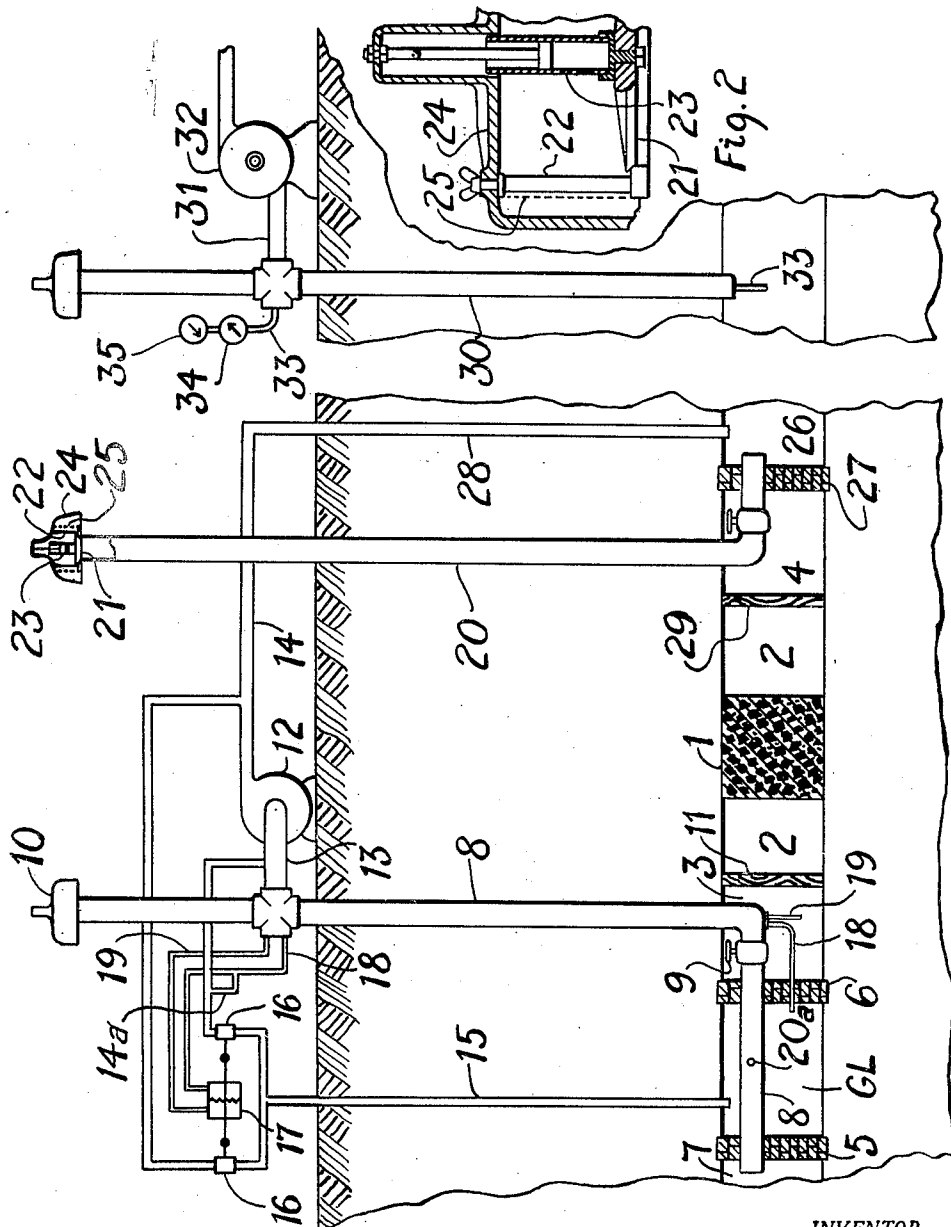


Fig. 1

Fig. 2

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COLLECTION AND REMOVAL OF MINE GAS

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In the underground mining of coal it is necessary to provide forced ventilation and where gas in appreciable amounts is present in the coal the quantity of ventilating air required may become very large. In order to reduce explosion hazards and hold ventilation requirements within reasonable limits, it is now customary to seal off sections of the underground workings as they are mined out, by erecting partition walls, called "seals," across the entries which connect these mined-out sections with the active areas of the mine.

The mined-out sections thus sealed off may contain 50% or more of the original coal, and gas in substantial amounts may be slowly released from this coal and from the marginal walls of the mined-out section for years or even decades. Because of the volume and persistence of the flow, the gas has been sometimes assumed to come into the mine from lower gas reservoirs, but I have found that it is unnecessary to assume communication with any extraneous source of gas because the total volume, rate of delivery, and rate of decline of the mine gas are all consistent with experimental determination of the absorbed gas content of coal samples.

To release this gas and prevent the building up of a gas pressure in the sealed chambers, it is customary to provide large open vent pipes extending from the sealed chambers to the surface.

Although these vent pipes are large enough to discharge gas to the atmosphere at rates greater than the rate of evolution of gas within the sealed chambers, it is nevertheless found that pressures appreciably above or below atmospheric occur within the chambers quite regularly. This is due to the changes which occur, sometimes with great rapidity, in the barometric pressure.

For example, a change of barometric pressure of one inch of mercury may occur within a period of ten hours or, in the event of a violent wind storm, in a much shorter period. In a typical mine two sealed-off chambers contain respectively 60,000,000 and 120,000,00 cubic feet of gas, these being the volumes of coal which are mined out of these areas before they were sealed off. In the smaller chamber, such a change of barometer would require admission of gas to the chamber or escape of gas from the chamber at a rate of about 200,000 cubic feet per hour or more. This quantity of gas can not be delivered through a long vent pipe of normal size, for example an 8" pipe, without a substantial pressure difference.

It follows, therefore, that in practice sealed

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mine chambers must breathe through their vent pipes at very substantial rates as the barometer changes, and this breathing action is superimposed upon the intended function of venting the gas which is slowly evolved from the underground coal faces.

There are two unfortunate consequences of this breathing action. In the first instance, the pressure in the sealed chamber sometimes builds up to a substantial figure, for example 6" of water or more, during a rapid fall of the barometer. In consequence there is usually some leakage of gas through or around the seal and into the active area of the mine. This hazard makes it desirable to install a special "split" in the mine ventilation system, by which an entirely separate current of ventilating air is passed continuously over the mine face of the seal to carry away such leaking gas without permitting it to enter the main ventilating current. A second hazard arises when the barometric pressure increases rapidly. Under these conditions the vent pipes inhale air instead of venting gas, and air also tends to leak into the sealed chambers through or around the seal. Thus there may be created a zone of very large volume in the sealed underground chamber in which an explosive mixture of gas and air may be found. The accidental ignition of this mixture from natural electrical discharges, chemical action, sparks from roof falls, is therefore a possibility.

Safety in underground mining operations requires that, to the fullest extent practicable, explosion hazards should be eliminated by preventing the formation of explosive mixtures as well as by preventing ignition of such mixtures. It is the purpose of my invention to improve the construction and operation of the equipment used in underground mines of the type described so as to minimize or eliminate the existing hazards and at the same time to recover and deliver the gas which is slowly evolved from the coal in the purest practical form.

My invention will be fully understood from the following specification taken in connection with the annexed drawing in which Figure 1 illustrates in diagrammatic section a mine installation in which the invention is utilized and Figure 2 shows in fragmentary section the details of the vent valve.

In this drawing the numeral 1 designates a coal pillar or rib in the center of an active entry 2 in an underground coal mine. The entry 2 and the active workings with which it connects are

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ventilated in the usual way by fresh air, at least part of which passes through the entry 2. In the plane of the drawing the entry 2 connects with cross entries 3 and 4 which lead to lateral areas of the mine which have been worked out to the existing economic point. It is well known, however, that as mining methods improve and prices advance it is often desirable to re-open such "mined-out" areas and extract further quantities of coal. For this reason it is desirable to avoid any action which would preclude this possibility or make it unduly expensive to re-open the "mined-out" areas. The entry 3 is cut off from the mined-out section by an inner seal 5. The seal 5 is of masonry, recessed into the walls of the entry as indicated to reduce leakage around the seal. While only one seal is shown, it will be understood that main entries usually require several such seals since they may consist of multiple passages separated by ribs or pillars. Spaced away from the inner seal 5, by a distance of perhaps 100 feet, I provide an outer seal 6 which may be of identical construction or may be less costly for the reasons which will hereafter appear.

The chamber 7 beyond the inner seal may be of great size, for example 60,000,000 cubic feet free space, representing the volume of the coal which has been removed. There remains in this chamber an equal volume, more or less, of coal which it was not economical to mine out under the existing conditions. From this coal combustible gas, consisting essentially of methane, is continuously released at a rate which may be, for example, 400,000 cubic feet per day for many years after the chamber 7 has been sealed off and all active mining operations therein discontinued. To permit the gas to escape I provide a vent pipe 8, which may be of about 8" diameter and which passes through the inner and outer seals, extends into the mouth of the cross entry 3, and is there equipped with a hand-operated shut-off valve 9. Beyond the shut-off valve the vent pipe 8 turns upwardly, passes through the cover over the coal, which may be many hundreds of feet in thickness, and emerges at the surface of the ground where it is extended to a convenient height and equipped with a non-return safety type of vent valve 10 which will be later described. The cross entry 3 is cut off from the active entry 2 by a timber partition 11 which permits a separate stream of ventilating air to be circulated over the outer face of the outer seal 6 without admixture with the main current of air in the active entry 2. The entry 3 is accessible from the active entry 2 for inspection purposes at any time by a suitable door, not shown, in the timber partition 11.

The chamber designated GL between the inner seal 5 and outer seal 6 is utilized, in accordance with my invention, as a gas-lock which is kept continuously filled with gas withdrawn from the chamber 7 and at a pressure always equal to the pressure in the active area of the mine. This result is accomplished by three novel procedures.

First, the gas from chamber 7 is continuously and forcibly withdrawn from this chamber, through the vent pipe 8, by a blower or low pressure pump 12 located at the surface and taking suction on the vent pipe 8 through a suction line 13. The gas discharged from the blower 12 may be delivered directly to some point of consumption, or as will later appear it may be delivered to another sealed chamber in the same mine by a transfer line or delivery line 14.

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The gas-lock between the seals 5 and 6 is connected with the surface by a relatively small line 15. At the surface this line is branched, one branch connecting with the blower suction line 13 and the other branch with the blower delivery line 14. Each branch is equipped with a regulating valve, as indicated diagrammatically at 16. The two valves 16 are operated by a pressure regulator shown diagrammatically at 17 in the form of a chamber divided by a flexible diaphragm to which connecting links from the two valves 16 are affixed. The pressure on one side of the diaphragm is that of the gas-lock, while the pressure on the other side is that of the entry 3 which is the same as the pressure in the active mine adjacent the gas-lock. These two underground pressures may conveniently be transferred to the regulator 17 at the surface by means of small tubes 18 and 19 led down through the vent pipe 8 and terminating respectively in the gas-lock and in the entry 3. I prefer to make a small opening 20a in the vent pipe 8 within the gas-lock so as to ensure a constant small flow of gas through the gas-lock.

The construction of the vent valve is shown diagrammatically by the detailed section at the top of a second vent line 20 and by Figure 2. The essential operating features of the valve are that it should permit free escape of gas under low back-pressure, that it should prevent all ingress of air under any condition, that it should not chatter or vibrate, that it should not stick, freeze tight or corrode, and that it should prevent flash-back of a flame or explosion through the vent pipe if a combustible mixture should at any time exist.

These operating essentials are met by a valve comprising a horizontal pallet 21 of very light weight which seats by gravity on a horizontal seat, is loosely guided by vertical spaced bars 22, which support the hood over the valve, and restrained from tipping or chattering by a loose link connection with the piston of a damping cylinder 23 filled with light oil. The valve is protected by a hood 24 and flash-back of flame is prevented by a safety screen 25 surrounding the vertical hood supports which form the valve cage. The entire valve construction is of rust-proof metals.

The second vent pipe 20 communicates with a second sealed chamber 26 of very large capacity, for example 120,000,000 cubic feet. The chamber 26 is shown as cut off from the active mine by a single masonry seal 27. The entry 4 in which this seal is erected is separated from the main entry 2 by a timber partition 29 which permits entry 4 to be independently ventilated. The arrangements here shown are the same as for the chamber 7 save for the omission of the outer seal forming the gas-lock provided for chamber 7.

The discharge line 14 from the blower 12 is led into the chamber 26 by a connection 28 which extends directly downward from the surface through the cover above the coal.

At a point removed by a great distance, for example one mile, from the seal 27, vent 20 and transfer connection 28, there is provided a gas delivery pipe 30. This delivery pipe 30 may also be equipped with an automatic vent valve as heretofore described so that it may exhale gas directly to the atmosphere if necessary to relieve pressure in the chamber 26, but may not inhale air. The pipe 30 is in fact a gas well and serves as the outlet for the entire gase production of the chambers 7 and 26. For this purpose it car-

ries an outlet connection 31 which delivers into the suction side of a pump 32. By means of this pump the gas may be delivered under any desired pressure to a fuel gas distribution system or to any consuming outlet.

It is important to regulate the quantity of gas withdrawn from chamber 26 by the pump 32 so as to obtain the maximum gas recovery while remaining within the limits predetermined by observation and test as suitable and safe. This withdrawal rate may be substantially uniform but will decline slowly as the rate of evolution of the absorbed gas from the surfaces of the coal declines. For such regulation it is necessary at all times to know both the absolute pressure in the chamber 26 and the barometric pressure. To observe the absolute pressure in the chamber 26, without any possible error due to velocity effects and pressure drop in pipe 30, I introduce a separate pressure tubing 33 through a fitting on the pipe 30 above the surface, and connect this pressure tube with a gauge 34 which indicates, or if desired also records, the absolute pressure in chamber 33 at a point far enough from the opening of the pipe 30 to avoid velocity effects. In close proximity to the pressure gauge 33 I provide a barometer 35, which may also be of the recording type if so desired.

In the operation of the installations described above the sealed chambers 7 and 26 are at all times free to discharge gas to the atmosphere through the relief valves 10 on the ends of the vent pipes 8, 20 and 30. These valves may be designed to open under a pressure less than one inch of water, and so offer a minimum of resistance to the discharge of gas at periods when the barometer falls below the pressure in the chambers. If it is desired to conserve the gas and if tests show that there is very small leakage of gas from the sealed chambers into the active section of the mine, when the pressure in the chambers is higher than in the mine, the valves may be loaded to remain closed until the barometer drops as much as one half to one inch or more of mercury below the pressure in the chambers. Such setting of the valves will prevent waste of gas through the vents under all common fluctuations of the barometer but still leave them effective for storm conditions. It is common to encounter water in coal mines and in abandoned and sealed sections roof falls and squeezes may produce water traps through which the gas must pass on its way to the vents. These water traps have been found to cause pulsations in gas delivery which result in noisy and destructive chattering of the valves. For this reason all valves are preferably fitted with dampening devices such as the hydraulic cylinders illustrated. Despite all precautions it is also possible that a combustible mixture might sometime be formed in the chambers and vent pipes. Such a mixture might be exploded through atmospheric electrical discharges and it is, therefore, also very desirable to equip these relief valves with metal safety screens as shown at 25 so that no flame can be propagated through an open valve. The valve itself in the form illustrated is, however, a very effective flame arrester because the velocity of efflux of the gases through the opening between the valve and its seat is always very substantial, corresponding to the loading of the valve, and will usually exceed the rate of flame propagation.

From the foregoing it will be understood that as a basic principle of my invention the sealed chambers remain in direct connection with the

atmosphere through large diameter vent pipes which are always effective to prevent the build-up of any dangerous gas pressure in the chambers, but that through the installation of suitable vent valves and safety screens on these

5 pipes the entry of air into the chambers is positively prevented, flash-back of flame through the vents is prevented, and by loading the valves within limits approximating the most common
10 barometric changes, loss of gas to the atmosphere may be avoided without rendering the vents ineffective to release gas when and if the pressure difference between the chamber and the active mine should build up above a safe level.
15 This pressure difference may be visually observed by comparison of the two gauges 35 and 34 (which may be duplicated for chamber 7) since the pressure in the active mine will always be the barometric pressure with a constant correction for the depth of the mine and the pressure differential created by the mine ventilation system.

To forcibly remove the gas continuously evolved from the coal in the sealed chambers, there is provided the blower 12 and pump 32, and although the detailed arrangements used for that purpose are of course subject to change as required by variations in local conditions, the principles are well illustrated by the installations shown and described. Thus it is desirable, where maximum rate of recovery of gas is wanted, to carry a mean pressure in the sealed chamber below the mean pressure of the active mine. This lowered pressure accelerates the rate of release of gas from the coal. Where it is necessary to maintain the highest practical heating value on the gas, in-leakage of even small proportions of air through the seal or through the roof, floor or side walls around the seal, must be prevented. Also such in-leakage involves the hazard of creating a zone of explosive mixture within the chamber. I have, therefore, provided a gas-lock by installing a second or outer seal 6. This gas-lock I maintain always at the same pressure as the active mine
35 by circulating gas withdrawn from chamber 7 by the blower 12. The circulation is controlled by the pressure regulator 17 which is, through the pressure tubes 18 and 19, responsive to the pressure differential between the gas-lock and the active mine. Should the pressure in the
40 gas-lock tend to become lower than that in the mine the regulator opens the valve in the connection from the line 15 to the blower outlet 14, and simultaneously closes the valve in the connection to the blower inlet 13. Gas is thus delivered to the gas-lock, building up the pressure until it becomes equalized. Correspondingly, pressure in the gas-lock above that of the active mine passages 2 and 3 acts to open the
55 line 15 to the suction side of the blower and quickly restore the equilibrium. In all cases the hole 20a in the vent line within the gas-lock ensures a circulation of gas through the lock and prevents it from becoming a dead-end, which by slow in-leakage or diffusion of air might become an explosion hazard. The hole 20a may be considerably smaller than the tube 15 so that it cannot prevent the maintenance of the desired pressure equilibrium between the gas-lock and the active mine. In setting the pressure regulator 17 allowance must be made for the difference in specific gravity between the gas and air. Coal mine gas of good quality and free from substantial contamination with air is in fact "natural gas." Like the "natural gas"
75 recovered from non-carboniferous formations it

is principally methane and has a specific gravity in the approximate range of .57 to .64 and with deep mines the resultant difference in the weight of the column of gas in the pipe 18 and the column of air in the pipe 19 may be over 6" of water. This correction if not made and maintained will render the gas-lock ineffective as a practical means for closely balancing gas and air pressures and avoiding contamination of the mine air by out-leakage of gas on the one hand, or danger of creating an explosive mixture behind the seal by in-leakage of air on the other hand. In order to maintain constant conditions corresponding to the correction made as above, it is desirable to provide a small air hole in the tube 19 at the surface to ensure very slow circulation of air through this tube, and also to provide a very small gas connection between tube 18 and the inlet line 13 of the blower, as indicated at 14a. In both cases the amount of circulation is too small to create velocity effects or give an error in the pressure reading but sufficient to ensure constant quality of gas in tube 18 and air in tube 19 corresponding to the calculated correction for the difference in weight of the gas and air columns in the two tubes.

The blower 12 is driven by some suitable prime-mover, not shown, to apply suction to the vent 8 and forcibly remove the gas and deliver it under pressure into the outlet line 14. It is regulated to operate at a constant rate of delivery less than or equal to the rate of evolution of gas from the coal in chamber 7, and as indicated above, this evolution rate is itself affected by the absolute pressure in the chamber. By the use of the gas-lock GL in which the pressure is equalized with the mine pressure the chamber 7 may be carried at constant absolute pressure below the mean pressure in the mine. Gas recovery is thereby accelerated, and at the same time mine safety conditions are improved. There is no out-leakage of gas through or around the outer seal 6 because of the equilibrium of pressures, and while there may be appreciable leakage from the gas-lock into the chamber 7, it is gas only which enters the chamber.

In the case of most large mines a number of separate sealed chambers will be created successively as mining operations proceed. In such cases it is desirable to utilize one of these chambers as a delivery chamber for all gas to be furnished to consumers. I have shown the chamber 26 as used for this purpose. The gas from the blower outlet 14 is, therefore, discharged through a direct connection 28 into the chamber 7. This leaves the full capacity of vent pipe 20 available as an outlet for emergency relief of excessive pressures in chamber 26. The chamber chosen as the delivery chamber will preferably be one of very large volume. This makes it most effective as a pressure equalizing and mixing reservoir and has the additional advantage of permitting the outlet to be located at a point so far removed from the inlet and from the seal and vent 20 that any air which may enter by leakage at these points will remain for long periods in contact with the coal in the chamber 26 before reaching the outlet pipe 30. I have found that under these conditions the oxygen content of the leakage air disappears by slow chemical reaction with the coal to form carbon dioxide. This is very desirable where the gas is to be delivered into a distribution system.

As a specific example of the method of operation of the equipment and installation above described the following is cited. The sealed chambers are filled with air from the mine ventilation system up to the time when they are cut off from the active mine, and it follows that there is a long introductory period during which the gas slowly evolves from the coal replaces and expels the air. Throughout this period large zones of explosive mixture necessarily exists in the sealed chambers and it is therefore very important that the valves and safety screens function perfectly to avoid any flash-back. In the course of time this hazard diminishes as the gas percentage increases and the oxygen content of the residual air is reduced by slow combination with the coal to form CO₂. When the pumps are started the valve 10 on vent pipe 8 is loaded to open at a pressure of one inch of water. The mean barometric pressure at the surface of the ground in the locality in question is 29 inches of mercury, and correcting for the height of the air column in the mine shaft and the pressure loss of the mine ventilation system the mean pressure in the active mine is 29.5 inches of mercury. The blower 12 is regulated to maintain an absolute pressure of 28.25 inches of mercury in the chamber 7, under which condition it is found that the blower delivers 400,000 cubic feet per day of gas having a specific gravity of .60 into the transfer line 14. This is the rate of evolution of the gas from the coal in chamber 7 and will be found to be substantially constant for any constant absolute pressure, declining slowly with the passage of time. The blower 12 may deliver the gas at a pressure of 5 pounds per square inch, which is adequate to discharge the gas into the chamber 26 through line 28. Through the valve 15 gas enters the pressure equalizing line 15 and is conveyed to the gas-lock, building up the pressure there to the same level as in the entry 3. This is a mean pressure of 29.5 inches but changes continuously with the fluctuations of the barometer and on some occasions may even drop below the absolute pressure of 28.25 maintained in the chamber 7. When this happens the pressure regulator 17 opens the line 15 into the suction line 13 of the blower until the equilibrium is reached. Line 13 is small enough so that there is always a pressure drop in the line sufficient to operate the system as described. If the barometric pressure at the surface falls sufficiently or if the blower 12 ceases to operate for any reason, the automatic valve on the vent 10 opens to release gas directly from chamber 7 to the atmosphere and thus protect the active mine against in-leakage of gas from the chamber.

Under normal operating conditions, the gas delivered into chamber 26 through transfer line 28, together with the gas evolved from the coal in this chamber, is continuously removed by the well-pipe 30 and pump 32, and may be delivered at high pressure directly into a long-distance transmission line. The pump 32 may be regulated to hold, for example, in chamber 26 an absolute pressure of 29.5 inches of mercury corresponding to the mean pressure in the active mine. The relief valves on the vent 20 and well-pipe 30 may be loaded to open at a pressure of 3 inches of water, above atmospheric pressure, it having been determined that this much pressure differential may be tolerated without important leakage of gas from the chamber 26 into the active mine. Since the mean pressure in the chamber 26 is slightly above the mean pressure of the mine there is no danger of in-leakage of air into cham-

ber 26 save during brief and infrequent periods of unusually high barometric pressure, and the large flow of gas into the chamber 26 adjacent the seal 27 through the transfer line 28 prevents this in-leakage from forming a zone of explosive mixture near the seal which might otherwise occur. As has been pointed out, occasional small in-leakage of air at this point does not appreciably affect the quality of the gas delivered through vent 30 because of the remote location of the latter and because in its travel through the maze of passages which exist in the worked-out area the oxygen content of the air disappears and is replaced by a much smaller amount, one-half or less, of carbon dioxide. In the event the delivery pump 32 should cease to operate the vent valve on top of well-pipe 30 is available to release gas from the chamber 26, supplementing the valve in vent pipe 20.

I am aware that it has heretofore been proposed to recover gas from virgin coal seams in situ by specially piercing such seams with bores, drifts, and tunnels and applying a vacuum.

The present invention is not directed to this problem but to the special problems which arise when active mining operations have been or are being conducted in a gassy coal seam. The primary need under this latter condition is to reduce the gas hazard involved in the mining itself. By the installations and procedure of my invention this primary need is met in a manner which also permits the collection and delivery of the maximum amount of the highest quality gas from the coal still remaining in the workings when further removal of coal becomes uneconomical. I have illustrated and described two interconnected sealed chamber systems of this kind, one of which operates under a mean pressure slightly below that of the active mine, and the other of which operates under a mean pressure slightly above that of the active mine. In both cases direct communication with the atmosphere is provided through special venting appliances, and in both cases the pumps used for the delivery of this gas to a point of consumption are also employed to reduce the pressure build-up within the sealed chambers. For simplicity the instrumentation required for these systems has been reduced to diagrammatic showings and not duplicated.

For the purpose of making my invention clear, I have shown and described in some detail and by the aid of specific examples the principles and method of use of my invention. Through use of these principles and methods of application, it is possible to add material amounts of natural gas to the world's current fuel supplies, while at the same time eliminating or reducing the hazards of fire and explosion associated with the active mining of coal in gassy underground mines. The same installations and methods may be used in mines in which active mining has been temporarily or indefinitely suspended since these installations best lend themselves to the state of the mine when active operations were suspended and leave open the possibility of re-opening the mine at minimum expense. Often it is possible by transfer of gas from one underground chamber to another, as illustrated in the example given, to save the cost of gathering and transmission lines and at the same time secure greatest uniformity of gas quality.

I do not regard the invention as limited to any

of the details shown or described save in so far as such limitations are included within the appended claims in which it is my intention to claim all novelty inherent in my invention as broadly as is permissible in view of the prior art.

What I claim is:

1. The method of minimizing gas hazards in underground coal mining operations and simultaneously making possible the recovery of the maximum amount of highest quality gas at a uniform rate declining only with the slow decline of the rate of gas evolution, which method comprises sealing off a mined-out section of the underground workings by a partition wall across the entry connecting it with the areas in which active mining continues, connecting the sealed chamber with the surface by a gas flow conduit normally closed against the atmosphere, forcibly withdrawing gas from the chamber at a rate not exceeding that at which it is evolved from the exposed coal surfaces under a constant pressure approximating atmospheric pressure, and opening such chamber to the atmosphere through said flow conduit only when accumulation of excess gas or a falling barometer causes the chamber pressure to exceed atmospheric pressure by a predetermined small amount.

2. An operation conducted according to preceding claim 1, and including the additional steps of employing a second partition spaced away from said first named partition to form a gas-lock, and forcibly circulating a portion of the withdrawn gas through said gas-lock while maintaining therein a pressure varying with the barometer and always equal to the pressure in the adjacent active mine area, whereby leakage of gas from the sealed chamber into the active mine or leakage of air from the active mine into the sealed chamber under pressure differentials created by forcible withdrawal of gas or by changing barometric pressures are both prevented.

3. An operation conducted according to preceding claim 1 involving a plurality of sealed chambers, and including the additional steps of forcibly transferring gas withdrawn from one sealed chamber into another sealed chamber and forcibly withdrawing the transferred gas as well as the evolved gas from the second chamber.

4. An operation conducted according to preceding claim 1 involving a plurality of sealed chambers and involving the additional steps of forcibly transferring gas withdrawn from one sealed chamber into another sealed chamber at a point adjacent the sealing partition and forcibly withdrawing the transferred gas as well as the evolved gas from the second chamber at a point remote from the sealing partition.

5. An operation conducted according to preceding claim 1 in which the gas is forcibly removed from the sealed chamber at a point remote from the sealing partition.

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