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Keller, Jr. et al.

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[54] **APPLICATION FOR THE BENEFACTION OF COAL UTILIZING HIGH VOLATILE LIQUIDS AS CHEMICAL COMMINUTANTS**

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[52] **U.S. Cl.** **241/1,** 241/15, 241/18, 241/24, 241/39, 241/79.1

[51] **Int. Cl.** **B02c 19/00**

[58] **Field of Search** ..... 241/14, 16, 1, 15, 18, 241/19, 20, 24, 25, 30, 38, 39, 46 R, 79, 79.1; 75/1; 299/10

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Attorney, Agent, or Firm—Misegades, Douglas & Levy

[57] **ABSTRACT**

Mined coal of all grades contains numerous solid impurities such as slate, shale, and iron pyrites. The treatment of such coal with certain high vapor pressure chemical comminutants such as liquid anhydrous ammonia at - 33°C renders the coal into smaller particle sizes and separates it from its inherent impurities by means of the apparatus of the invention which includes a reactor receiving the coal to which is applied a chemical agent such as liquid anhydrous ammonia, and which separates the impurities from the coal and recovers the ammonia from both for reuse in the apparatus.

30 Claims, 8 Drawing Figures

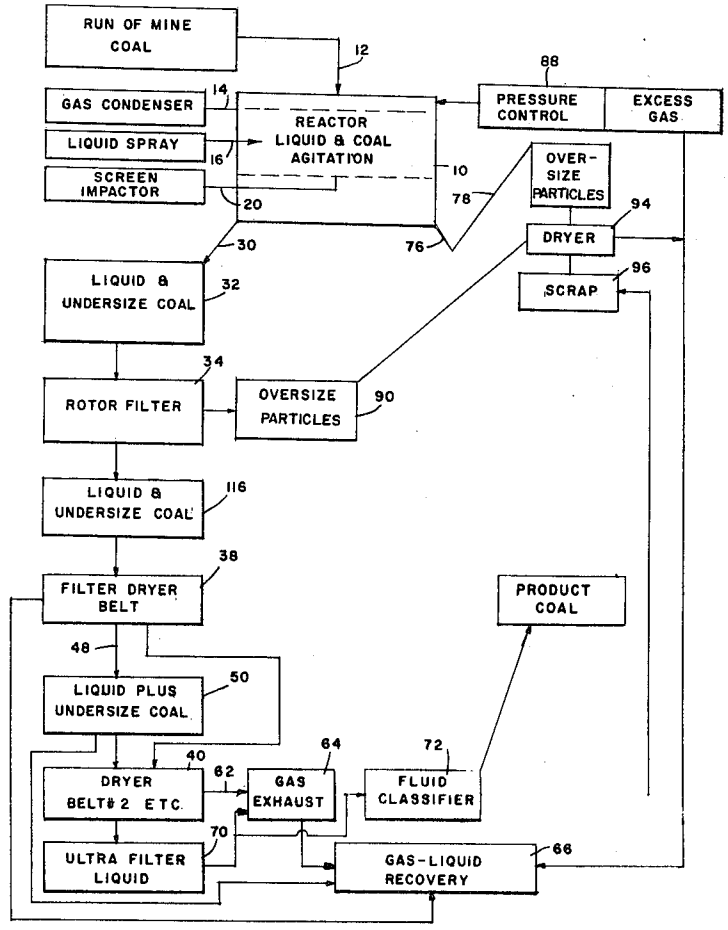


FIG. 1

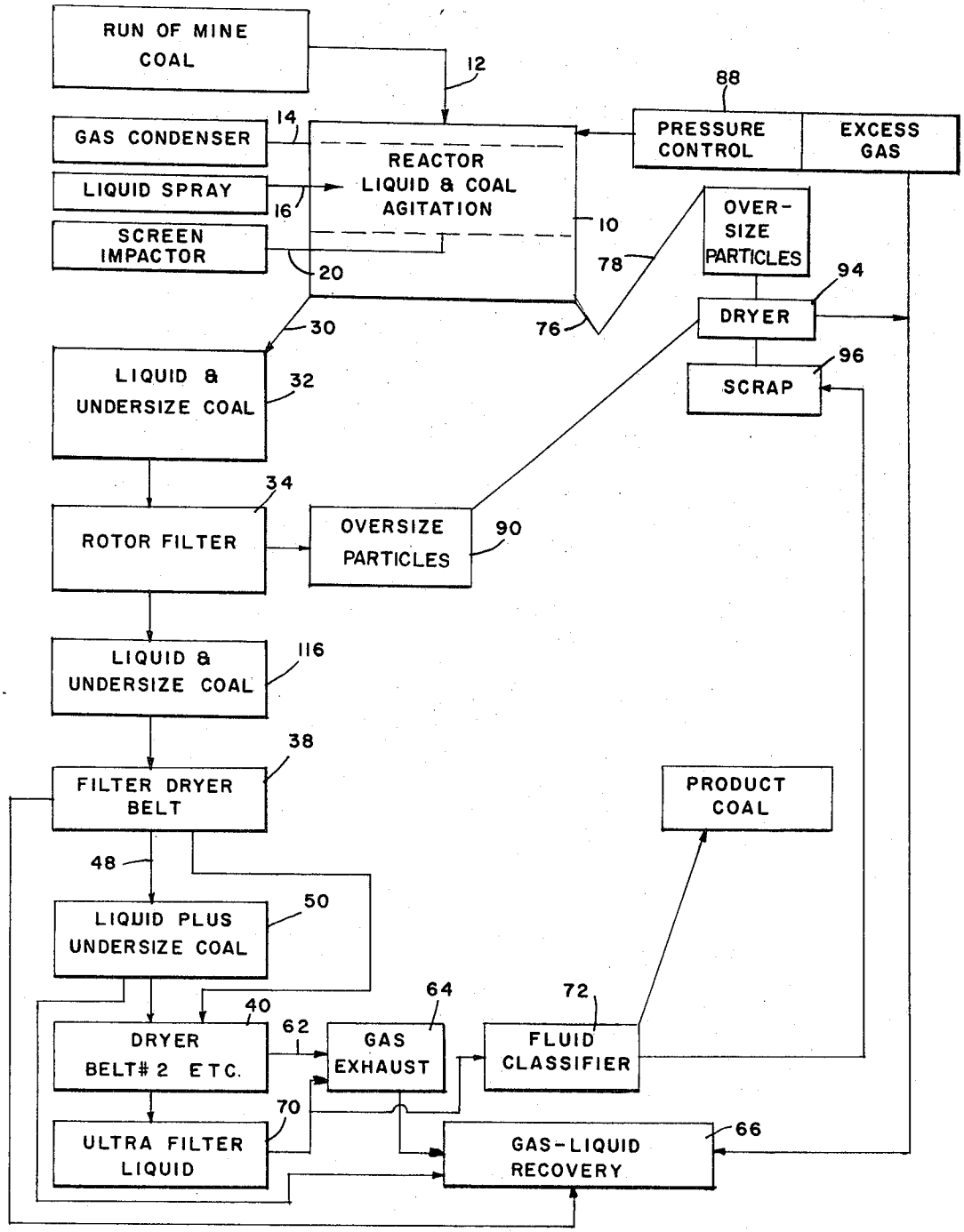
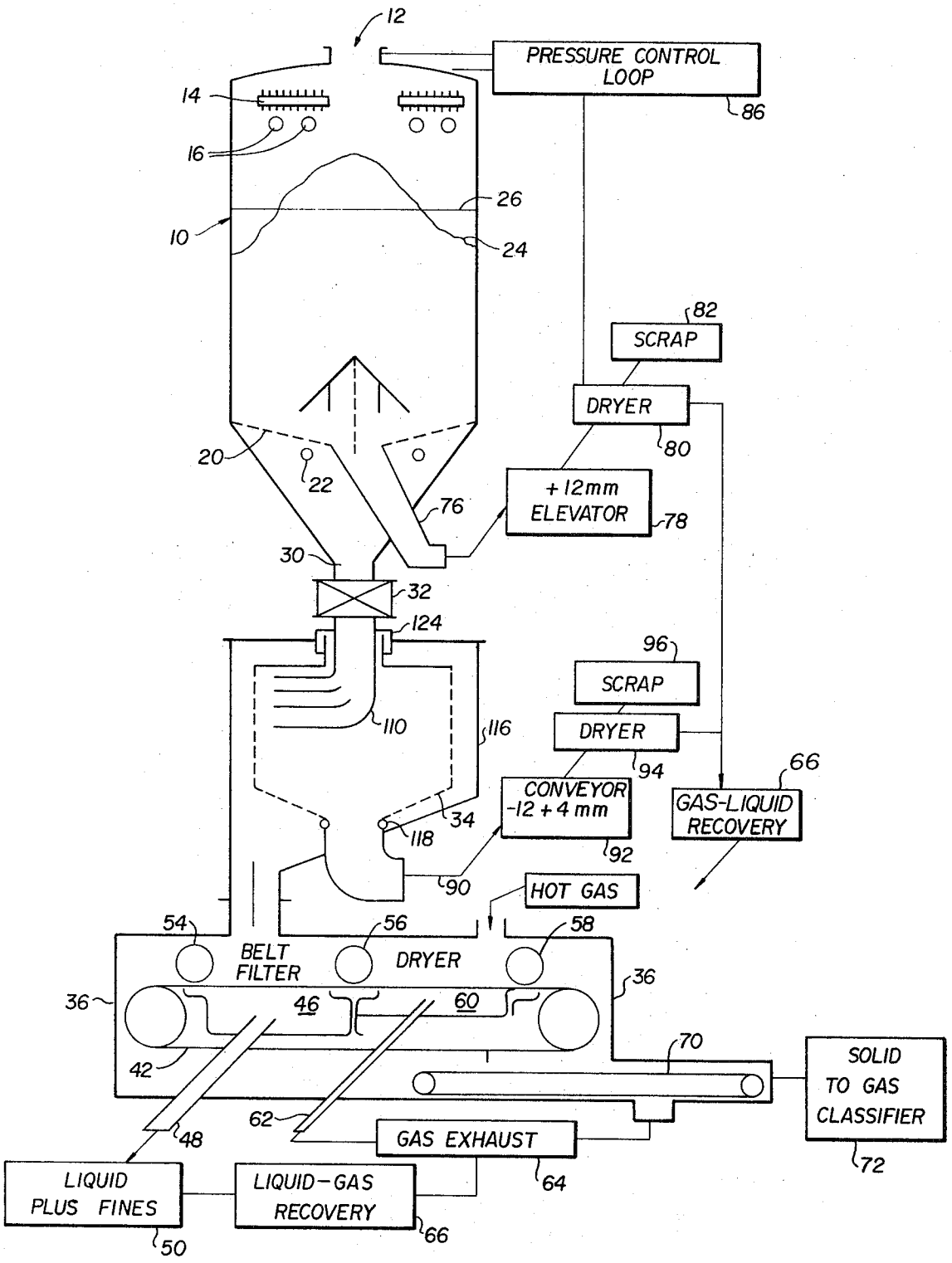

RUN OF MINE COAL
12
88
GAS CONDENSER
14
PRESSURE CONTROL
EXCESS GAS
LIQUID SPRAY
16
REACTOR LIQUID & COAL AGITATION
10
OVER-SIZE PARTICLES
SCREEN IMPACTOR
20
78
94
DRYER
30
76
LIQUID & UNDERSIZE COAL
32
96
SCRAP
34
ROTOR FILTER
OVERSIZE PARTICLES
90
LIQUID & UNDERSIZE COAL
116
38
FILTER DRYER BELT
PRODUCT COAL
48
LIQUID PLUS UNDERSIZE COAL
50
64
72
40
62
DRYER BELT# 2 ETC.
GAS EXHAUST
FLUID CLASSIFIER
70
66
ULTRA FILTER LIQUID
GAS-LIQUID RECOVERY

FIG.2


12
PRESSURE CONTROL LOOP
86
14
16
26
10
24
82
SCRAP
DRYER
80
20
22
+12mm ELEVATOR
78
76
30
32
124
96
SCRAP
110
116
DRYER
94
66
CONVEYOR -12 + 4 mm
GAS-LIQUID RECOVERY
34
118
92
90
HOT GAS
54
56
58
BELT FILTER
DRYER
36
36
46
60
70
42
SOLID TO GAS CLASSIFIER
62
48
GAS EXHAUST
64
LIQUID PLUS FINES
LIQUID-GAS RECOVERY
66
50
72

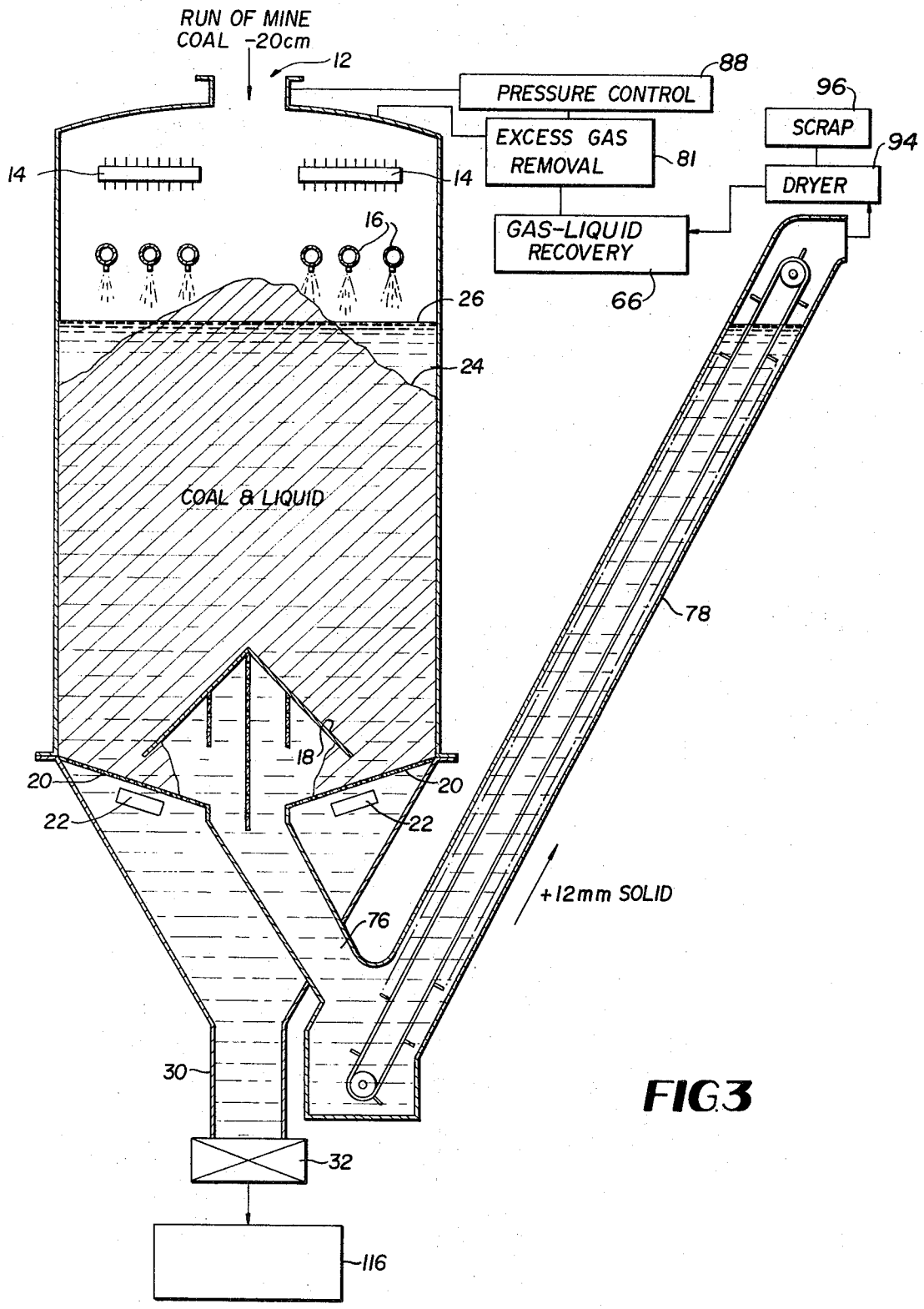
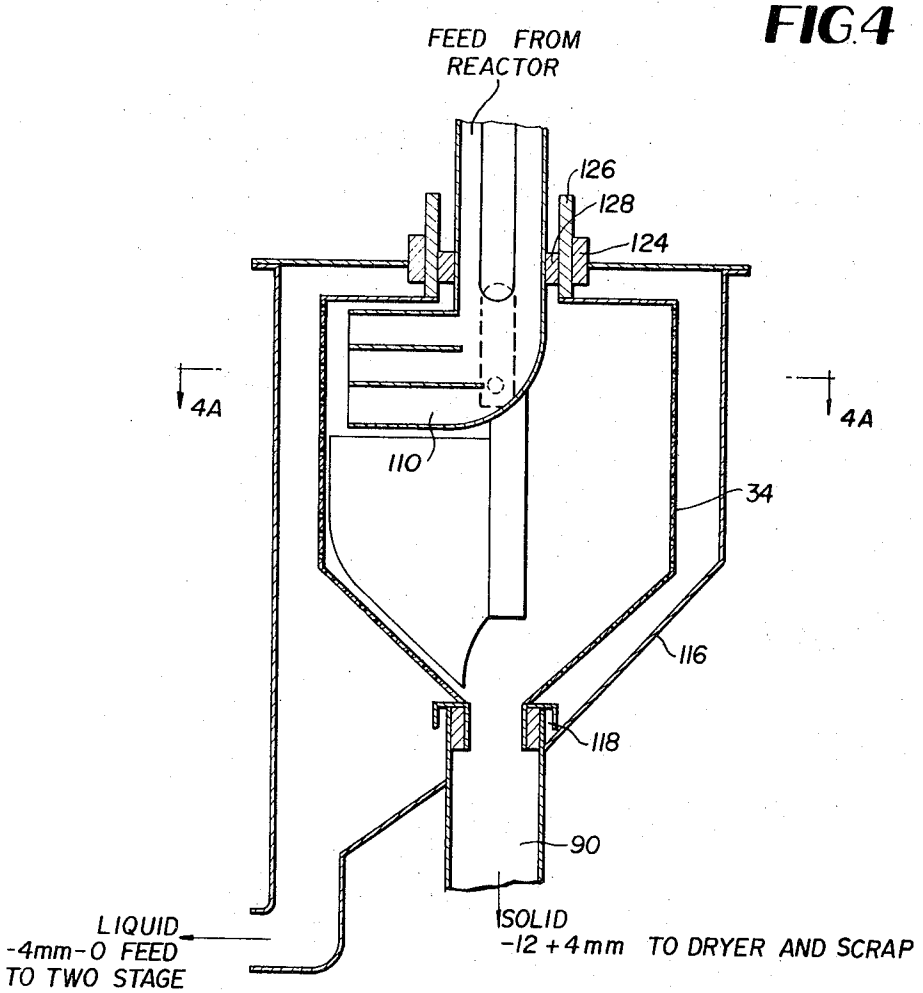

RUN OF MINE
COAL -20cm
12
88
PRESSURE CONTROL
96
SCRAP
94
DRYER
EXCESS GAS
REMOVAL
81
14
14
16
GAS-LIQUID
RECOVERY
66
26
24
COAL & LIQUID
78
18
20
20
22
22
+12mm SOLID
76
30
32
116

FIG3

FIG.4


FEED FROM REACTOR
126
128
124
4A
4A
110
34
116
118
90
LIQUID -4mm-0 FEED TO TWO STAGE FILTER
SOLID -12 +4mm TO DRYER AND SCRAP

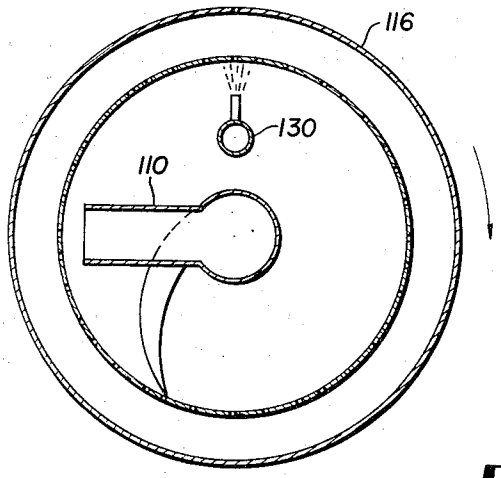

116
130
110

FIG.4A

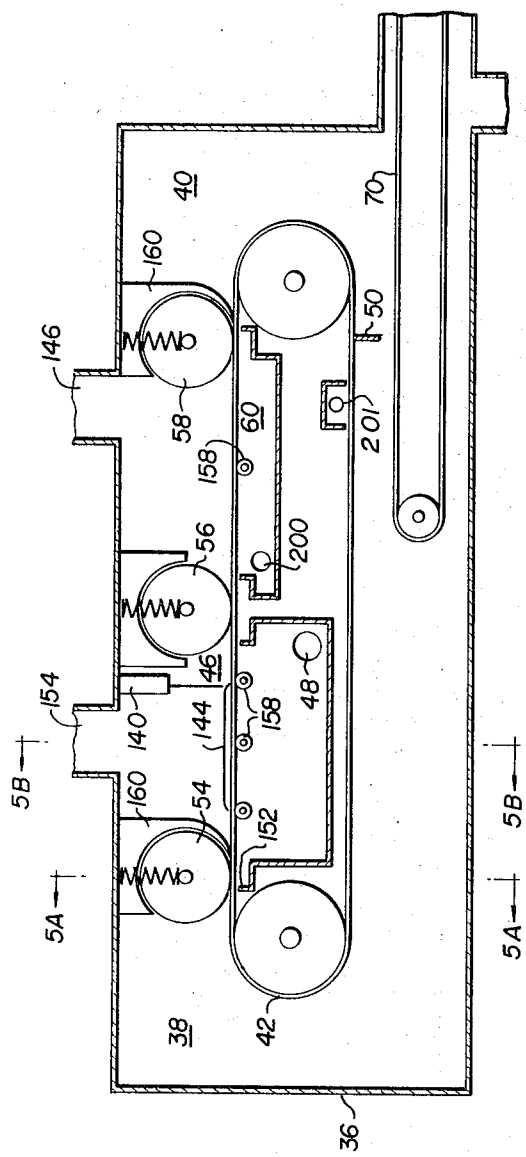


FIG.5

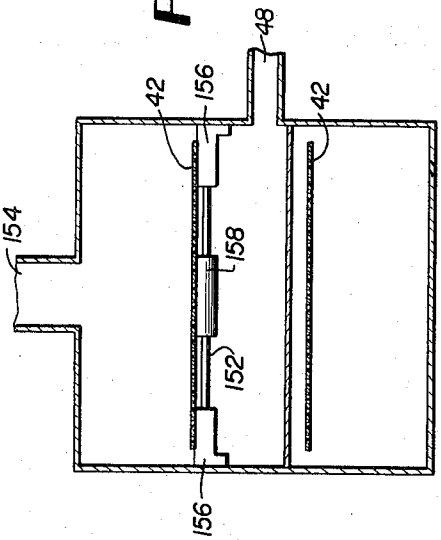


FIG.5B

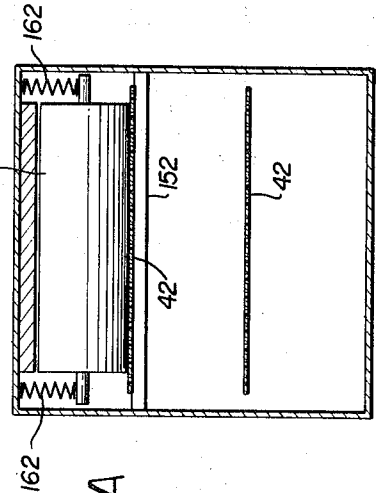


FIG.5A

APPLICATION FOR THE BENEFACTION OF COAL UTILIZING HIGH VOLATILE LIQUIDS AS CHEMICAL COMMINUTANTS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention relates to an apparatus which relates to the chemical reaction referred to in a co-pending patent application of R. G. Aldrich, D. V. Keller, Jr., and R. G. Sawyer, for "Chemical Communication and Mining of Coal," filed Feb. 14, 1972, Ser. No. 232,324. No claim of rights is made under 35 U.S.C. ss 119, 120 or 121.

FIELD OF THE INVENTION

The invention relates to apparatus to provide for the treatment of "run of the mine" coal to be treated with high vapor pressure chemical agents, such as those that tend to reduce substantially the solid surface tensions effective between solid mixtures or combinations thereof, of compounds found in coal, resulting thereby in the subsequent separation and recovery of said chemical or physical agents. Examples of such agents are anhydrous ammonia used in liquid form.

The separate constituents derived from the coal may be used for commercial, industrial and utility uses and recovery of the liquid and gases reused in the process. The coal product is anhydrous and essentially freed from the undesirable impurities which are also anhydrous. A particular aspect of the invention relates to providing use of the impurities in their final form as being of relative commercial importance.

BACKGROUND OF THE INVENTION

Natural coal as it is mined from its natural beds may contain more than 40 percent noncombustible constituents such as shale or slate, as well as generally high concentrations of undesirable minerals such as iron pyrites. The common process for the benefaction of such natural coal is to subject the run of the mine material to a hydro-benefaction treatment in which the coal is mechanically reduced in particle size and subjected to a series of water-chemical flotation treatments which remove substantial quantities of noncombustible rock and which render the coal a somewhat more efficient chemical and energy-producing material. Such hydro-benefaction types of treatment for coal do not provide a complete separation of the impurities from the coal in many cases. As a consequence, flotation or air classification procedures are inefficient often producing a coal product with considerably more than 5 percent impurities. The high concentration of impurities effects an increase in shipping costs, excessive corrosion during the energy conversion process, contamination during chemical usages, and excessive environmental pollution in the form of ash and the oxides of sulfur when the coal is oxidized. The product of such a process is also subject to loss in calorific value due to surface oxidation due to the high concentration of very fine particles generated in the process in contact with surface water.

According to recent disclosures, coal when subjected to certain high vapor pressure compounds such as anhydrous liquid ammonia (boiling point − 33.4° C), is determined to be reduced in particle size by a process called chemical comminution. This size reduction effect appears to change the particle size of only the coal and not other constituents of the coal bed materials which are undesirable in final usage of the coal. For example, slate, shale or iron pyrites are often found imbedded in a coal matrix as found in nature and when this composite is treated with the liquid, the particle size of the coal is rapidly and substantially reduced, whereas the undesirable slate, shale or iron pyrites are unaffected. The chemical properties of the coal are essentially unchanged, yet the coal is physically separated from the massive impurities. Also it is found that supernatent water in the coal has been removed.

SUMMARY OF THE INVENTION

The apparatus of the invention as disclosed herein provides for the interaction of the high vapor pressure chemical comminutants, which are often hazardous when in bodily contact, with run of the mine coal such as to effect a physical separation of the coal from its impurities without the loss of the chemical comminutants and essentially complete recovery of the coal and impurities. The recovery of the chemical comminutants for reuse in subsequent cycles of chemical comminution establishes the economy of the apparatus and will tend to maintain environmental pollution to a minimum.

Accordingly, an object of the invention is to provide apparatus for a closed loop cycle in which coal is exposed to certain liquids which are herein identified as chemical comminutants, either by a continuous or with simple modifications, a batch system effecting a useful coal product, useful by-products, and a reusable chemical comminutant.

Another object of the invention is to expose the coal to the liquid or gas for some specific period of time under the conditions of a small variational mechanical stress, cyclical or otherwise, which is insufficient to cause mechanical failure of the untreated run of the mine coal, but large enough to improve the coal recovery efficiency. By mechanical failure is meant the physical structure collapse, or fracture of coal under an imposed stress.

A further object of the invention is the direct use of coal as it is received from the coal mining operation.

A more significant object of the invention is to effect a greater than 95 percent separation of coal from the common impurities such as slate, shale and iron pyrites of the mine product utilizing a reducing atmosphere and an essentially anhydrous process. The calorific value of the coal is essentially unchanged since air or water exposure is maintained to a minimum.

Another object of the invention is to effect improved separation of the impurities from coal without developing large quantities of coal aerosol which are a known health hazard.

A further object is to establish a separation of the individual by-product materials from the coal and each other for eventual use in industry.

A further object is to reduce significantly the air and water pollution generated by benefaction of coal.

A further object of the invention is to remove supernatent water from coal.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects and advantages of the invention will become apparent upon full consideration of the following detailed description and accompanying drawings in which:

FIG. 1 shows a schematic block flow sheet diagram of the entire process which indicates the various material flows in accordance with a preferred embodiment of the invention;

FIG. 2 shows a schematic detail sketch and block diagram of the apparatus including the interaction of the reactor and three stages of size separation under a high vapor pressure liquid;

FIG. 3 shows a schematic enlarged detail diagram of the reactor and its salient features according to the preferred embodiment of the invention;

FIG. 4 shows in part a detailed diagram in vertical cross-section of the flow control from the reactor and the second stage of sizing the product;

FIG. 4A is a sectional view taken along line 4A—4A of FIG. 4;

FIG. 5 shows a vertically oriented schematic detailed diagram of the stage filter-dryer according to the preferred embodiment of the invention;

FIG. 5A is a cross-sectional view taken along lines 5A—5A of FIG. 5; and

FIG. 5B is a cross-sectional view taken along lines 5B—5B of FIG. 5, each and all within the scope and purview of the invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

Essentially anhydrous liquid ammonia having a boiling point of −33.4° C has been shown to act as one of what is to be identified herein as a more successful high vapor pressure chemical comminutant used in the benefaction of coal and, as such, serves as an excellent example for use in an explanation of the disclosed apparatus. The low boiling point and toxicity demonstrate the special requirements required of the apparatus which is capable of handling a large material flow characteristic of the coal industry, e.g., in the range of hundreds of tons per hour. This example should not be construed as a limiting case for various chemical comminutants have been cited such as ethylamine, methylamine, including many others and mixtures thereof. Any combination of these chemical comminutants can be used in the disclosed apparatus with suitable modification for materials of construction and reaction temperature and rate adjustments.

Experimentation has quite conclusively shown that the reaction of coal with anhydrous ammonia requires a finite exposure time and the existance of a very mild mechanical stress in order to perform an efficient separation of the coal from its impurities. The extent of the exposure time is from seconds to large fractions of an hour; the extent of the mechanical stress which is always much less than the fracture stress of the untreated coal is dependent on the source of the coal. Bituminous coal from one Pittsburgh seam, for example, required nearly an hour for complete reaction; whereas that from another required only a few seconds exposure to disintegrate under its own stress. It should be noted that mechanical stresses which are large enough to cause the mechanical failure of untreated coal, such as those experienced in grinding mills or extensive impact caused by certain materials handling procedures, should be considered as a gross disadvantage to the effectiveness of this separation process, since the impurities must be carried along to the density separation phase. For example, the optimum coal feed material for this process would be 100 percent of the coal with diameters greater than 12 mm, that is, no extensive mechanical fracture prior to chemical comminution, such that the impurities are removed at the earliest possible stage. Since modern mining procedures do not conform to this optimum, mechanical particle size reduction after the coal is received from the mine should be held to a minimum as is accomplished in the disclosed apparatus. Excessive water present in the run of the mine coal, such as coal from hydromining techniques, can represent an inefficiency in the process, water removal can be achieved by drying before the coal is added to the reactor or within the reactor itself. The water when added to the reactor along with the coal is for the most part removed by dissolution into the anhydrous ammonia establishing a water - ammonia solution. This solution is then separated into its components water and anhydrous ammonia by a fractionation step which is common to the industry. Thus, supernatent water is readily removed from coal by use of the apparatus and method of the present invention.

Referring now to the drawings, there is shown in FIG. 1 a flow sheet diagram illustrating the generally descriptive phases and steps of the system according to a preferred embodiment of the invention; and FIG. 2 shows the apparatus of the reactor and filter assembly. The reactor **10** is of general and conventional construction forming an insulated tank and includes an entry means **12** to introduce run of the mine coal, a gas condenser **14**, liquid spray means **16**, a burden deflector **18**, a screen **20** and an impactor **22**. The reactor **10** is filled as shown with coal **24** and a liquid up to liquid level **26**.

The reactor has exit means **30** that passes only − 12mm to zero material from screen **20** through a valve **32**, thence to a rotary screen **34** which passes − 12mm material to liquid-solid separator means such as a continuous filter belt, rotary filter-dryer system **36** having a belt filter assembly **38** and a dryer portion assembly **40**. The belt **42** moves in a clockwise direction and the liquid plus fines pass the belt into a space **46** and pass to a tube **48** to a container **50**. Roller element seals **54,56,58**, are for separating and aiding the drying of the reactants.

Oversize reactant particles that do not pass into space **46** may pass into the dryer portion **60** where they are exposed to hot ammonia gas for drying. The gas passes to space **60** then through a tube **62** into a gas exhaust chamber **64**. Oversized particles pass to a further conveyor belt **70** and which then passes the solid to a fluid classifier **72**. Gas is recovered in gas-liquid recovery means **66**.

From the reactor **10**, oversized particles of plus 12mm size pass through oversize exit means **76** to an elevator **78**, thence to a dryer **80** and pass to a scrap container **82**. The liquid comminutant which was introduced by the liquid spray **16** at about −33.4° C interacts with the run of the mine coal at ambient temperature causing a quantity of the liquid to boil. As shown in FIG. 3 described below, some of the gas is recovered by the condensers **14** and the gas, not thereby condensed, is removed from the reactor **10** by excess gas removal means **81** an passed to recovery means **66**.

Pressure control means **88** insures that the rate of gas removal is such that the reactant gas does not escape from entry means **12** into the atmosphere. The anhydrous liquid interacts with the relatively hot coal by excessive boiling and vaporization of the ammonia resulting in a high pressure over the coal at the entry means **12**, FIG. **3**. Recovery of this gas is achieved by removal of the excess ammonia gas. This may be accomplished by a pressure sensor at entry means **12**, such as in the gas recovery pressure control means **88** (FIG. **3**), which at excessive pressure removes excess gas by pump or gas removal means **81**.

The particles from the rotary screen **34** that are sized between − 12+4mm pass from the pipe **90** to a lift and conveyor means **92** to a dryer **94**, and separation between the liquid and scrap is made so that scrap is collected in scrap unit **96** and the liquid-gas is passed to a gas recovery unit **66**.

The description of FIG. **2** has been set out above and, for purposes of understanding FIG. **1**, similar and corresponding sets of reference nuemrals are applied throughout to both FIGS. **1** and **3**, among other figures wherein similar elements or components are given corresponding reference numerals to those described in FIG. **2**.

The reactor in order to be applicable in all situations of varying feed stock coal is provided with control means for the reactor that has at least three essential requirements: (1) an ability to recover the massive amount of ammonia gas generated during boiling as the mine run coal is cooled with the liquid ammonia to −33° C from ambient conditions using either a saturating spray or liquid immersion; (2) a dwell time exposure to an essentially anhydrous ammonia bath in an insulated tank for periods variable to at least one hour under conditions of a reciprocating mild mechanical stress; and (3) separation of the large masses, usually greater than 12mm diameter impurities, from the useful product coal which is normally less than 1.5 mm diameter provided the exposure was adequate. Requirement (2) is accomplished by a proper balance of feed rate of run of mine coal to the reactor, the exhaust rate of the treated coal from the reactor, and bed of reacting coal size (depth and diameter). Assuming equal input and outputs of coal, the depth of coal bed in the reactor establishes the desired "dwell time" while the bed load (e.g., mass) provides a portion of the mild mechanical stress. An added mild mechanical stress is provided with impactors **22** for improved efficiencies. The reactor stage illustrated in FIG. **3** provides these requirements in an optimum configuration. Mined coal to be used in the reactor **10** is normally 40cm in diameter down to micron particle size mixed with slate, shale and pyrites and other impurities. This feed material is continuously added to the chamber in reactor **10** through entry means **12** and exposed to a spray means **16** of anhydrous ammonia forming a mixed mass of coal and liquid below or at −33° C. The ammonia gas evaporated during the temperature reduction of the coal from ambient to −33° C is recondensed on finned chiller elements forming the gas condenser **14** located in the top portion of the reactor, and the liquid product is permitted to drop and reenter the bed in the reactor. A standard refrigeration cycle cools the coils of the gas condenser **14** to a temperature well below the condensation point of the ammonia gas. The ammonia gas pressure at the coal entrant point **12** in the reactor **10** is maintained slightly below atmospheric pressure to insure that no gas is lost during the coal cooling procedure. This is accomplished with a pressure control **88** at the throat of the vessel which controls a conventional evacuation blower at the top of the vessel. The excess gas is transported to the gas recovery station **66**. The location of the condenser **14** in the top of the reactor **10** is by convience since all of the gas could be removed by an exit pipe, recondensed and returned to the system by the sprays.

The coal bed **24** in the reactor **10** is a mixture of unreacted coal, coal at various stages of size disintegration, large masses of the impurity material and liquid ammonia. The large masses of impurities which have not disintegrated provide the mild mechanical stresses which are necessary for efficient contaminant separation, bed vibration, screen clearing and ultimate effective separation of the − 12mm to zero and the larger than 12mm diameter material. A gas driven impactor **22** placed in the vicinity of the 12mm screen **20** creates mild shock waves in the bed by injecting bursts of relatively hot ammonia gas into the bed and/or just below the screen to cause bubble cavitation and the resulting shock wave upon the condensation of the gas. Control of the quantity of gas, e.g., intensity of the shock wave, and the pulse length to any frequency provides controllable screen and bed agitation. The agitation permits the desired mechanical stress during reaction, screen separation of the − 12mm to zero particles, the removal of the + 12mm scrap and destruction of mechanical bridges in the bed. Other mechanical means of bed agitation might also serve this purpose. A burden deflector **18** or deflectors, mounted such as not to interrupt the flow of the + 12mm particles, insures that all of the charge passes across the 12mm screen. The larger than 12mm material is transported to an elevator **78** in an exit pipe and is removed from the process by depositing in a mechanical conveyor **78** for removal to a rotary dryer **94** for gas recovery and the solid to crap **96**. A conventional rotary kiln or screen might be used to remove the absorbed liquid ammonia. In the cases of coals from several sources, material of particle size greater than 4 mm could be considered scrap; therefore, either the 12mm screen could be reduced to 4mm, or a second screen added below the 12mm screen would effect a more refined separation.

In the case where only the 12mm screen was used, the −12mm to zero material which passes the screen **20** is collected in the bottom of the reactor for conveyance to the next stage of size separation. Clearly, no severe modifications of this apparatus are necessary to use the reactor in a high pressure mode of a batch process since after filling of the system, a cap should be provided at the filling port. After subsequent reaction and pressure adjustment back to atmospheric pressure, the processing of material separation continues. Furthermore, the −12mm to zero particles could, less efficiently, be mechanically conveyed in a manner similar to the +12mm material for kiln drying and ammonia gas separation. A more efficient process is to transport the liquid in a flow with the −12mm to zero material to a rotor case screen **34**, as illustrated in FIG. **4**. The mixture, −12mm to zero solid and liquid, as emitted from the reactor **10**, is fed through a high capacitance orifice **110** directly to the surface of rotating screen **34** with, for example, 4mm hole diameters such that the anhydrous liquid ammonia and solids −4mm to zero pass

through the screen, while the +4mm to −12mm particles are retained on the surface of the screen. The particles on the screen are, in rotation, washed with pure liquid ammonia and then scraper into the discharge tube by a scraper **112.** Since the oversized particles are in some cases over 90 percent non-coal products, this material is sent to the rotary kiln dryer **94** used for the +12mm scrap, and the ammonia gas is also recovered in recovery **66,** as shown in FIG. **1.**

The rotary screen **34** of FIG. **4** is disposed within an insulated housing **116,** and the screen turns on a sealed load bearing **118** for supporting an exit pipe **90** described above. The screen is cleaned by means of a scraper **112.** The screen turns on an axis (FIG. **4A**) coaxial with the vertical portion of orifice **110.** Similarly to bearings **118,** a bearing seal **124** and a driver **126** with a bearing seal **128** are provided as shown in FIG. **4.** Basket screen **34** is rotated by drive **126** and causes material deposited by orifice **110** to pass the spray heads **130** and then dislodged by stationary scraper **112.**

Other than performing an essential separation, the continuous rotary filter **34** whether in the physical orientation shown or mounted horizontally (not shown), also performs a second important function. That is, the regulation of the flow from the reactor **10** such that the complete liquid ammonia head in the reactor system is not dissipated. The liquid pressure exiting from the rotating filter is very nearly atmospheric, whereas that entering the system is at the head pressure of the reactor. The atmosphere within the entire filter is anhydrous ammonia gas. All components, gaskets, bearings, seals and lubricants, some of which are shown in FIGS. **3, 4** and **5,** must therefore be compatible with the atmosphere such as is consistent with those requirements as clearly described in the ammonia industry. In the event a two-stage screen (not shown) is used in the reactor and the output is −4mm − 0, the rotor filter is unnecessary.

The −4mm to zero material in anhydrous liquid ammonia mixture can, at this point, be separated by a simple filter technique, the solid being dried in a kiln for ammonia gas recovery and dry sized for final separation of the coal and impurities. more efficiently, the mixture can be placed in the continuous filter-dryer **36,** shown in FIG. **5.** The −4mm to zero material in anhydrous liquid ammonia is fed in a tubulent fashion onto a continuous belt screen **42** with, for example, 2mm diameter openings such that the liquid and undersized material passes through the screen to an exhaust. The liquid ammonia and fine material is fed "in a turbulent fashion" to the bed filter as illustrated in FIG. **2,** i.e., by position in the system. If this slurry were permitted to stagnate the fines would settle out and block the flow. The continuous belt moves at a rate controlled by a solid bed sensor **140** of a mechanical deflector type, which establishes a depth of filter bed material **144.** The belt illustrated moves from left to right and after the elastic rotor seal **56** at the center, the bed is exposed to hot anhydrous ammonia gas which enters through openings **146** from above the bed and exits through the bed at exit **200** to tube **62** such as to dry the bed completely. The distance between the rotor seals **56, 58** is such as to permit the bed material complete drying. The dry residue −4 + 2mm coal and impurities is then mechanically removed from the screen to a conveyor belt for density classification, i.e., the separation of coal from impurities. The filter belt **42** is then cleaned by mechanical means **50** and/or air brushing means **50** and then returned to the liquid chamber for further liquid filtering. Two elastic rotor seals **54, 56** essentially isolate the liquid chamber from the rest of the system.

The two-stage filter dryer **36** shows the rotary element seals **54, 56, 58** in FIG. **5** and FIG. **5A** shows the details of the elastic rotor seal **54,** the belt **42** and its support **152.** Feed stock entry **154** is shown in FIG. **5B** and the various supports, namely, slide supports **156, 156** and roller support **158.** The configuration of the rotor seals and a mask **160, 160** for the seals **54** and **58,** respectively, in FIG. **5** is apparent, and the roller seals **54, 56, 58** are each mounted on a spring bias arrangement **162, 162** urging the rotor seal into engagement with the bed **144.**

The undersized particles and excess anhydrous liquid ammonia are removed from the chamber immediately below the belt through tube and used as feed stock for a second, third, etc., filter-dryer unit which would provide as many size fractions as was desirable. For example, the product of the filter-dryer **36** just described would be essentially −4 to +2mm. Such a product, a mixture of coal, slate or shale and pyrites, is an excellent feed stock for fluid density classification such as a fluid bed separation or cyclone separation, since the diameters of all components are very nearly the same and the density of the coal is about 1.1 gms/cc as compared to the rock which is in the range of 2.3 gms/cc. Pyrites has a density of about 5.6 gms/cc and can readily be separated from the rock and coal. Clearly, the range of particle sizes which can be tolerated in one or more stages of filtration for an acceptable product from gas classification are dependent on the chemistry and morphology of the bed coal and the exact specific gravities of the components which are used in the process. The addition of one or more washing sections or additional dryers to the filter-dryer component may be provided within the degree of reasonableness shown and described above. It has been established that liquid bed screening is much more efficient for the separation of small particle size materials than are in air screening techniques, e.g., problems of dusting and crushing are essentially eliminated.

Throughout the three main stages, i.e., reactor **10,** preliminary filtering **34** and final filtering **36,** a minimum of liquid ammonia has been transported to the drying stage which constitutes an efficiency in this system. As a consequence, after final filtration of the liquid to remove the ultra fine particles, it can be returned to the cycle at the reactor stage. The residue gases from the three stages and final drying processes can be used as such for filtrate drying or submitted to a typical mechanical or absorption refrigeration cycle for liquification, purification and readmittance to the cycle.

The coal after treatment exists in particle sizes less than 2mm; all particles larger are essentially scrap. The coal is sized to within rather narrow size ranges, dried and subjected to ammonia gas classification by well-etablished fluid bed or cyclone separation techniques to effect the final separation of coal from the other impurities. The coal at the conclusion of this stage has not been exposed to an oxidizing atmosphere which would tend to reduce its calorific value to some degree by surface absorption process. The particle size of the prod-

uct is in the range 2 to 0.2mm and is essentially free from impurities.

The residue from the benefaction process consists of sized slate, shale, iron pyrites and other stone materials of unique specific gravity. Density separation of the materials can be used to isolate, for example, iron pyrites as a source material for iron and/or sulfur production or separation of the slate for processing and use in the building trades industry.

As will be apparent from the foregoing, the present invention provides novel means for the separation of certain impurities from natural coal. There are also provided a number of advantages in operation over the prior benefaction processes for the removal of these impurities. The apparatus is simple and comparatively inexpensive and non-complex in operation. Supernatent water is readily removed from coal by use of the apparatus and method of the present invention.

It should be recognized that the apparatus illustrated in the drawings is essentially diagrammatic and that it is not intended to show all of the well-known details of construction which would be required in the building of apparatus for carrying out the invention. The invention has been described above with respect to the benefaction of bituminous coal with anhydrous liquid ammonia. Nevertheless, it will be understood that substantially identical apparatus may be employed in the benefaction of other grades of coal with other high vapor pressure chemical comminutants for the purpose of removing the natural impurities.

Additional embodiments of the invention in this specification will occur to others and therefore it is intended that the scope of the invention be limited only by the appended claims and not by the embodiment described hereinabove. Accordingly, reference should be made to the following claims in determining the full scope of the invention.

What is claimed is:

1. Apparatus for comminuting coal comprising:

a reactor containing coal essentially submerged in a liquid chemical comminutant for producing reactants, such as impurity materials and product coal, the reactor including (1) means to provide a small variational mechanical stress on the coal by the comminutant, and (2) means to provide at least a partial separation of the impurity materials from the coal without generating environmental pollutants or physical hazards.

2. The invention according to claim **1** wherein said reactor includes means for applying the liquid comminutant at a pressure above that of atmospheric.

3. The invention according to claim **1** wherein said coal is run of the mine coal.

4. The invention according to claim **1** wherein said liquid chemical comminutant has gaseous and liquid phases, the reactor is connected to means recovering the liquid chemical comminutant in its gaseous and liquid phases, means processing the gaseous phase into the liquid phase, means feeding the liquid phase to the reactor to form a closed loop, and a continuous rotary filter-dryer means also disposed in said loop and is connected to the reactor as a second stage to provide removal of all particle sizes larger than 1.5mm essentially without uncontrolled loss of the liquid in said closed loop.

5. The invention of claim **1** in which the reactor has an outlet for the separated coal connected to a continuous rotary filter-dryer means to separate undersized particles and liquid and oversized particles.

6. The invention according to claim **1** wherein the reactor has an outlet for the separated coal connected to a ganged continuous belt filter-dryer means to provide particle size separation.

7. The invention according to claim **1** in which the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant and recovering means provides essentially total recovery of the high vapor pressure chemical comminutant throughout the apparatus.

8. The invention according to claim **1** in which said reactor has an outlet for the separated impurity materials.

9. The invention according to claim **3** in which a continuous belt rotary filter-dryer means is connected to receive the reactants from the reactor for separation of the undersized particles and liquid and filter bed drying of the oversized particles in one continuous operation.

10. The invention according to claim **2** wherein said reactor has an outlet connected to a ganged continuous belt filter means to provide particle size separation.

11. The invention according to claim **7** wherein said reactor has an outlet connected to a ganged continuous belt dryer means and includes means to provide particle size separation.

12. The invention according to claim **4** wherein the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant and the recovering means provides essentially total recovery of the high vapor pressure chemical comminutant throughout the apparatus.

13. The invention according to claim **5** wherein the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant and the recovering means provides essentially total recovery of the high vapor pressure chemical comminutant throughout the apparatus.

14. The invention according to claim **4** in which said reactor has an outlet for the separated impurity materials.

15. The invention according to claim **5** in which said reactor has an outlet for the separated impurity materials.

16. Method for comminuting coal comprising:

reacting coal essentially submerged in a liquid chemical comminutant in a reactor to produce reactants such as impurity materials and product coal, applying a small variational mechanical stress on the coal and (2) partially separating the reactants from the coal.

17. The invention according to claim **16** wherein said step of reacting includes processing the coal with the liquid comminutant at a pressure above that of atmospheric.

18. The invention according to claim **16** wherein said coal in the reactor is run of the mine coal from which supernatant water in the coal has been removed.

19. The invention according to claim **16** wherein subsequent to the step of partially separating reactants from the coal is the step of removing all the particle sizes larger than 1.5mm without uncontrolled loss of the liquid by a rotary filter-dryer means.

20. The invention of claim **17** which includes the step of receiving the reactants from the reactor by a continuous belt rotary filter-dryer to separate the undersized

particles and liquid and drying of the over-sized particles in one continuous operation.

21. The invention according to claim **16** wherein is the further step of separating and drying by use of a ganged continuous belt means.

22. The invention according to claim **16** wherein the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant, and a recovering step for essentially total recovery of the high vapor pressure chemical comminutant.

23. The invention according to claim **16** in which after the step of reacting is the further step of recovering of impurity materialo naturally found in said coal.

24. The invention according to claim **18** which includes the step of separating of the undersized particles and liquid, and drying of the oversized particles.

25. The invention according to claim **22** wherein is the further step of separating and filter-drying by use of a ganged continuous belt means.

26. The invention according to claim **23** wherein is the further step of separating and filter-drying by use of a ganged continuous belt means.

27. The invention according to claim **19** wherein the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant and a recovering step for essentially total recovery of the high vapor pressure chemical comminutant.

28. The invention according to claim **20** wherein the liquid chemical comminutant in the reactor is a high vapor pressure chemical comminutant and a recovering step for essentially total recovery of the high vapor pressure chemical comminutant.

29. The invention according to claim **19** in which after the step of reacting is the further step of recovering of impurity materials.

30. The invention according to claim **20** in which after the step of reacting is the further step of recovering of impurity materials.

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