

# United States Patent [19]

[11] **3,850,477**

**Aldrich et al.**

[45] **Nov. 26, 1974**

[54] **CHEMICAL COMMINATION AND MINING OF COAL**

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[22] Filed: **June 29, 1973**

[21] Appl. No.: **375,280**

### Related U.S. Application Data

[62] Division of Ser. No. 232,324, Feb. 18, 1972, Pat. No. 3,815,826.

[52] U.S. Cl. .... **299/5, 44/51, 166/307, 208/8, 299/18, 302/22, 302/40, 302/45, 302/66**

[51] Int. Cl. .... **E21c 41/04**

[58] Field of Search ..... 299/4, 5, 17; 175/64, 12; 44/51; 208/8; 302/66, 22, 40, 45, 46; 166/271, 307, 308

### [57] ABSTRACT

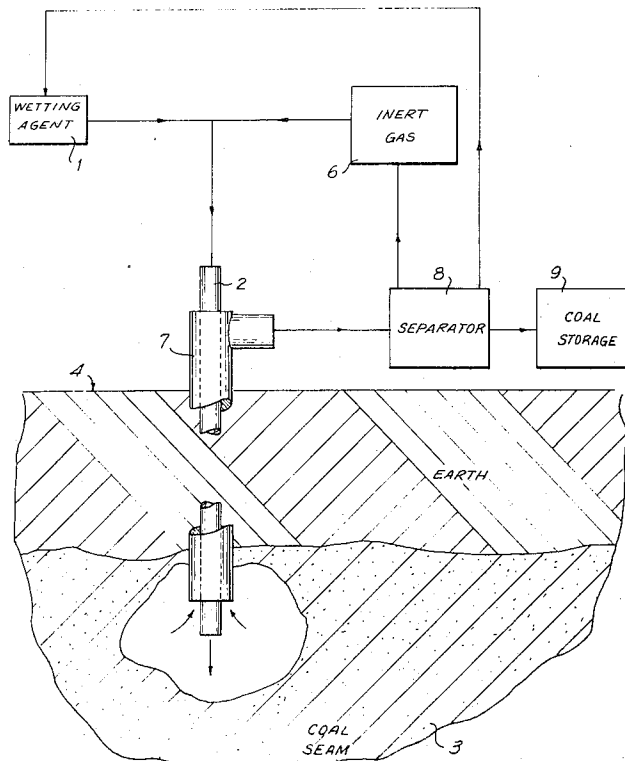
Coal, whether in a sub-surface stratum or in large lumps as mined by standard means is reduced to fragments by treatment with compounds which weaken interlayer forces at natural interfaces present in the coal. When coal below the earth's surface is treated with such compounds, the fragments can be suspended in inert gas moving at a sufficiently rapid rate and carried to the surface where the comminuted coal can be collected.

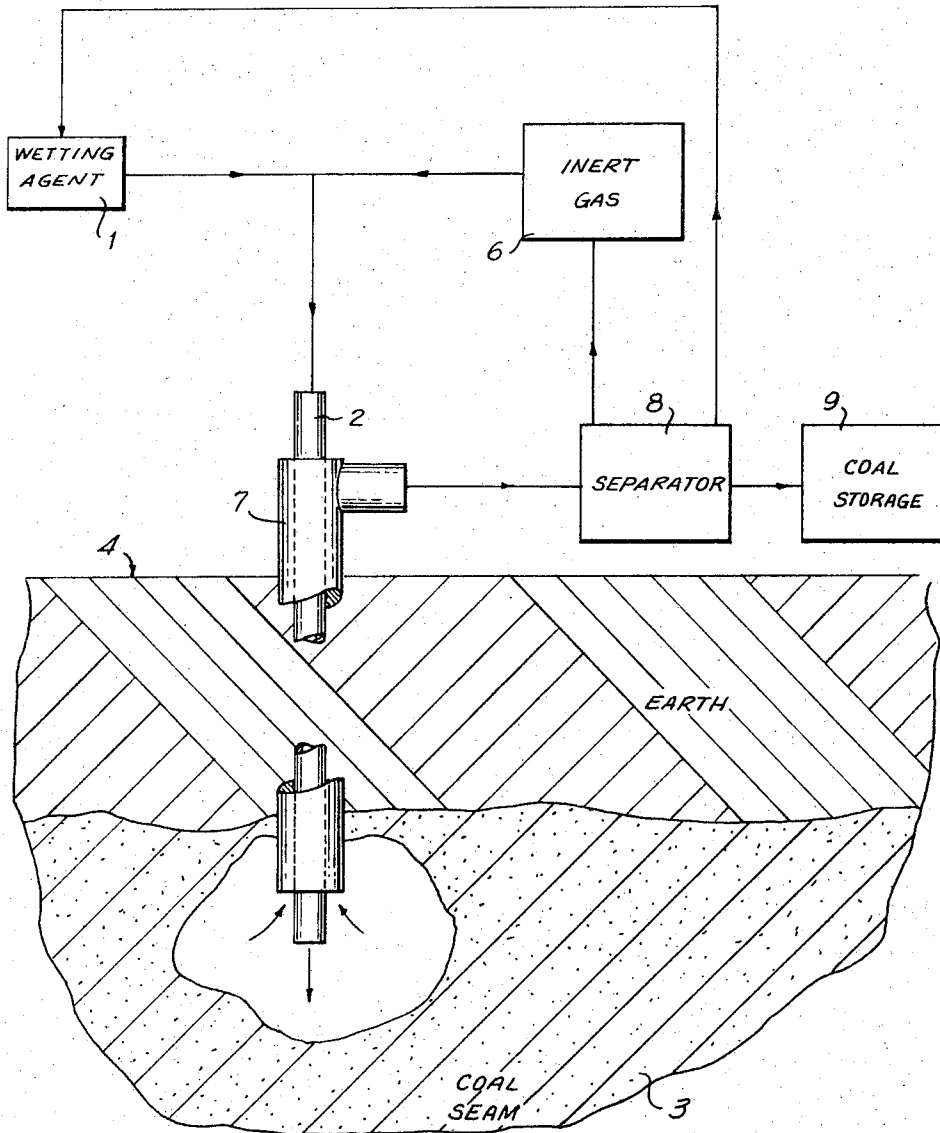
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**6 Claims, 1 Drawing Figure**





## CHEMICAL COMMINUTION AND MINING OF COAL

This is a division, of application Ser. No. 232,324, filed Feb. 18, 1972 and now U.S. Pat. No. 3,815,826.

### BACKGROUND OF THE INVENTION

According to usual coal-mining procedures, sub-surface coal is broken into pieces of manageable size by the use of explosives, picks or other mechanical means, and finally brought to the surface mostly in the form of large lumps which are then broken down by mechanical procedures such as crushing, milling, grinding, pulverizing, etc. The degree of reduction in size is suited to the application for which the coal is to be used.

Methods have been disclosed wherein the addition of inorganic or organic salts and weak aqueous solutions have suppressed the formations of fragments in the airborne size range during conventional coal cutting, although no particular advantage was cited in the size reduction processes (Poelnev, A.P., et al., "Control of Coal Dust in Mines," Akad. Nauk SSR Sb. Statu 7 (1967), 72.)

The usual methods for the breakage of coal which is found in the natural state as massive solid beds include the use of drilling, cutting or explosive mining techniques as aforementioned. All of these are normally used in conjunction with each other and require an excessive energy expenditure including man power. Since numerous industrial processes which consume coal use the extracted product in particulate form, e.g. one-half inch size or less, further size reduction operations are required. Each of these subsequent processes employed for further particle size reduction requires large additional expenditures of energy and produces excessive volumes of coal dust, hazardous due to its explosive nature and the effect on the health of workers carrying out the operations.

### SUMMARY OF THE INVENTION

The treatment of coal with compounds disclosed herein results in fracture of the coal by weakening of the interlayer forces at natural interfaces present in the coal. The weakening of the forces is sufficiently great so that in some cases, the coal breaks into particles small enough to be airborne without the application of further force. Other compounds disclosed herein, when applied to coal, weaken the interlayer forces sufficiently so that only minimal energy is required to fragment the coal.

The chemical comminution of coal can be used for mining coal from sub-surface strata by injecting any of said compounds into a sub-surface stratum, following this with the injection of an inert gas at a rate high enough to form a suspension, and carrying the suspension back to the surface where the comminuted coal is separated from the carrier gas.

Accordingly, an object of the present invention is to provide a low energy consumption method for the fragmentation of raw coal.

Another object of this invention is to provide a low energy consumption method for the fragmentation of raw coal in natural beds or seams.

A further object of the present invention is to provide a low energy consumption method for the fragmentation of coal during the preparation of coal subsequent to its retrieval from a mine.

Yet another object of this invention is to provide a method for the fragmentation of coal which is free of airborne dust production.

Yet a further object of this invention is to provide a means for particle size reduction of coal without affecting the particle size of rock or mineral impurities.

A significant object of the present invention is to provide an improved means for fragmentation of coal without detriment to the calorific value of the coal.

A further object of the present invention is to provide an improved basis for rock and mineral impurity separation from coal.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others thereof, which will be exemplified in the method hereinafter disclosed, and the scope of the invention will be indicated in the claims.

### BRIEF DESCRIPTION OF THE DRAWING

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawing, in which:

The single FIGURE shows schematically the fragmentation and mining of coal in accordance with the method of the present invention.

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

A number of materials have been found which when brought in contact with coal weaken interlayer forces to a useful extent. In view of the fact that these compounds affect surface forces, they will be referred to as surface active agents or wetting agents despite the fact that these compounds are not normally so regarded.

It is known that aqueous solutions of ammonia and a number of other inorganic compounds tend over a long period of time to cause interlayer weaknesses in the natural interfaces of coal; however, such compounds have not been effective to accomplish purposes of the invention. The ability of small molecules to diffuse through the internal surface structure of coal appears to be essential to accomplish the purposes set forth. For example, anhydrous ammonia in the liquid or gaseous state in contact with massive coal immediately impregnates the coal structure causing a reduction in internal boundary strength to near zero. The massive coal system after impregnation has almost no resistance to a crushing force; some coals virtually collapse under their own weight to a finely divided coal product when treated with anhydrous ammonia or other compounds to be named below.

A preferred method of particle size reduction would initiate in the natural coal bed itself wherein the finely divided coal is removed as the product of the combined action of, for example, substantially anhydrous liquid (or gaseous) ammonia under pressure and mechanical devices which essentially form a boring tool. The boring tool is first used as a means of reaching a sub-surface coal seam and providing a passage through which one or more pipes can be inserted into the seam. The pipes essentially seal the passage, and the pipes can be arranged, preferably essentially concentrically, so that wetting agent and inert carrier gas can be brought

to the seam, and a fluidized suspension of comminuted coal can be brought to the surface where finely divided contaminants can be separated from the suspension. The ammonia can be recovered by a suitable process for recycling. The coal particles can then be classified for further size reduction in an ammonia atmosphere, for further contaminant isolation or for direct sale.

The single FIGURE shows schematically how such a process is carried out. Wetting agent, stored in tank 1 is supplied to pipe 2 and transported therethrough to coal seam 3 lying below the surface of the earth 4. An inert gas stored in tank 6 is likewise transported through pipe 2 to coal seam 3. The rate of supply of inert gas is such that coal fragments produced by contact of the wetting agent with the coal seam are fluidized and carried upward through pipe 7. From pipe 7 the fluidized product is carried to separator 8 which screens the coal fragments from rock and other impurity objects which are of larger size. The fragmented coal is transferred to coal storage bin 9. Such wetting agent as is recovered in separator 8 is transferred back to tank 1. Similarly, the inert gas used for fluidizing the coal fragments is returned to inert gas storage tank 6. The various pumps, valves, etc. necessary for the operation are not shown since the provision of such accessories would be within the skill of one familiar with the art. Furthermore, although pipes 2 and 7 are shown as being concentric this is merely a matter of convenience since the drilling of only one hole is required with such an arrangement. Also, three concentric tubes could as conveniently be used, one to carry the wetting agent, a second to carry the inert gas, and the third to lead the fluidized coal fragments to the surface.

Treatment of coal chunks with the wetting agents of the present invention is also useful where the chunk coal is obtained by strip mining operation or by standard techniques. In such cases, the fluidizing technique is not needed.

Essential to the process is the exposure of massive or chunk coal to a surface active agent such as liquid or gaseous ammonia, methanol or other organic compounds of molecular weight less than 100, including some as solvents with the addition of inorganic compounds which effect a substantial drop in internal boundary strength. No precise time, temperature or pressure can be specified for the impregnation step as it will naturally depend on the morphology and chemistry of the coal and the ability of the agent to diffuse through all of the interfaces. Time, temperature and pressure control the rate of diffusion.

The postulated mechanism for the decrease in boundary strength due to the effects of the surface active agents is as follows: the low molecular weight ammonia, for example, penetrates the massive coal structure by rapid diffusion and capillary along the natural bedding planes and other structural defects of the coal. The strong hydrogen bonding ammonia is adsorbed on each of the two surfaces constituting the boundary, renders the natural atomic bonding system of the interface inactive and substitutes a boundary surface which has little attractive force for its counterpart surface. The consequence is that all boundaries which were exposed have essentially no resistance to applied forces. Since only natural boundaries or internal surfaces are attacked, i.e., homogeneous volumes do not appear to be affected, and since these surfaces are the most likely for the precipitation of sulfur bearing deposits, fracture

along these planes will expose the non-coal constituents and facilitate the removal of such impurities.

The generation of fine particles with a hydrogen bonded film of ammonia or other surface active agent facilitates transport. The presence of the adsorbed surface active agent film is not detrimental to the calorific value of the coal and does not induce deleterious side reactions which could present a health hazard or interfere with industrial processing.

The process of the invention is further illustrated by the following examples:

Samples of Illinois No. 6, Lower Cherokee and Pittsburgh coals approximately 5 inches in length, 5 inches in width and 5 inches in thickness were cut from larger pieces and placed in separate glass containers at room temperature. A mixed stream of gaseous and liquid anhydrous ammonia was directed at each sample individually for a period of approximately three minutes. During this period continuous visual observations were made as to the extent of spontaneous breakage in each sample.

Within 1-2 minutes after the start of spraying both the Lower Cherokee and Illinois No. 6 coals began crumbling without the application of any externally applied force. During a 30 minute standing period coal particles spontaneously fragmented were typically in the size range 100 mesh X O. In the case of Pittsburgh coal an approximate time of 5 minutes elapsed before significant breakage occurred with the fragmented particles typically in the size range 10 mesh X O. It was observed in all tests that non-coal contaminants, e.g. pyrite, calcite, shale, rock, were not significantly affected by exposure to this environment. Pieces of these materials up to three-fourth inch in size were found after exposure. Microscopic examination of the fragmented coal particles subsequent to breakage indicated that the particles tended to have irregular shapes with sharply defined edges such as would be expected as a consequence of brittle fracture. The absence of any rounded or smoothed particle shapes further illustrated that the application of anhydrous ammonia had not significantly interacted to dissolve or otherwise modify the bulk structure of the coal. Chemical interactions are postulated to have occurred within adjoining surficial layers of macroscopic and microscopic internal boundaries within the coal.

In order to verify that no portion of the observed effect was attributable to the low temperatures of the liquid-gas ammonia stream additional experiments were performed wherein samples of Illinois No. 6 and Pittsburgh coals were immersed in tap water at room temperature for one hour, cooled in air at an approximate rate of 50°F/hour to 0°F, and thawed at room temperature in tap water. No effects were observed to occur during or as a consequence of these processes. Similarly a sample of Lower Cherokee coal was chilled by immersion in a liquid-gas stream of nitrogen for approximately 5 minutes and thawed in air. Microscopic examination indicated that coal breakage had not been effected by the freezing process.

Samples of Illinois No. 6, Lower Cherokee and Pittsburgh coals approximately 3 inches in length, 4 inches in width and 3 inches in thickness were placed separately in glass containers filled with a mixture of 150 ml anhydrous methanol, 50 ml distilled water and one-fourth mole sodium hydroxide. To ensure a minimum of moisture pickup from the air the sample containers

were placed separately in desiccators with calcium chloride added. The samples were allowed to stand for several hours; at selected regular intervals each was examined to determine breakage effects induced by the methanol. After 1 hour exposure light tapping of the coal resulted in significant breakage and after 3 hours spontaneous fragmentation had progressed sufficiently to reduce the coals to the 10 mesh X O size range.

Table 1 shows compounds which have been tested and found effective in the comminution of lump coal.

TABLE 1  
WETTING AGENTS

Substantially anhydrous methanol  
Substantially anhydrous methanol plus one-fourth mol NaOH/liter  
Substantially anhydrous ethanol  
Substantially anhydrous ethanol plus one-fourth mol NaOH/liter  
Substantially anhydrous isopropanol  
Substantially anhydrous isopropanol plus one-fourth mol NaOH/liter  
Glacial acetic acid  
70 percent Ethylamine  
40 percent Methylamine  
Acetone  
3 percent Hydrogen peroxide

It will be noted that all of the compounds listed are below 100 in molecular weight.

A number of mixtures of these wetting agents have also been found to be effective in fragmentation of lump coal. Such mixtures are listed in Table 2. In each of the binary solutions listed, the components are present in equal volumes.

TABLE 2  
WETTING AGENTS

40 percent methylamine/anhydrous methanol  
70 percent ethylamine/anhydrous ethanol  
anhydrous methanol/acetone  
anhydrous ethanol/acetone  
anhydrous isopropanol/acetone  
glacial acetic acid/acetone

It has been observed that total immersion in the liquid phase of whatever surface active agent is used is not a necessary condition, although the rate of reaction may be greater if the coal is totally immersed. The quantity of reagent required for comminuting a unit weight of coal is directly dependent upon the particular reagent used, the final physical and chemical specifications of the coal product and the nature of the specific mining or processing techniques employed.

Results obtained thus far indicate that about 100 pounds of reagent are required per ton of coal. The net loss of reagent, that is the fraction of reagent not recoverable, has been found to be about 4 pounds per ton of coal, so that the efficiency of agent recovery is about 96 percent.

Tests have shown that the concentration of alkali in alcohol is not critical, and have also shown that the ratio of reagents in mixtures need not be 1 to 1 by volume. For instance, a solution consisting of 40 parts of methanol and 60 parts of methylamine has been found to be effective. This is evident from the fact that a mixture consisting of 150 ml of anhydrous methanol, 50 ml

of distilled water and one-fourth mole of sodium hydroxide has been found to be effective.

Although it appears that the effectiveness of the various compounds and mixtures listed above is due to their low molecular weight, and to their ability to form hydrogen bonds to carbon at interfaces, the invention is not to be deemed dependent on any particular theory of mode of operation or limited to the specific methods illustrated.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above method without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A method of mining sub-surface coal comprising the steps of forming at least one opening into a sub-surface stratum of solid coal, injecting into said sub-surface stratum an effective amount of a compound selected from the group consisting of substantially anhydrous liquid ammonia, anhydrous gaseous ammonia, anhydrous methanol, anhydrous methanol containing about one-fourth mole of sodium hydroxide per liter, anhydrous ethanol, anhydrous ethanol containing about one-fourth mole of sodium hydroxide per liter, anhydrous isopropanol, anhydrous isopropanol containing about one-fourth mole of sodium hydroxide per liter, glacial acetic acid, 70 percent ethylamine, 40 percent methylamine, pure acetone, 3 percent hydrogen peroxide and a mixture consisting of 150 ml of anhydrous methanol, 50 ml of distilled water and one-fourth mole of sodium hydroxide, said compounds being capable of reducing interlayer forces at natural interfaces present in said coal, injecting an inert gas into the region of said sub-surface stratum of coal treated with said compound at a rate high enough to form a suspension of coal particles in said inert gas, and leading said suspension of comminuted coal in inert gas to the surface for collection of said comminuted coal.

2. The method of claim 1, wherein said comminuting compound and said inert gas are forced through one of two pipes leading through said opening from the surface to said stratum of coal and said suspension of comminuted coal in inert gas is led to the surface through the other of said pipes.

3. The method as defined in claim 1, wherein said pipes are essentially concentric.

4. The method as defined in claim 1, wherein said comminuting agent is introduced through said opening into said stratum of coal, allowed to remain in contact with said coal for a period sufficient for comminution of said coal, after which said inert gas is introduced to form said suspension and carry said suspension through said opening to the surface.

5. The method as defined in claim 1 further comprising the step of fragmenting said coal in said stratum with a boring-tool.

6. A method of mining sub-surface coal as defined in claim 1, wherein said compound is one of the following solutions, the two members of each solution being present in roughly equal volumes, 40 percent methylamine with anhydrous methanol, 70 percent ethylamine with anhydrous ethanol, anhydrous methanol with acetone, anhydrous ethanol with acetone, anhydrous isopropanol with acetone, glacial acetic acid with acetone.

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