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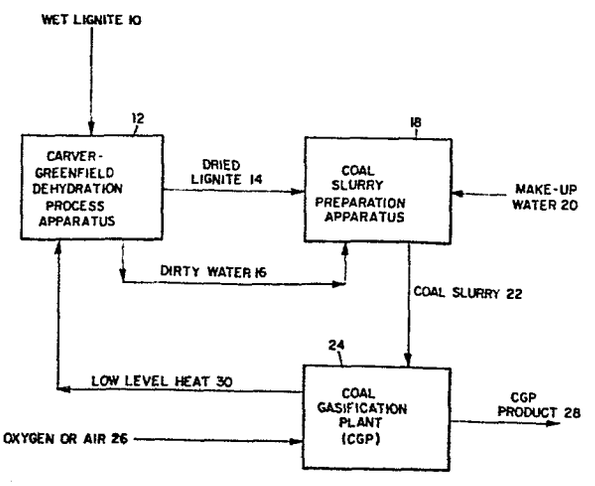
(54) Gasification process.

(57) This invention relates to a process for the gasification of a low quality solid carbonaceous fuel containing bound water such as sub-bituminous coal, lignite, and peat. The process incorporates a Carver-Greenfield dehydration system (12, 34) which removes most of the bound water from the fuel. In one embodiment of the invention (Figure 1), all the fuel is dried in the dehydration system (12) and the dried fuel (14) fed to a slurry preparation apparatus (18) where it is mixed with water to form a fuel slurry (22). The slurry (22) is then fed to a coal gasification plant (24) where it is subjected to partial oxidation using oxygen or air to produce a product gas (28). Dirty water (16) from the dehydration system (12) may be used to form the fuel slurry (22) in the slurry preparation apparatus (18), and low level heat (30) from the gasification plant may be recycled for use in the dehydration system (12).

In an alternative embodiment (Figure 2), only a first portion of wet fuel from a store (32) is fed to a Carver-Greenfield dehydration system (34) from which dried fuel is fed direct to the gasification plant (42). A second portion of wet fuel is fed direct from the storage (32) to the plant (42) where the wet and dried fuel blend to provide a feedstock for the plant (42) with a predeterminable water content.

FIG. 1



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GASIFICATION PROCESS

The invention relates to the gasification of carbonaceous fuels containing bound water; for example low quality fuels such as sub-bituminous coal, lignite or peat. The invention has particular application as a coal feed preparation process for a coal gasification plant.

There are basically two types of coal gasification processes that are currently in commercial operation. The first type requires a dry feed and the coal is fed into the gasifier through some mechanical means, such as a screw feeder or a lock hopper system.

The second type uses a slurry feed. An example of this type is the Texaco Coal Gasification Process (TCGP) which may be practiced according to the disclosure of, for example, U.S. Patent No: 3,544,291 to which reference is directed. The TCGP operates using either oxygen or air as the oxidizing medium for the coal feed. The coal is fed as a water slurry with the water typically amounting to 50% or more of the total weight of the slurry.

The advantage of the water slurry is that it can be pumped at high pressure and eliminates the need for complicated lock hoppers or other feed systems. The water content of the slurry is a function of the desired degree of pumpability of the slurry. However, the water content of the slurry has an adverse impact on the thermal efficiency of the gasifier, the higher the water content of the slurry then the more water which must be vaporized in the gasifier, thus consuming more coal and more oxygen or air.

U.S. Patent No: 4,166,802 further describes the gasification of solid carbonaceous fuels which are introduced into the gasification zone in the form of a water slurry. Slater et al indicate that a problem arises when the solid carbonaceous fuel is of low quality, such as sub-bituminous coal, lignite, or peat, because all of these fuels contain a considerable amount of combined or bound water, a most undesirable ingredient insofar as gasification of the fuel is concerned in that although bound water is present in the solid fuel it does not play any part in the formation of the slurry vehicle and consequently has no effect on the viscosity or pumpability of the slurry. It has an adverse effect on the gasification reaction as it introduces more water into the gasifier than is necessary to form the slurry and thus has an undesirable effect on the thermal efficiency of the generator.

Patent No: 4,166,802 describes a solution to this excess water problem whereby the solid fuel, in finely-divided form, is introduced into a quench zone with water. The solid fuel and the water may be introduced separately into the quench zone or they are introduced together into the quench zone in the form of a slurry. In the quench zone, the slurry is contacted with a hot synthesis gas (comprising carbon monoxide and hydrogen) which has been prepared by the partial oxidation of a solid carbonaceous fuel, preferably the same type of fuel as in the slurry.

The hot synthesis gas, which leaves the partial oxidation zone at a temperature between about 1800° and 3200°F., is introduced substantially immediately into the quench zone and contact is made with the slurry, preferably by discharging the hot synthesis gas from a dip tube under the surface of the slurry.

The present invention is also directed to solving the problem of excess water in a partial oxidation coal gasification process when feeding a low quality solid carbonaceous fuel containing bound moisture, such as sub-bituminous coal, lignite, or peat.

As discussed above, certain types of fuel, such as sub-bituminous coal, lignite, and peat contain excessive quantities of bound moisture in terms of being useful feedstock for a slurry fed gasifier. The bound water content of lignite is typically about 35 to 50 percent by weight. Normal thermal drying processes would require a rather large heat input and would create an energy inefficiency in the overall process. This energy inefficiency should be minimized and the invention is a process which provides that benefit.

The invention involves using the Caryer-Greenfield dehydration process which is normally used to dehydrate sewage sludge. The Carver-Greenfield process may be practiced according to the disclosures in, for example, U.S. Reissue Patent No: 26,352 and U.S. Patent No: 3,323,575 to

which reference is directed. The Carver-Greenfield process uses a multi-stage evaporation system combined with a drying oil to produce a dry solid product, typically containing about 0.5 to 3.0 percent by weight water. In the present invention, the Carver Greenfield process is applied to certain types of coal to produce a dry solid product which is then delivered to a coal slurry preparation apparatus where it is mixed with water and subjected to a wet grinding process to produce coal particles of the final size required for the gasification process.

In order to achieve dehydration in the Carver-Greenfield system, the solids are slurried in a drying medium, typically a light gas oil, such as "ISOPAR", and then the slurry proceeds through the unit. The typical unit includes a number of stages to achieve the desired degree of dryness in the solid product. This typically would be three stages. Steam is required to operate the dryers. Alternatively, some other source of low level heat could be used. The Carver-Greenfield process offers the flexibility of varying the temperature between the various stages and through this mechanism it is possible to recover and reuse the steam from each of the subsequent stages in the evaporation train. This re-utilization of process heat results in a much higher energy efficiency than could be achieved in a single stage unit.

A by-product of the Carver-Greenfield process is the water which is driven off from the lignite or other low quality fuel that is being dried. This water is typically dirty and oily and, to prevent environmental pollution, would require treatment before disposal. One significant advantage of the present invention is that, in one preferred embodiment, this dirty water is used to prepare the coal slurry. The coal slurry containing the dirty water is fed into the gasifier which converts the environmentally harmful materials contained in the dirty water into useful products in the gasification process. Also the quantity of bound water to be removed from the lignite or other type of feedstock is normally rather large and is close to the total water requirement of the coal slurry preparation system. Thus, make-up water to the system is minimal as compared with alternative means of drying.

It was described above that a drying oil is used to assist the dehydration in the Carver-Greenfield drying process. One of the final steps in the conventional Carver-Greenfield process is the separation of the drying oil from the dried product. Oil separation is normally desirable both to minimize oil loss and also to minimize the contamination of the dried product with the drying oil. Oil removal may also be necessary for economic reasons. One advantage however, of the present invention is that it is not necessary to completely remove the drying oil from the dried fuel product. The dried fuel product

containing the drying oil can be satisfactorily processed in the coal slurry preparation system and then gasified into useful products.

Tests have shown that the dried fuel material does not take up water in the slurry to achieve the same composition as the original wet feedstock going into the Carver-Greenfield process. Thus, the slurrying of the dried fuel material with water does not cause the dry fuel to revert to its original state. Therefore, the present invention allows the use of a relatively low cost wet feedstock as a feed for a coal gasification plant while still using a coal slurry preparation system.

According to one embodiment of the present invention a process for the gasification of a solid carbonaceous fuel containing significant quantities of bound moisture comprises:-

(a) feeding the wet fuel into a dehydration apparatus in which the wet fuel is subjected to a Carver-Greenfield dehydration process whereby most of said bound water is removed and dried fuel is produced;

(b) conveying the dried fuel to a slurry preparation apparatus where it is ground and mixed with water to form a fuel slurry; and

(c) pumping the fuel slurry to a gasification plant where it is subjected to partial oxidation using oxygen or aid to produce a product gas.

In an alternative embodiment of the invention the process comprises:-

(a) feeding a first portion of the wet fuel drawn from a wet fuel storage unit into a dehydration apparatus in which the wet fuel is subjected to a Carver-Greenfield dehydration process whereby most of said bound water is removed and dried fuel is produced;

(b) conveying the dried fuel to a coal gasification plant wherein the dried fuel is subjected to partial oxidation using oxygen or air to produce a product gas; and

(c) feeding a second portion of the wet fuel drawn from the wet fuel storage unit to the gasification plant wherein said wet fuel is subjected to partial oxidation using oxygen or air to produce a product gas.

In this alternative process, the sizes of the first and second portions can be controlled to supply amounts of wet and dried fuel to the gasification plant to provide a feedstock with a predetermined water content overall. In this way, the successful operation of the gasification plant can be ensured.

Two embodiments of the invention will now be described by way of example and with reference to the accompanying drawings wherein:-

Figure 1 is a schematic diagram illustrating the process steps involved in a first embodiment;

Figure 2 is a schematic diagram illustrating the process steps involved in a second embodiment; and Figure 3 is a graph showing the percent of total coal dried versus the final moisture content in weight percent.

The process illustrated in Figure 1 shows the use of lignite as the feedstock, but it should be understood that the process may also be used to treat other low grade solid carbonaceous fuels containing significant amounts of bound water, such as sub-bituminous coal and peat.

Wet lignite 10 containing about 45 to 50 percent by weight bound water is introduced into the dehydration apparatus 12 which collectively performs the Carver-Greenfield dehydration process as described, for example, in U.S. Reissue Patent No: 26,352 and U.S. Patent No: 3,323,575. Wet lignite 10 is preferably crushed into particles having no cross-sectional dimension greater than about 1/2 inch (12.7 millimetres) prior to introduction into the dehydration apparatus 12.

Dried lignite 14 exits from the dehydration apparatus 12 after undergoing the Carver-Greenfield process and is conveyed to the coal slurry preparation apparatus 18. Experimental test data proves that the Carver-Greenfield process removes most of the bound moisture in the lignite so that dried lignite 14 contains about 0.5 to 3.0 percent by weight bound water. This is a particular advantage of the present invention as compared to the process disclosed

in U.S. Patent No: 4,166,802 which contains no experimental data to indicate that the bound moisture in the coal has been removed.

Since dried lignite 14 is a highly reactive material, it is preferably conveyed to coal slurry preparation apparatus 18 using an enclosed conveyor system blanketed with an inert gas, such as nitrogen.

In the coal slurry preparation apparatus 18, dried lignite 14 is fed into a hopper and then into a milling apparatus where the lignite is subjected to a wet grinding process and is formed into a slurry preparation. Dirty water 16 from the Carver-Greenfield process is preferably used for this purpose and additional make-up water 20 may be used as needed. The wet grinding process produces particles of feed material which have no cross-sectional dimension greater than about 1/4 inch (6.35 millimetres). Preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve and, more preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

The resulting coal slurry 22 containing between about 50 to 75 percent solids by weight on a dry basis is then pumped to a conventional coal gasification plant (CGP) 24 such as described in, for example, U.S. Patent No: 3,544,291, where the coal is partially oxidized using oxygen or air 26 to produce the desired conventional product gas 28.

Low level heat 30, which may be in the form of steam or hot water, from the coal gasification plant is conveyed to the dehydration apparatus 12 where it is efficiently and economically used in carrying out the Carver-Greenfield dehydration process.

A second embodiment of the invention is illustrated in Figures 2 and 3. Again lignite is shown as the feedstock, but the process may also be used to treat any low grade solid carbonaceous fuel containing significant amounts of bound water, such as sub-bituminous coal and peat. As described above, one type of coal gasification process uses a dry feed rather than a water slurry feed. In the dry feed type of coal gasification process, the feedstock may contain whatever bound water was in the fuel when received at the plant. The bound water may have a detrimental effect on the gasifier operation.

Drying the fuel can be accomplished. However, this may impose a severe energy penalty. Some wet fuels may be successfully gasified whereas others may contain too much water to be satisfactorily gasified.

An example of a fuel which would be in this category would be a lignite with a moisture content of about 45 to 50 percent by weight. Drying a portion of the lignite will provide a satisfactory feedstock. This procedure allows the feeding of a lignite blend with a satisfactory moisture content while restricting the amount of lignite actually dried, thereby saving on energy and capital investment.

Referring now to Figure 2, a first portion of the wet lignite (containing about 35 to 50 percent by weight bound water) from the wet lignite storage unit 32 is introduced into the dehydration apparatus 34 which collectively performs the Carver-Greenfield dehydration process as described, for example, in U.S. Reissue Patent No: 26,352 and U.S. Patent No: 3,323,575. The wet lignite is preferably crushed into particles having no cross-sectional dimensions greater than about 1/2 inch (12.7 millimetres) prior to introduction into the dehydration apparatus 34.

Dried lignite (now containing about 0.5 to 3.0 percent by weight water) exits from the dehydration apparatus 34 after undergoing the Carver-Greenfield dehydration process and is conveyed to the dried lignite storage unit 36 or optionally to the coal gasifier 42 without going to storage. Since the dried lignite is a highly reactive material, it is preferably conveyed to the coal gasifier 42 using the dried lignite feed system 38 which includes an enclosed conveyor system blanketed with an inert gas, such as nitrogen. The dried lignite feed system 38 includes a grinding process which produces particles of feed material which have no cross-sectional dimension greater than about 1/4 inch (6.35 millimetres). Preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve and, more preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

A second portion of wet lignite from the wet lignite storage unit 32 is conveyed to the coal gasifier 42 using the wet lignite feed system 40. The wet lignite feed system 40 includes a grinding process which produces particles of feed material which have no cross-sectional dimension greater than about 1/4 inch. 6.35 millimetres). Preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve and, more preferably, 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

As shown by the graph in Figure 3, drying 35 percent by weight of the wet lignite and feeding this amount of the dried lignite along with 65 percent by weight of wet (undried) lignite results in a final overall moisture content of 30 percent by weight for the feedstock of the coal gasifier 42. Thus, the blend of wet lignite and dried lignite provides a feedstock with a satisfactory overall water content so that the coal gasifier 42 can be successfully operated.

Coal gasifier 2 is a conventional coal gasification plant such as described in, for example, U.S. Patent No: 3,544,291 where the coal is partially oxidized using oxygen or air to produce the desired conventional product gas. Low level heat, which may be in the form of steam or hot water, from the coal gasifier 42 may be conveyed to the dehydration apparatus 34 where it is efficiently and econ-

omically used in carrying out the Carver-Greenfield dehydration process.

CLAIMS:-

1. A process for the gasification of a solid carbonaceous fuel containing significant quantities of bound water, which process is characterised by the following steps:-

(a) feeding the wet fuel (10) into a dehydration apparatus (12) in which the wet fuel is subjected to a Carver-Greenfield dehydration process whereby most of said bound water is removed and dried fuel (14) is produced;

(b) conveying the dried fuel (14) to a slurry preparation apparatus (18) where it is ground and mixed with water to form a fuel slurry (22) and

(c) pumping the fuel slurry (22) to a gasification plant (24) where it is subjected to partial oxidation using oxygen or air to produce a product gas (18).

2. A process according to Claim 1 wherein water mixed with the dried fuel is dirty water (16) from the Carver-Greenfield dehydration process performed in the dehydration apparatus (12).

3. A process according to Claim 2 wherein additional make-up water (20) is added as needed.

4. A process according to any preceding Claim wherein the fuel slurry (22) formed contains fuel particles of a size wherein 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

5. A process according to any preceding Claim wherein the

fuel slurry (22) contains 50 to 75 percent solids by weight on a dry basis.

6. A process for the gasification of a solid carbonaceous fuel containing significant quantities of bound water comprising:-

(a) feeding a first portion of the wet fuel drawn from a wet fuel storage unit (32) into a dehydration apparatus (34) in which the wet fuel is subjected to a Carver-Greenfield dehydration process whereby most of said bound water is removed and dried fuel is produced;

(b) conveying the dried fuel to a coal gasification plant (42) wherein the dried fuel is subjected to partial oxidation using oxygen or air to produce a product gas; and

(c) feeding a second portion of the wet fuel drawn from the wet fuel storage unit (32) to the gasification plant (42) wherein said wet fuel is subjected to partial oxidation using oxygen or air to produce a product gas.

7. A process according to Claim 6 wherein the second portion of wet fuel blends with the dried fuel in the gasification plant (42).

8. A process according to Claim 7 wherein the amounts of wet and dried fuel fed to the gasification plant (42) are controlled to provide a feedstock with a predetermined water content.

9. A process according to any of Claims 6 to 8 wherein the

first portion of wet fuel is substantially 35 percent by weight of the wet fuel drawn from the storage unit and the second portion of wet fuel is substantially 65 percent by weight of the wet fuel drawn from the storage unit.

10. A process according to any of Claims 6 to 9 wherein the dried fuel consists of fuel particles of a size wherein 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

11. A process according to any of Claims 6 to 10 wherein the second portion of wet fuel consists of fuel particles of a size wherein 100 weight percent of the solid fuel will pass through a 14 mesh sieve with not more than 30 weight percent passing through a 325 mesh sieve.

12. A process according to any preceding Claim wherein the wet fuel is selected from the group consisting or subbituminous coal, lignite, and peat.

13. A process according to Claim 12 wherein the wet solid carbonaceous fuel is lignite.

14. A process according to any preceding Claim including the step of crushing the wet solid carbonaceous fuel into particles having no cross-sectional dimension greater than 12.7 millimetres before feeding the fuel to the dehydration apparatus.

15. The process defined in any preceding Claim wherein the dried fuel contains 0.5 to 3.0 percent by weight water.

16. A process according to any preceding Claim wherein the dried fuel is conveyed to the slurry preparation apparatus using an enclosed conveyor system blanketed with an inert gas.

17. A process according to Claim 16 wherein the inert gas is nitrogen.

18. A process according to any preceding Claim including the step of conveying low level heat (30) produced in the coal gasification plant to the dehydration apparatus for use in performing said Carver-Greenfield dehydration process.

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FIG. 1

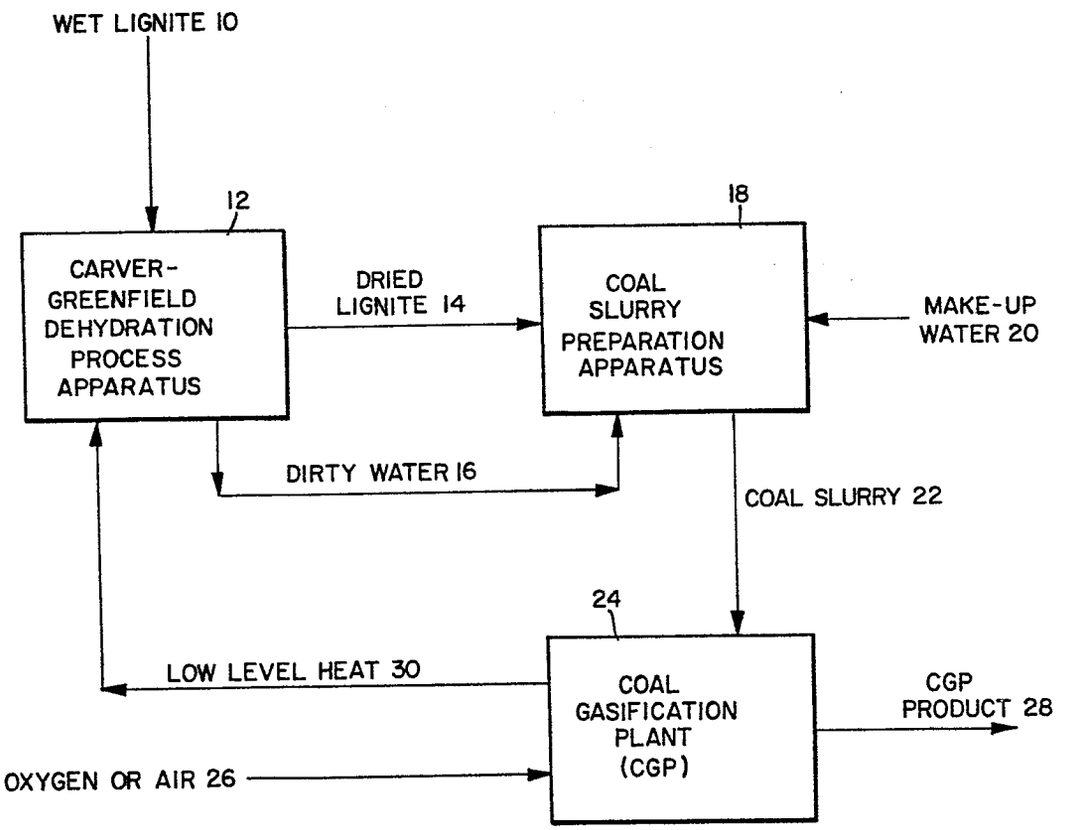


FIG. 3.

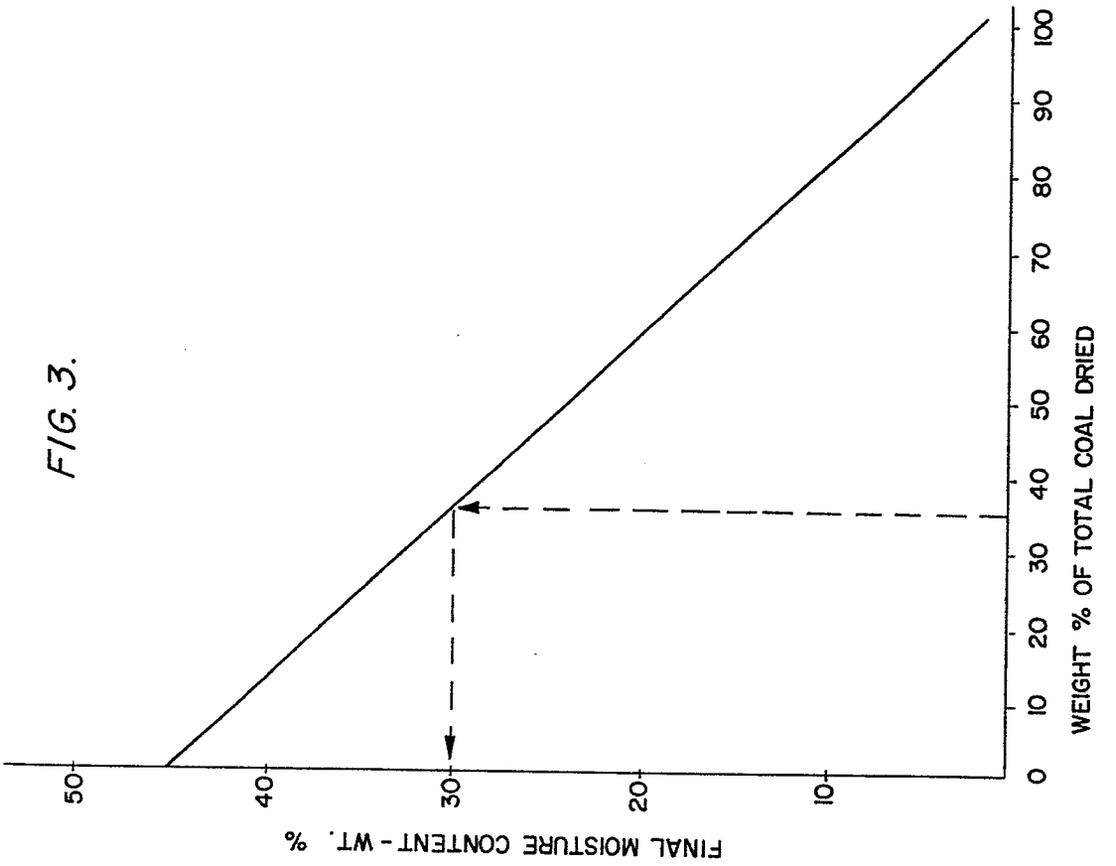
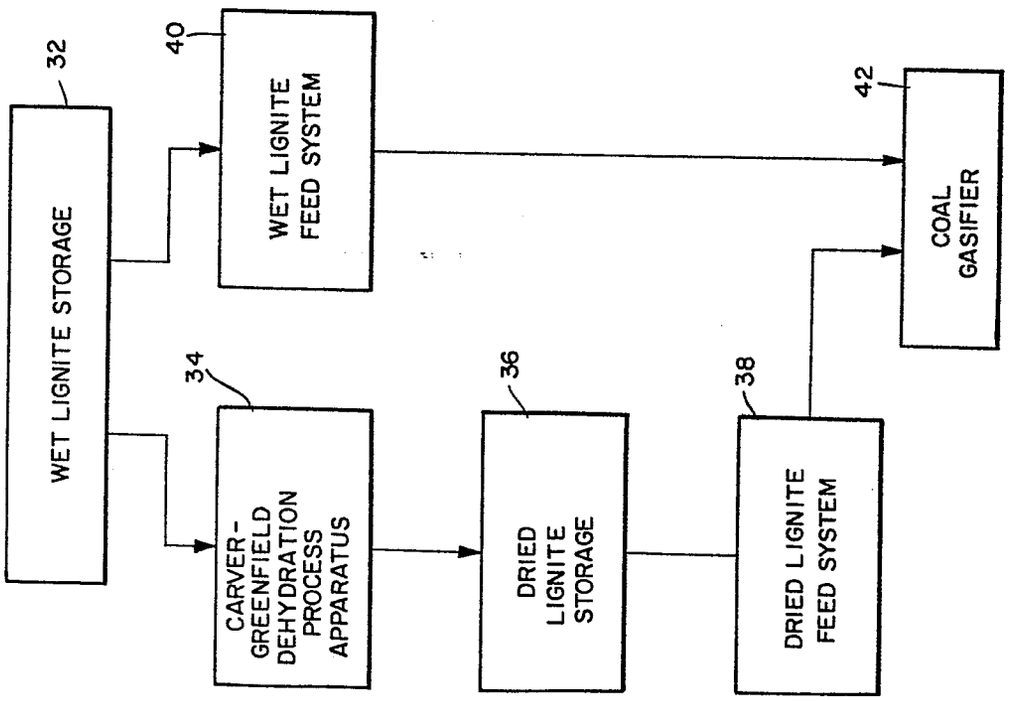

FINAL MOISTURE CONTENT - WT. %
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
WEIGHT % OF TOTAL COAL DRIED

FIG. 2


32
WET LIGNITE STORAGE
40
WET LIGNITE FEED SYSTEM
42
COAL GASIFIER
34
CARVER-GREENFIELD DEHYDRATION PROCESS APPARATUS
36
DRIED LIGNITE STORAGE
38
DRIED LIGNITE FEED SYSTEM