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**Wang et al.**

(54) **COAL WATER SLURRY AND METHODS FOR MAKING THE COAL WATER SLURRY**

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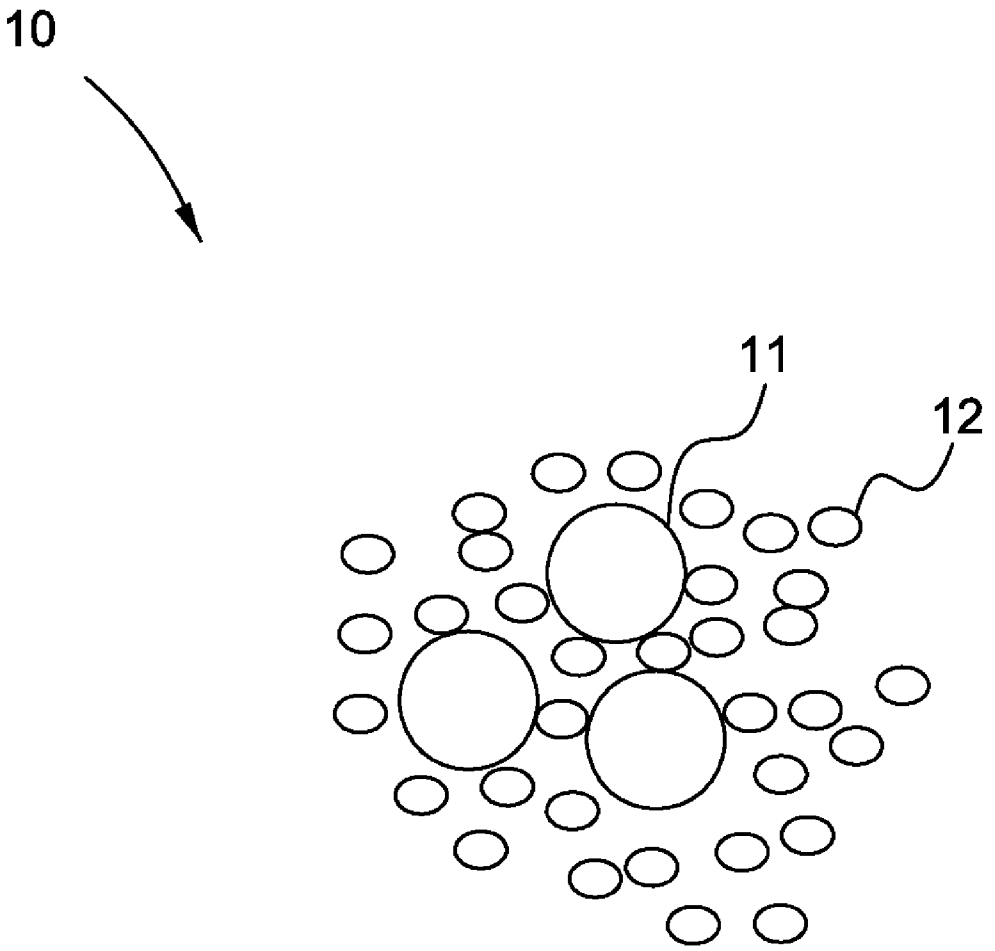
(57) **ABSTRACT**

A coal water slurry comprises smaller and larger coal particles. The smaller coal particles are in a range of from about 20 wt % to about 90 wt % of the coal in the coal water slurry and comprise a mean particle size smaller than 25 μm. The larger coal particles are in a range of from about 10 wt % to about 80 wt % of the coal in the coal water slurry and comprise a mean particle size in a range of from 50 μm to 200 μm.



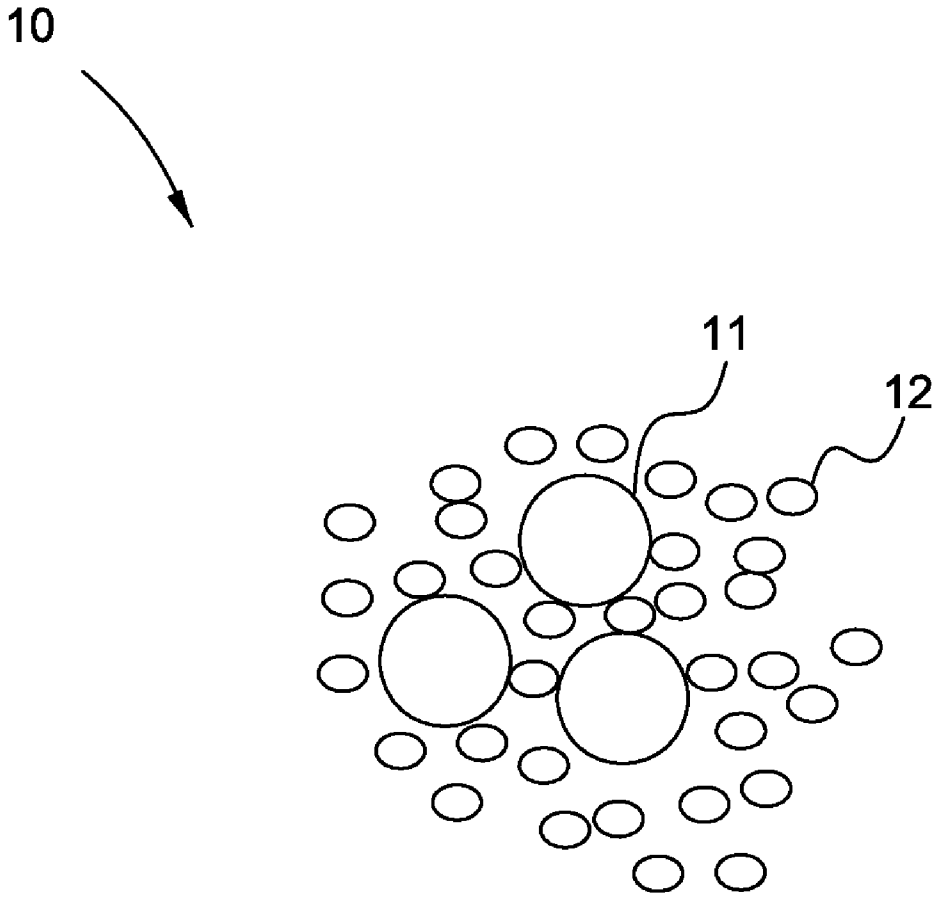



FIG. 1

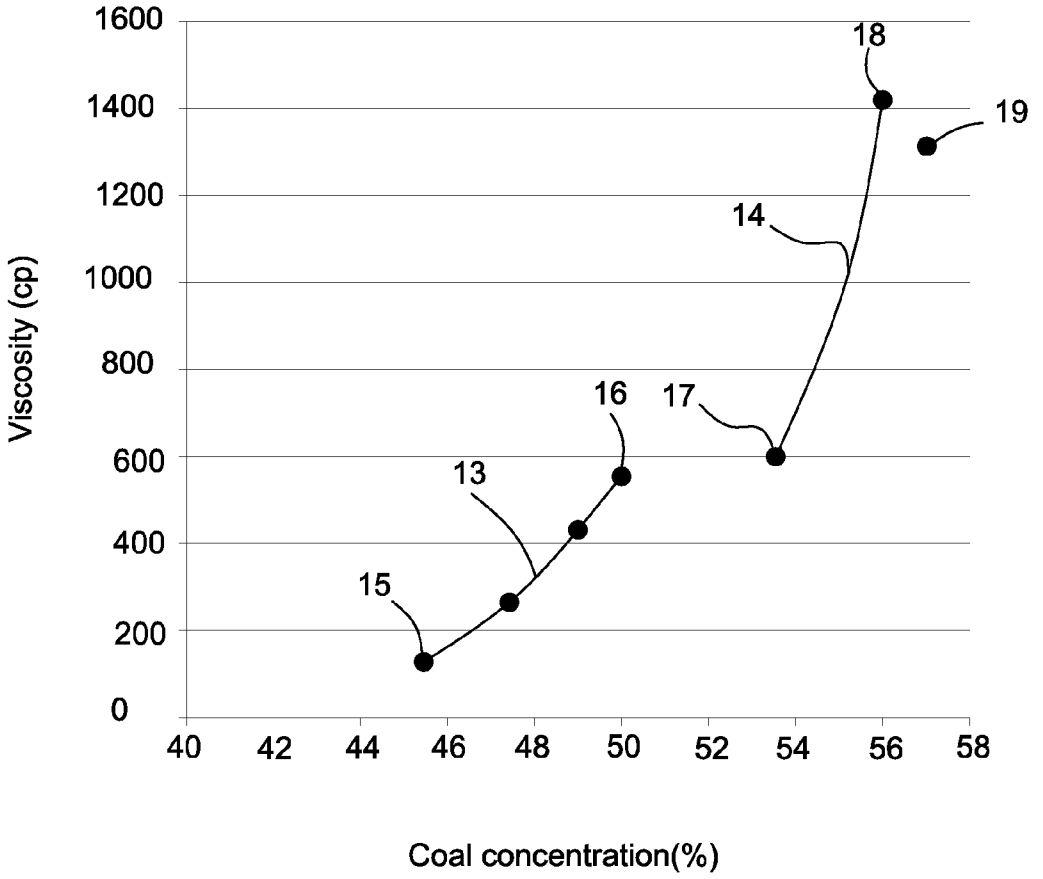

1600
1400
1200
1000
800
600
400
200
0
Viscosity (cp)
40
42
44
46
48
50
52
54
56
58
Coal concentration(%)
15
13
16
17
14
18
19

FIG. 2

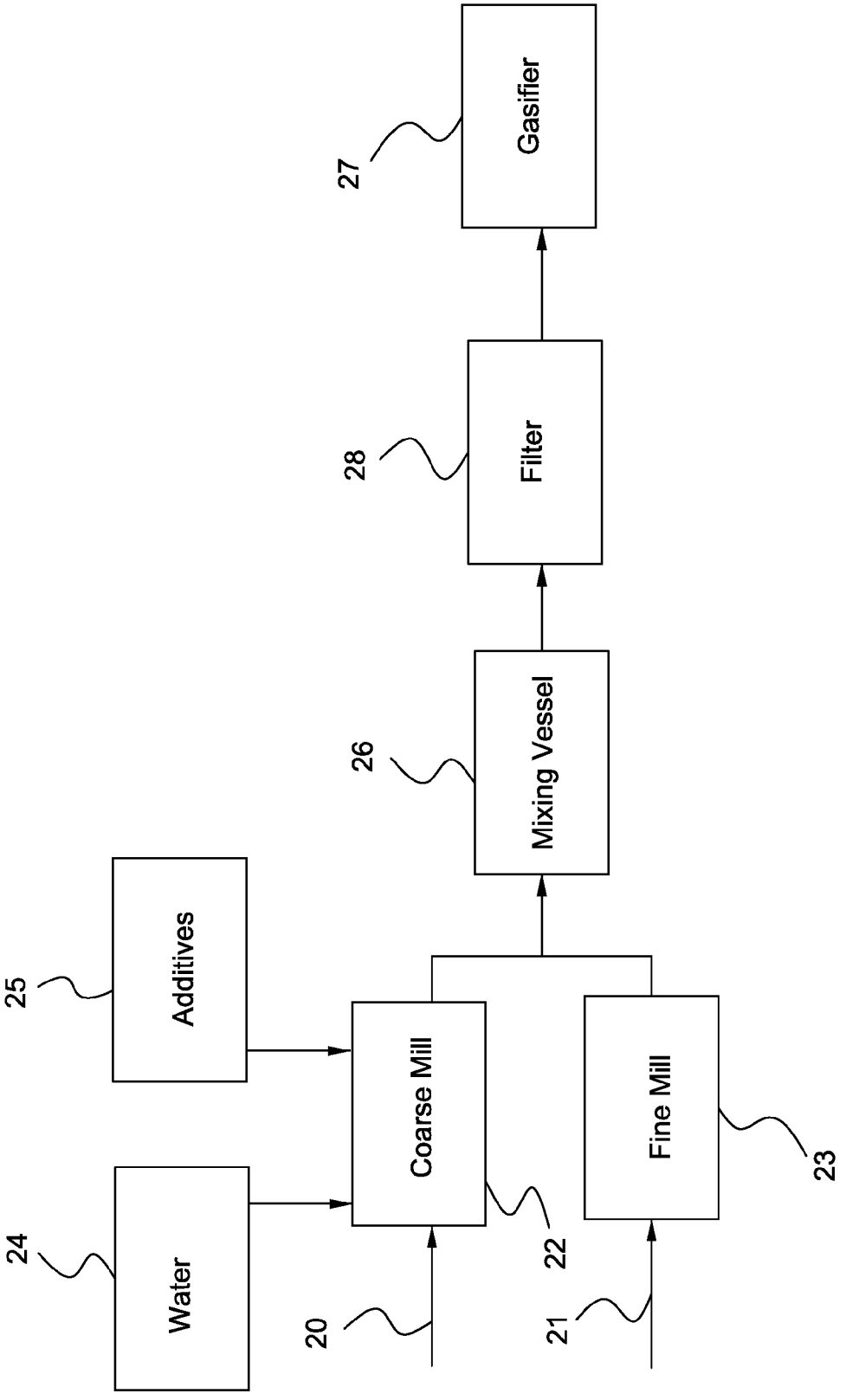

Gasifier
27
Filter
28
Mixing Vessel
26
Additives
25
Coarse Mill
Fine Mill
23
Water
24
22
20
21

FIG. 3

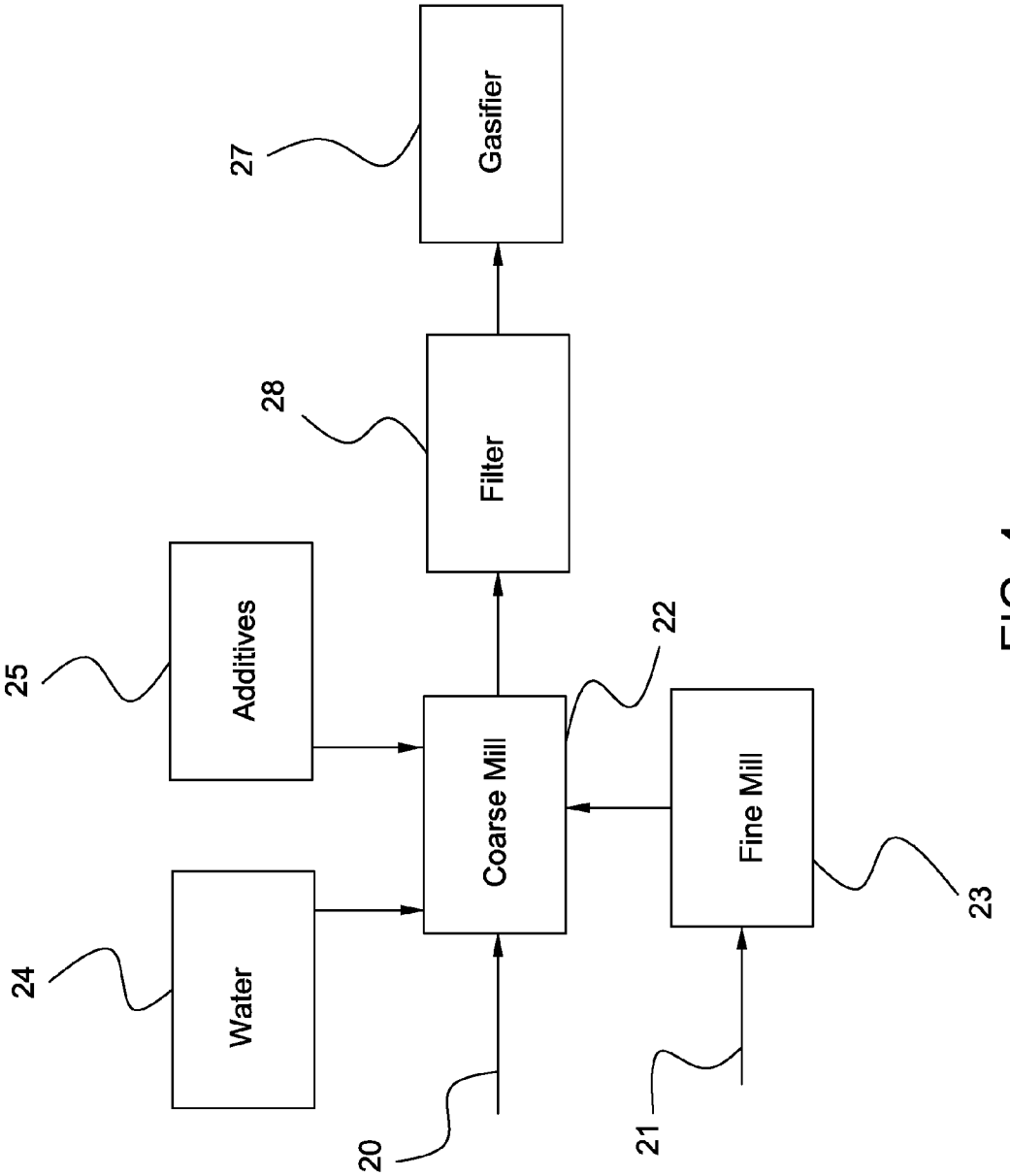

Gasifier
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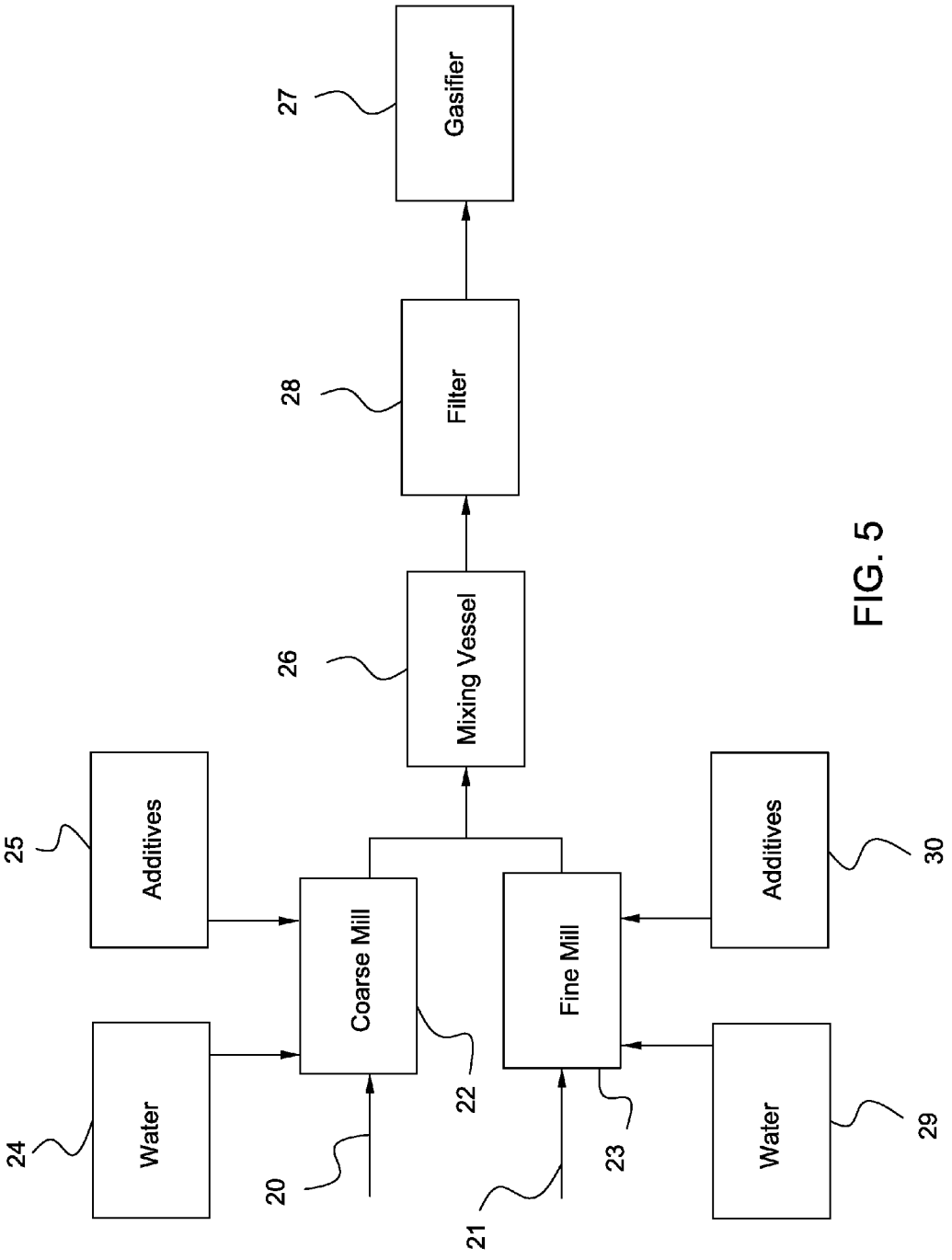
FIG. 4


Gasifier
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Water
29

FIG. 5

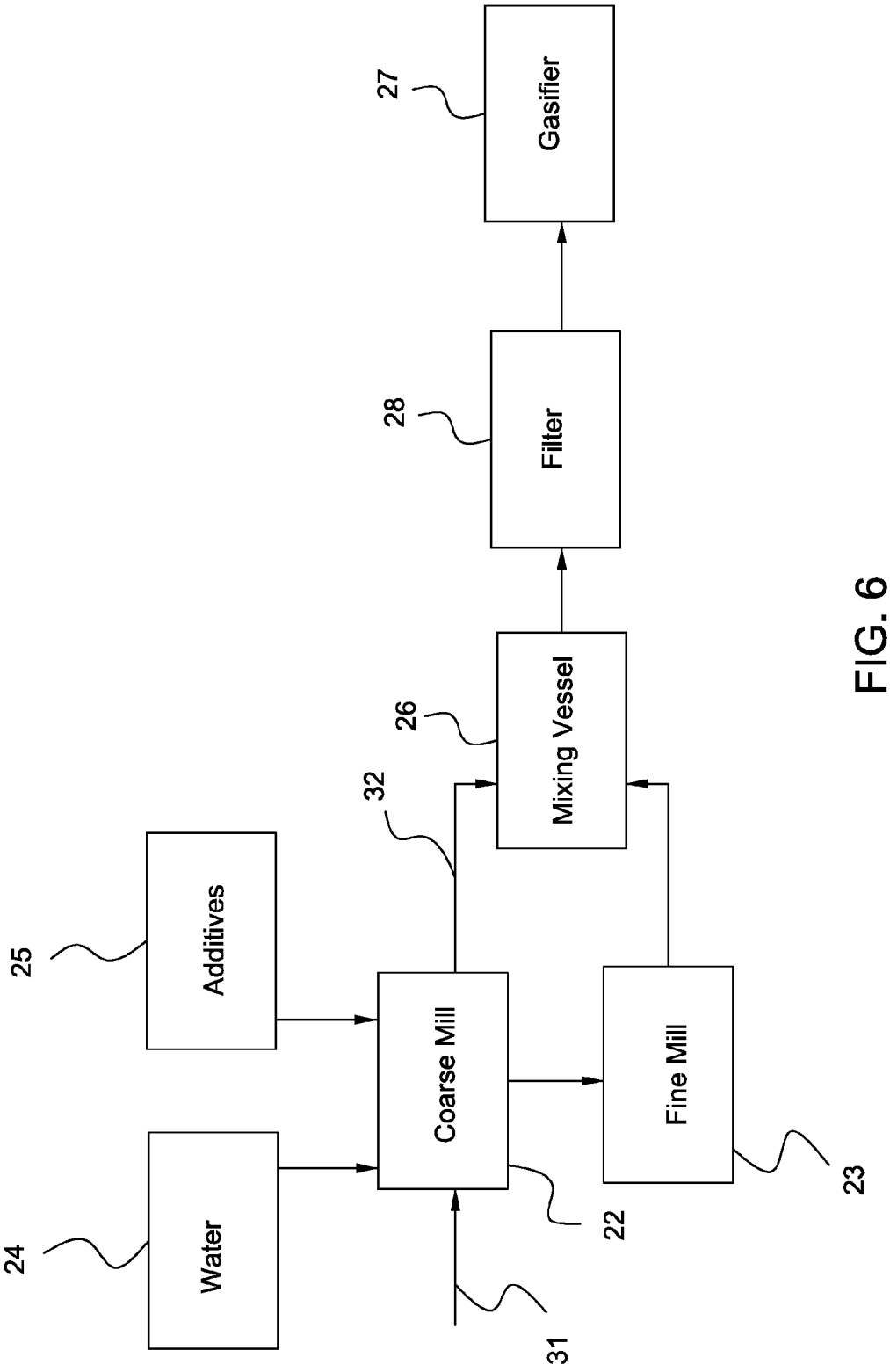
Gasifier
27
Filter
28
Mixing Vessel
26
32
Additives
25
Coarse Mill
Fine Mill
23
22
Water
24
31

FIG. 6

# COAL WATER SLURRY AND METHODS FOR MAKING THE COAL WATER SLURRY

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of the Invention

**[0002]** Embodiments of the invention relate generally to coal water slurry and methods for making the coal water slurry. More particularly, embodiments of the invention relate to particle size distribution of coal in coal water slurry and methods for making the coal water slurry.

**[0003]** 2. Description of Related Art

**[0004]** In coal gasification fields, two types of methods are usually employed to supply coal to a gasifier for gasification. One is pneumatically transporting pulverized coal with pressurized nitrogen and spraying the coal into a gasifier. Another is preparing a slurry of coal and water, which hereinafter is referred to as "coal water slurry," and supplying the coal water slurry to a gasifier. The "coal water slurry" method has been widely used because it is more reliable, easy transportable and adaptable to a higher gasification pressure than the method employing coal in a dry state.

**[0005]** Generally, higher coal concentration of a coal water slurry leads to higher gasification efficiency and lower consumption of coal and oxygen. Thus, during preparation, it is desirable to have higher concentration of the coal so as to economically gasify the coal water slurry.

**[0006]** There have been attempts to increase the coal concentration. For example, particle size distribution of coal in the coal water slurry may be modified to increase the coal concentration. However, in some current applications, the coal concentration may not be as high as desirable and may cause undesirable viscosity in the coal water slurry with the increase of the coal concentration in the water slurry concentration by modification of the coal particle size distribution.

**[0007]** Therefore, there is a need for new and improved coal water slurry and methods for making the coal water slurry to increase the coal concentration and avoid undesirable viscosity.

## BRIEF SUMMARY OF THE INVENTION

**[0008]** A coal water slurry is provided in accordance with one embodiment of the invention. The coal water slurry comprises smaller and larger coal particles. The smaller coal particles are in a range of from about 20 wt % to about 90 wt % of the coal in the coal water slurry and comprise a mean particle size smaller than 26 μm. The larger coal particles are in a range of from about 10 wt % to about 80 wt % of the coal in the coal water slurry and comprise a mean particle size in a range of from 50 μm to 200 μm.

**[0009]** A method for making a coal water slurry is provided in accordance with another embodiment of the invention. The method comprises milling smaller coal particles in a range of from about 20 wt % to about 90 wt % of the coal in the coal water slurry and comprising a mean particle size smaller than 26 μm, milling larger coal particles in a range of from about 10 wt % to about 80 wt % of the coal in the coal water slurry and comprising a mean particle size in a range of from 50 μm to 200 μm, and mixing the smaller coal particles, the larger coal particles, and water.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

**[0010]** The above and other aspects, features, and advantages of the present disclosure will become more apparent in light of the following detailed description when taken in conjunction with the accompanying drawings in which:

**[0011]** FIG. **1** is a schematic diagram of a coal particle size distribution in a coal water slurry in accordance with one embodiment of the invention;

**[0012]** FIG. **2** is an experimental diagram illustrating comparison of correlations of coal concentration and viscosity with and without smaller coal particles in the coal water slurry; and

**[0013]** FIGS. **3-6** are schematic flow charts illustrating preparation of the coal water slurry in accordance with various embodiments of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

**[0014]** Preferred embodiments of the present disclosure will be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail to avoid obscuring the disclosure in unnecessary detail.

**[0015]** FIG. **1** illustrates a schematic diagram of a particle size distribution of coal for producing a coal water slurry in accordance with one embodiment of the invention. As used herein, the term "coal water slurry" may indicate a mixture of certain amounts of coal, water and additives for producing energy used in generating electricity, heating, support processing, and manufacturing. In recent years, use of coal water slurry has become an alternative to use of conventional fuel oil and coal.

**[0016]** Typically, a coal water slurry may comprise from about 55 wt % to about 70 wt % of coal particles, from about 30 wt % to about 45 wt % of water, and less than about 1 wt % of additives. It should be noted that embodiments of the invention do not limit to any particular type of coal or additives for the coal water slurry. Non-limiting examples of additives include alkylnaphthelene sulfonate and polyoxyalkylene alkyl ether.

**[0017]** Generally, it is desirable to increase the coal concentration in the coal water slurry so as to improve gasification efficiency and reduce consumption of coal and oxygen. Higher coal concentration may be produced by pulverizing coal into a suitable particle size distribution while selecting suitable additives and appropriately mixing the coal, water and additives to manufacture the coal water slurry with suitable concentration, viscosity, stability, and quality. In embodiments of the invention, the coal particle size distribution in the coal water slurry may be selected so that smaller coal particles are dispersed into spaces between larger coal particles so as to increase the coal concentration in the coal water slurry.

**[0018]** As illustrated in FIG. **1**, the particle size distribution of the coal **10** for producing the coal water slurry may comprise smaller coal particles **12** in a range of from about 20 wt % to about 90 wt % of a weight of the coal **10** and having a mean particle size smaller than about 26 μm, and larger coal particles **11** in a range of from about 10 wt % to about 80 wt % of the weight of the coal **10** and having a mean particle size in a range of from about 50 μm to about 200 μm. In some applications, the particle size distribution of the coal may comprise the small coal particles **12** in a range of from about 30 wt % to about 90 wt % and the larger coal particles **11** in a range of from about 10 wt % to about 70 wt % of the weight of the coal **10**, respectively. As used herein, wt % means a weight percentage.

**[0019]** In other applications, the particle size distribution of the coal **10** may comprise the small coal particles **12** in a range of from about 40 wt % to about 90 wt % and the larger coal particles **11** in a range of from about 10 wt % to about 60 wt % of the weight of the coal **10**, respectively. In certain applications, the particle size distribution of the coal **10** may comprise the small coal particles **12** in a range of from about 50 wt % to about 75 wt % and the larger coal particles **11** in a range of from about 25 wt % to about 50 wt % of the weight of the coal **10**, respectively.

**[0020]** Additionally, in some examples, the smaller coal particles **12** may have a mean particle size smaller than about 25 μm, about 20 μm, or about 15 μm. In other examples, the smaller coal particles **12** may have a mean particle size smaller than about 10 μm or about 5 μm. In certain examples, the smaller coal particles **12** may have a mean in a range of from about 5 μm to about 15 μm. Alternatively, the smaller coal particles **12** may have a mean in a range of from about 10 μm to about 15 μm, or from 5 μm to about 10 μm. The larger coal particles **11** may have a mean particle size in a range of from about 50 μm to about 70 μm, from about 70 μm to about 140 μm, from about 90 μm to about 140 μm, from about 100 μm to about 140 μm, or from about 140 μm to about 200 μm.

**[0021]** Accordingly, after mixing, the smaller coal particles may be dispersed between the larger coal particles so as to increase the coal concentration of the coal water slurry to be produced. In some embodiments, the coal may comprise one or more of high rank coal, such as bituminous and anthracite, and low rank coal, such as sub-bituminous coal and lignite. In some examples, the coal particle distribution may comprise a mixture of the smaller low rank coal particles and the larger high rank coal particles, or the smaller high rank coal particles and the larger low rank coal particles. In one non-limiting example, both types of coal particles comprise low rank coal, such as the sub-bituminous coal and the lignite. Since the cost of low rank coal is lower, it may be cost-effective in some examples to produce the coal water slurry having higher coal concentration using the low rank coal.

**[0022]** Table-1 illustrates an experimental example of the coal particle size distribution for producing a coal water slurry in accordance with one embodiment. In this example, the coal comprises a low rank coal.

TABLE 1

| Coal particle size distribution | | |
|---|---|---|
| Mesh | Particle size (μm) | Weight percentage (wt %) |
| >8 | >2500 | 0 |
| 8-14 | 1400-2500 | 3 |
| 14-40 | 850-1400 | 12 |
| 40-325 | 45-850 | 60 |
| 325-540 | 26-45 | 12.5 |
| <540 | <26 | 50 |

**[0023]** As can be seen from Table-1, the coal comprises about 50 wt % of the smaller coal particles and about 50 wt % of the larger coal particles. Particle sizes of the smaller coal particles are less than 26 μm, and particle sizes of the larger coal particles in the range of from about 26 μm to about 2500 μm. For the embodiments of the invention, the smaller coal particles have a mean particle size smaller than 26 μm. The larger coal particles have a mean particle size in a range of from about 50 μm to about 200 μm based on distribution of the weight percentages and the particle sizes thereof, as mentioned above.

**[0024]** FIG. **2** is an experimental diagram illustrating comparison of correlations of the coal concentration in the coal water slurry and viscosity with and without the smaller coal particles in the coal particle size distribution in accordance with one embodiment. As illustrated in FIG. **2**, lines **13-14** illustrate the correlations of the coal water slurry concentration and the viscosity without and with the smaller coal particles, respectively.

**[0025]** As can be seen from the line **13**, at a point **15**, in the initiation of production of the coal water slurry, the coal concentration in the coal water slurry is less than 46%. With the amount of the coal increasing, the coal concentration reaches about 50% at a point **16** where the viscosity there of is less than 600 cp. However, during preparation of the coal water slurry without the smaller coal particles, the flowability of the coal water slurry becomes worse at the point **16** such that it becomes disadvantageous to increase the coal concentration further in the coal water slurry.

**[0026]** For the line **14**, under the similar operating conditions as those for the line **13**, in the initiation, at a point **17**, since the smaller coal particles are mixed with the larger coal particles, the coal concentration in the coal water slurry reaches about 54%. With the amount of the mixed coal increasing, the coal concentration reaches above 56% at a point **18** where the viscosity thereof exceeds 1400 cp. Then, a certain amount of the additives may be added to decrease the viscosity of the coal water slurry to about 1300 cp at a point **19**, which is suitable for the flowability of the coal water slurry.

**[0027]** Accordingly, for the comparison of the lines **13-14** illustrated in FIG. **2**, the coal water slurry having the mixture of the smaller coal particles and the larger coal particles may have the higher coal concentration and higher flowability than the coal water slurry without mixture of the smaller coal particles.

**[0028]** FIGS. **3-6** illustrate schematic flow charts illustrating preparation of the coal water slurry in accordance with various embodiments of the invention. As illustrated in FIG. **3**, during preparation, according to a determined proportion of the smaller coal particles and the larger coal particles, certain amounts of starting coals **20**, **21** are introduced into a coarse mill **22** and a fine mill **23** for milling, respectively.

**[0029]** It should be noted that in some applications, one or more coarse mills **22** and one or more fine mills **23** may be employed although one coarse mill **22** and one fine mill **23** are illustrated in FIG. **3**. The particle sizes of the starting coals **20**, **21** may be less than 3 mm. Although two starting coals **20**, **21** are illustrated in FIG. **3**, one or more starting coal supply sources (not shown) may be employed to provide one or more starting coals **20**, **21**.

**[0030]** For the illustrated arrangement in FIG. **3**, the coarse mill **22** is for wet milling of the starting coal **20** and the fine mill **23** is for dry milling of the starting coal **21**. In non-limiting examples, the coarse mill **22** and the fine mill **23** may comprise ball mills, and the particle sizes of the starting coals **20**, **21** may be different and not less than 3 mm. In certain applications, either or both of the starting coals **20**, **21** may comprise one or two of the low rank coal and the high rank coal, and the starting coals **20**, **21** may be the same or different from each other. In one non-limiting example, the starting coals **20**, **21** are the same low rank coal.

**[0031]** Accordingly, after the starting coals **20**, **21** are introduced into the coarse mill **22** and the fine mill **23**, respectively, according to determined particle size distribution of the smaller and larger coal particles, the fine mill **23** mills the starting coal **21** to produce the dry smaller coal particles having a mean particle size less than about 26 μm. Meanwhile, with introduction of the starting coal **20** into the coarse mill **22**, determined amounts of water **24** and additives **25** are also introduced into the coarse mill **22** to produce a coarse coal water slurry comprising the large coal particles having a mean particle size in the range of from about 50 μm to about 200 μm.

**[0032]** Subsequently, the dry smaller coal particles from the fine mill **23** and the coarse coal water slurry from the coarse mill **22** are introduced into a mixing vessel **26** for mixing to produce the coal water slurry with higher concentration for further processing, for example, for introduction into a gasifier **27** to produce energy. For some arrangements, during mixing, a mixer (not shown) may be employed to mix the dry smaller coal particles and the coarse coal water slurry within the mixing vessel **26**, and feed rates of the dry smaller coal particles may be controlled into the mixing vessel **26** so as to ensure the water in the coarse coal water slurry to contact with the smaller coal particles and the smaller coal particles to disperse between the larger coal particles.

**[0033]** In certain applications, as illustrated in FIG. **3**, before the coal water slurry with higher coal concentration is introduced into the gasifier **27** for processing, a filter **28** may be employed to receive and filter the coal water slurry from the mixing vessel **26** to remove impurities, such as rock in the coal water slurry, which is advantageous for processing of the coal water slurry in a gasifier. Alternatively, the filter **28** may not be employed.

**[0034]** FIG. **4** illustrates a schematic flow chart of the preparation of the coal water slurry in accordance with another embodiment of the invention. The arrangement in FIG. **4** differs from the arrangement in FIG. **3** in that the mixing vessel **26** in FIG. **3** is not employed in the arrangement in FIG. **4**. For the arrangement in FIG. **4**, the dry smaller coal particles from the fine mill **23** are introduced into the coarse mill **22** to mix with the larger coal particles, water and the additives while the starting coal **20** is milled in the coarse mill **22**. In certain applications, a mixing vessel may also be employed behind the coarse mill **22**. Again, a filter **28** may optionally be used before the coal water slurry is sent to the gasifier **27**.

**[0035]** FIG. **5** illustrates a schematic flow chart of the preparation of the coal water slurry in accordance with yet another embodiment of the invention. In the arrangement in FIG. **5**, during preparation of the smaller coal particles in the fine mill **23**, certain amounts of water **29** and optionally additives **30** are also introduced into the fine mill **23** while the starting coal **21** is milled in the fine mill **23** to mix with the smaller coal particles. In some applications, one or more water supply sources and one or more additive supply sources may be employed to provide the water **24**, **29** and the additives **25**, **30** respectively. The water **24**, **29** and the additives **25**, **30** may be the same or different from each other. In some applications, the additives **25** and/or **30** may only be introduced into one of the mills or may be introduced into the mixing vessel **26**.

**[0036]** In the arrangement of FIG. **6**, all of the starting coal **31** is introduced into the coarse mill **22** for wet milling. During milling, a certain amount of a coarse coal **32** from the coarse mill **22** is introduced into the mixing vessel **26**, which acts as the larger coal particles, and another amount of the coarse coal from the coarse mill **22** flows into the fine mill **23** for further wet milling to produce the smaller coal particles. Then, the smaller coal particles are mixed with the larger coal particles from the coarse mill **22** in the mixing vessel **26** to produce the coal water slurry with higher concentration. In certain applications, certain amounts of water and additives may be added into either of the mills or into the mixing vessel.

**[0037]** In embodiments of the invention, from about 20 wt % to about 90 wt % of the smaller coal particles **12** having a mean particle size smaller than 25 um may be mixed with from about 10 wt % to about 80 wt % of larger coal particles **11** having a mean particle size in the range of from about 50 μm to about 140 μm so as to produce the coal water slurry with higher coal concentration. In some applications, low rank coal may be used to produce the coal particle size distribution so as to produce the coal water slurry with higher coal concentration, which is cost effective. In addition, during preparation of the coal water slurry, wet milling and/or dry milling may be employed so as to improve system flexibility to produce the coal water slurry.

**[0038]** While the disclosure has been illustrated and described in typical embodiments, it is not intended to be limited to the details shown, since various modifications and substitutions can be made without departing in any way from the spirit of the present disclosure. As such, further modifications and equivalents of the disclosure herein disclosed may occur to persons skilled in the art using no more than routine experimentation, and all such modifications and equivalents are believed to be within the spirit and scope of the disclosure as defined by the following claims.

What is claimed is:

**1**. A coal water slurry, comprising:

smaller coal particles in a range of from about 20 wt % to about 90 wt % of the coal in the coal water slurry and having a mean particle size smaller than 26 μm; and

larger coal particles in a range of from about 10 wt % to about 80 wt % of the coal in the coal water slurry and having a mean particle size in a range of from 50 μm to 200 μm.

**2**. The coal water slurry of claim **1**, wherein the smaller and larger coal particles comprise low rank coal.

**3**. The coal water slurry of claim **1**, wherein the coal water slurry comprises the smaller coal particles in a range of from about 40 wt % to about 90 wt % and the larger coal particles in a range of from about 10 wt % to about 60 wt % of the coal in the coal water slurry, respectively.

**4**. The coal water slurry of claim **1**, wherein the coal water slurry comprises the smaller coal particles in a range of from about 50 wt % to about 75 wt % and the larger coal particles in a range of from about 25 wt % to about 50 wt % of the coal in the coal water slurry, respectively.

**5**. The coal water slurry of claim **1**, wherein the coal water slurry comprises the smaller coal particles in a range of from about 30 wt % to about 50 wt % and the larger coal particles in a range of from about 50 wt % to about 70 wt % of the coal in the coal water slurry, respectively.

**6**. The coal water slurry of claim **1**, wherein the larger coal particles have the mean particle size in a range of from about 50 μm to about 140 μm.

**7**. The coal water slurry of claim **1**, wherein the large coal particles have a mean particle size in a range of from 90 μm to 140 μm.

**8**. The coal water slurry of claim **1**, wherein the large coal particles have a mean particle size in a range of from 100 μm to 140 μm.

**9**. The coal water slurry of claim **1**, wherein the large coal particles have a mean particle size in a range of from 140 μm to 200 μm.

**10**. The coal water slurry of claim **1**, wherein the smaller coal particles have the mean particle size less than about 25 μm.

**11**. The coal water slurry of claim **1**, wherein the smaller coal particles have the mean particle size less than about 15 μm.

**12**. The coal water slurry of claim **1**, wherein the smaller coal particles have the mean particle size less than about 10 μm.

**13**. The coal water slurry of claim **1**, wherein the smaller coal particles have the mean particle size in a range of from about 10 μm to about 15 μm.

**14**. A method for making a coal water slurry, comprising:

milling smaller coal particles in a range of from about 20 wt % to about 90 wt % of the coal in the coal water slurry and comprising a mean particle size smaller than 26 μm;

milling larger coal particles in a range of from about 10 wt % to about 80 wt % of the coal in the coal water slurry and having a mean particle size in a range of from 50 μm to 200 μm; and

mixing the smaller coal particles, the larger coal particles, and water.

**15**. The method for making the coal water slurry of claim **14**, further comprising filtering the coal water slurry after mixing of the smaller coal particles and the larger coal particles.

**16**. The method for making the coal water slurry of claim **14**, wherein milling comprises using a coarse mill for producing the larger coal particles and a fine mill for producing the smaller coal particles.

**17**. The method for making the coal water slurry of claim **16**, wherein using the coarse mill comprises wet milling and using the fine mill comprises dry milling.

**18**. The method for making the coal water slurry of claim **17**, wherein mixing comprises introducing the smaller coal particles and the larger coal particles respectively into a mixing vessel.

**19**. The method for making the coal water slurry of claim **17**, wherein mixing comprises introducing the smaller coal particles into the coarse mill for mixing.

**20**. The method for making the coal water slurry of claim **16**, wherein using the coarse mill comprises wet milling and using the fine mill comprises wet milling.

**21**. The method for making the coal water slurry of claim **20**, further comprising introducing a portion of a coarse coal from the coarse mill into a mixing vessel and another portion of the coarse coal into the fine mill to produce the smaller coal particles for introduction into the mixing vessel.

**22**. The method for making the coal water slurry of claim **14**, wherein the large coal particles have a mean particle size in a range of from about 100 μm to about 140 μm.

**23**. The method for making the coal water slurry of claim **14**, wherein the mean particle size of the smaller coal particles is less than about 25 um.

**24**. The method for making the coal water slurry of claim **14**, wherein the smaller coal particles are in a range of from about 50 wt % to about 75 wt % and the larger coal particles are in a range of from about 25 wt % to about 50 wt % of the coal in the coal water slurry, respectively.

* * * * *