Ube Industries, Ltd., of 12-32, Nishihonmachi 1-chome, Ube-shi, Yamaguchi-ken, JAPAN, hereby apply for the grant of a standard patent for an invention entitled:

Solid Fuel-Water Slurry Composition and Process for the Preparation of the Same

which is described in the accompanying complete specification.

Details of basic application(s):

<table>
<thead>
<tr>
<th>Basic Applic. No</th>
<th>Country</th>
<th>Application Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>61-313429</td>
<td>JAPAN</td>
<td>26 December 1986</td>
</tr>
<tr>
<td>62-5841</td>
<td>JAPAN</td>
<td>12 January 1987</td>
</tr>
<tr>
<td>62-20789</td>
<td>JAPAN</td>
<td>31 January 1987</td>
</tr>
</tbody>
</table>

The address for service is:

Spruson & Ferguson
Patent Attorneys
Level 33 St Martins Tower
31 Market Street
Sydney New South Wales Australia

DATED this TWENTY THIRD day of DECEMBER 1987

Ube Industries, Ltd.

By: [Signature]

Registered Patent Attorney
COMMONWEALTH OF AUSTRALIA

THE PATENTS ACT 1952

DECLARATION IN SUPPORT OF A
CONVENTION APPLICATION FOR A PATENT

In support of the Convention Application made for a patent for an invention entitled:

SOLID FUEL-WATER SLURRY COMPOSITION AND
PROCESS FOR THE PREPARATION OF THE SAME

I

Yasuo Shimizu, President

Ube Industries, Ltd.

of 12-32, Nishihonmachi 1-chome,

Ube-shi, Yamaguchi-ken, Japan

do solemnly and sincerely declare as follows:

1. I am/We are the applicant(s) for the patent

(or, in the case of an application by a body corporate)

1. I am/We are authorised by Ube Industries, Ltd.

the applicant(s) for the patent to make this declaration on its/their behalf.

2. The basic application(s) as defined by Section 141 of the Act was/were made

Basic Country(ies) in Japan

Priority Date(s) on December 26, 1986, January 12 and January 31, 1987

Basic Applicant(s) all by Ube Industries, Ltd.

3. I am/We are the actual inventor(s) of the invention referred to in the basic application(s)

(or where a person other than the inventor is the applicant)

3. Morihiko Sawada, Takashi Hongo, Akira Ohnaka,

Kouji Ogura and Hirosuke Yoshimura

all of c/o Ube Laboratories, Ube Industries, Ltd., 1978-5,

Kogushi, Ube-shi, Yamaguchi-ken, Japan

(respectively)

are the actual inventor(s) of the invention and the facts upon which the applicant(s) is/are entitled to make the application are as follows:

by assignment in accordance with Contract assigning the invention from the inventors to the applicant.

4. The basic application(s) referred to in paragraph 2 of this Declaration was/ were the first application(s) made in a Convention country in respect of the invention(s) the subject of the application.

Declared at Yamaguchi this 4th day of December, 1987

To: The Commissioner of Patents

Yasuo Shimizu, President

Ube Industries, Ltd.

Signature of Declarant(s)

Yasuo Shimizu, President

Ube Industries, Ltd.
1. A solid fuel-water slurry composition containing 50-80 weight % of solid fuel particles of coal and/or petroleum coke wherein a geometric mean diameter (Dp50) of the particles is not more than 74 μm, and a particle size distribution is adjusted in such manner that an arithmetic mean value of an upper geometric standard deviation (6g+) and a lower geometric standard deviation (6g-) in logarithmic normal distribution is in the range of 6-12, and a ratio thereof (6g+/6g-) is not more than 0.6.

The solid fuel-water slurry composition which comprises 100 weight parts of solid fuel-water slurry containing 50-80 weight parts of solid fuel particles of coal and/or petroleum coke, 0.01-3 weight parts of a dispersant and 0.01-0.5 weight part of a stabilizer which comprises 1-20 weight % of at least one water-soluble polymer selected from the group consisting of natural gum, modified natural gum, polyvinyl alcohol, polyacrylamide, carboxylmethyl cellulose and hydroxyethyl cellulose and 93-99 weight % of fine particles of at least one inorganic...
material selected from the group consisting of bentonite, attapulgite, sepiolite and chrysotile asbestos.

14. A process for the preparation of a solid fuel-water slurry composition according to claim 1 which comprises:

a first step for pulverizing a solid fuel comprising coarse particles of coal and/or petroleum coke which have a geometric mean diameter of not more than 20 mm in an aqueous solution of an additive to prepare a solid fuel-water slurry having solid fuel particles of a geometric mean diameter ($D_{501}$) in the range of 30 to 149 μm; and

a second step for mixing the solid fuel-water slurry prepared in the first step with the above-mentioned coarse particles of coal and/or petroleum coke and an aqueous solution of an additive, and subjecting the resulting mixture to wet grinding using a rod mill, to prepare a solid fuel-water slurry which has solid fuel particles having a geometric mean diameter ($D_{502}$) of not more than 74 μm, and having such a relationship with the geometric mean diameter ($D_{501}$) of the solid fuel particles of the solid fuel-water slurry obtained in the first step that $R_s$ representing a ratio of $D_{501}/D_{502}$ is in the range of 0.8 to 4, that $R_w$ representing a ratio of $F_1/F_2$ wherein $F_1$ means the feed rate of the coarse solid fuel supplied to the first step, and $F_2$ means the feed rate of the coarse solid fuel particles supplied to the second step is in the range of 0.4 to 2.4, and that a ratio of $R_s/R_w$ is in the range of 1 to 3.
Complete Specification for the invention entitled:

Solid Fuel-Water Slurry Composition and Process for the Preparation of the Same

The following statement is a full description of this invention, including the best method of performing it known to me/us
SOLID FUEL-WATER SLURRY COMPOSITION AND
PROCESS FOR THE PREPARATION OF THE SAME

ABSTRACT OF THE DISCLOSURE

There is disclosed a solid fuel-water slurry composition containing a relatively large amount of solid fuel particles but showing a relatively low viscosity. The slurry composition contains 50-80 weight % of solid fuel particles of coal and/or petroleum coke wherein a geometric mean diameter (Dp50) of the particles is not more than 10 74 μm, and a particle size distribution is adjusted in such manner that an arithmetic mean value of a upper geometric standard deviation (Sg+) and a lower geometric standard deviation (Sg-) in logarithmic normal distribution is in the range of 6-12, and a ratio thereof (Sg+/Sg-) is not more than 0.6. A process advantageously employable for the preparation of the slurry composition is also disclosed.
BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a solid fuel-water slurry composition. More particularly, the invention relates to a solid fuel-water slurry composition containing a high content of solid fuel but showing a low viscosity, which can be easily transported, stored and handled, and to a process for the preparation of the slurry composition.

Description of prior art

Recently, solid fuels such as coal and petroleum coke are again paid attention as energy source replacing petroleum. However, there is a drawback in that a solid fuel finds difficulty in transportation and storage as compared with a liquid fuel such as petroleum. Further, working efficiency for handling solid fuels are not high.

In order to overcome these drawbacks, a solid fuel-water slurry obtainable by dispersing a finely pulverized solid fuel in water has been recently developed. However, the solid fuel-water slurry still has drawbacks in that increase of solid fuel content in the slurry causes prominent increase of viscosity of the obtained slurry. The solid fuel-water slurry having increased viscosity shows poor fluidity to make its handling and transportation through pipes difficult. Reduction of viscosity of a solid fuel-water slurry can be accomplished by lowering the content of the solid fuel in the slurry. However, the solid fuel-water slurry having such reduced solid fuel content gives poor transportation efficiency. Another disadvantage of the slurry having the reduced solid fuel
content resides in that use as fuel or source for gasification should be done after pre-dehydration treatment.

In order to obviate the above drawbacks, there have been proposed various measures such as addition of a dispersant or adjustment of particle size distribution.

However, it is observed that a solid fuel-water slurry having a high content of solid fuel which is reduced in its viscosity according to the known method is apt to produce sedimentation of solid fuel particles in long time storage or in the course of transportation on a tank lorry (i.e., tank truck) or a tanker. Further, the sedimented particles are then compacted under dehydration to give a consolidated mass. It is very difficult to re-disperse the consolidated mass for the use as solid fuel-water slurry. Accordingly, a further improvement in a method for stabilizing a solid fuel-water slurry is desired.

Further, there is observed another drawback in the known measure based on adjustment of particle size distribution. In more detail, Japanese Patent Provisional Publication No. 59(1984)-15486 describes that a solid fuel-water slurry of a high solid fuel content showing a low viscosity is obtainable by adjustment of particle size distribution to increase a geometric standard deviation (6g). In this method, the increase of geometric standard deviation is accomplished by enlarging the range of particle size distribution. The enlargement of the particle size distribution range is attained by increasing the content of coarse particles and/or the content of very fine particles. The increase of the content of coarse particles lowers stability of the slurry in storage and transportation and further causes unfavorable troubles such as clogging of burner in a spraying process and increase of unburnt particles in a burning process. Further, the increase of the content of the very fine particles necessarily brings about prominent increase of the specific surface area of the particles and hence requires an
increased amount of a dispersant. Furthermore, it is relatively difficult in practice to increase very fine particles without using a large pulverizing energy.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a solid fuel-water slurry composition containing solid fuel particles with a high content but showing a low viscosity.

It is another object of the invention to provide a solid fuel-water slurry composition containing solid fuel particles with a high content but showing a low viscosity which is so stabilized that the solid fuel particles are kept well dispersed in the slurry and essentially free from giving a consolidated sedimentation material when the slurry is stored for a long time or transported under severe conditions.

It is a further object of the invention to provide an advantageous process for the preparation of a solid fuel-water slurry composition which is improved as above.

There is provided by the present invention a solid fuel-water slurry composition containing 50-80 weight % of solid fuel particles of coal and/or petroleum coke wherein a geometric mean diameter (Dp50) of the particles is not more than 74 μm, and a particle size distribution is adjusted in such manner that an arithmetic mean value of a upper geometric standard deviation (6g+) and a lower geometric standard deviation (6g−) in logarithmic normal distribution is in the range of 6-12, and a ratio thereof (6g+/6g−) is not more than 0.6.

The terms "geometric mean diameter" and "geometric standard deviation" used herein are terms generally utilized for defining particle size and its distribution. In more detail, these terms are defined using diameter in the logarithmic normal distribution and a cumulative passing weight percent in the following manner:
Geometric mean diameter ($D_{p50}$): a diameter at which the cumulative passing weight percent corresponds to 50%;

Upper geometric standard deviation ($6g+$): a ratio of a diameter at which the cumulative passing weight percent corresponding to 84.13%, ($D_{p+6}$), to the geometric mean diameter ($D_{p50}$), that is ($D_{p+6}/D_{p50}$);

Lower geometric standard deviation ($6g-$): a ratio of the geometric mean diameter ($D_{p50}$) to a diameter at which the cumulative passing weight percent corresponding to 15.87%, ($D_{p-6}$), that is ($D_{p50}/D_{p-6}$);

Geometric standard deviation ($6g$): an arithmetic mean value of a upper geometric standard deviation ($6g+$) and a lower geometric standard deviation ($6g-$) (in logarithmic normal distribution), that is ($6g+ + 6g-1/2$).

The above solid fuel-water slurry composition can be advantageously prepared by a process which comprises:

- a first step for pulverizing a solid fuel comprising coarse particles of coal and/or petroleum coke which have a geometric mean diameter of not more than approx. 20 mm in an aqueous solution of additives to prepare a solid fuel-water slurry having solid fuel particles of a geometric mean diameter ($D_{p501}$) in the range of 30 to 149 µm; and

- a second step for mixing the solid fuel-water slurry prepared in the first step with the above-mentioned coarse particles of coal and/or petroleum coke and an aqueous solution of additives, and subjecting the resulting mixture to wet grinding using a rod mill, to prepare a solid fuel-water slurry which has solid fuel particles of a geometric mean diameter ($D_{p502}$) having not more than 74 µm, and having such a relationship with the geometric mean diameter ($D_{p501}$) of the solid fuel particles of the solid fuel-water slurry obtained in the first step that $R_s$ representing a ratio of $D_{p501}/D_{p502}$ is in the range of 0.8 to 4, that $R_w$ representing a ratio of $F_1/F_2$ wherein $F_1$ means the feed rate (by weight) of the solid fuel supplied to the first step, and $F_2$ means the feed rate (by weight)
of the coarse solid fuel particles supplied to the second step is in the range of 0.4 to 2.4, and that a ratio of Rs/Rw is in the range of 1 to 3.

There is further provided by the present invention a solid fuel-water slurry composition which comprises 100 weight parts of solid fuel-water slurry containing 50-80 weight parts of solid fuel particles of coal and/or petroleum coke, 0.01-3 weight parts of a dispersant and 0.01-0.5 weight part of a stabilizer (i.e., stabilizer composition) which comprises 1-20 weight % of at least one water-soluble polymer selected from the group consisting of natural gum, modified natural gum, polyvinyl alcohol, polyacrylamide, carboxymethyl cellulose and hydroxyethyl cellulose and 80-99 weight % of fine particles of at least 15 one inorganic material selected from the group consisting of bentonite, attapulgite, sepiolite and chrysotile asbestos.

**BRIEF DESCRIPTION OF DRAWING**

Fig. 1 shows a flow sheet which is employable for the preparation of a solid fuel-water slurry of the invention.

**DETAILED DESCRIPTION OF THE INVENTION**

The solid fuel used in the present invention is coal and/or petroleum coke. There is no specific limitation on the coal and petroleum coke, and most of generally employed coals and petroleum cookes are utilizable. Coal containing at most approx. 6 wt.% of ash is preferably used. Coal containing approx. 10 wt.% of ash can be also favorably employed after it is subjected to a deashing process such as a heavy medium beneficiation process to reduce the ash content to a level lower than approx. 5 wt.%.

The petroleum coke may be a petroleum coke obtained as a by-product in a petroleum refining process and may contain...
0.1 to 1 wt.% of ash.

The solid fuel-water slurry composition of the invention contains 50-80 weight %, preferably 65-75 weight %, of solid fuel particles. A geometric mean diameter (Dp50) of the particles is not more than 74 μm, preferably 20-53 μm. If the geometric mean diameter is 74 μm or more, content of coarse particles increases to cause various troubles in the operations in the use of the slurry. If the geometric mean diameter is too small, content of very fine particles increases. It is disadvantageous from the viewpoint of production efficiency to produce solid fuel-water slurry containing an increased amount of very fine particles. Moreover, an increased amount of a dispersant is required to disperse the solid fuel containing a large amount of very fine particles.

In the solid fuel to be used in the slurry of the invention, a particle size distribution is adjusted in such manner that an arithmetic mean value of a upper geometric standard deviation (6g+) and a lower geometric standard deviation (6g-) is in the range of 6-12 and a ratio thereof (6g+/6g-) is not more than 0.6, preferably not more than 0.4. By the adjustment of the particle size distribution in this way, a solid fuel-water slurry which contains an increased amount of solid fuel particles but shows a reduced viscosity value can be produced.

If it is intended to reduce content of coarse particles under such condition that a ratio (6g+/6g-) is 0.6 or more, it is necessary to decrease the geometric mean diameter (Dp50). This causes difficulty in industrial production of a solid fuel-water slurry containing a high concentration of solid fuel particles and showing a low viscosity value.

The solid fuel-water slurry composition having the adjusted particle size distribution according to the present invention can be advantageously prepared by the process comprising the following two steps.
(1) First step
A solid fuel comprising coarse particles of coal and/or petroleum coke which have a geometric mean diameter of not more than approx. 20 mm is pulverized in an aqueous solution of additives to prepare a solid fuel-water slurry having solid fuel particles of a geometric mean diameter (Dp501) in the range of 30 to 149 μm, preferably in the range of 44 to 149 μm. The content of the solid fuel particles in the resulting slurry preferably is in the range of 30 to 80 wt.%, more preferably in the range of 50 to 70 wt.%. The pulverizer for wet operation may be a known mill such as a ball mill, a tube mill, or an attrition mill. Examples of the additives include the aforementioned dispersant, stabilizer and pH adjusting agent such as sodium hydroxide, potassium hydroxide and ammonium hydroxide.

(2) Second step
The solid fuel-water slurry prepared in the first step is mixed with the above-mentioned coarse particles of coal and/or petroleum coke and an aqueous solution of additives, and the resulting mixture was subjected to wet grinding (or wet pulverizing) using a known mill, preferably a rod mill, to prepare a solid fuel-water slurry which has solid fuel particles of a geometric mean diameter (Dp502) having not more than 74 μm, preferably in the range of 20 to 53 μm, and having such a relationship with the geometric mean diameter (Dp501) of the solid fuel particles of the solid fuel-water slurry obtained in the first step that Rs representing a ratio of Dp501/Dp502 is in the range of 0.8 to 4, preferably in the range of 0.8 to 3.

As described above, a rod mill is advantageously employed for the grinding or pulverizing procedure in the second step, because the desired solid fuel-water slurry can be easily prepared within a relatively short period of time by the grinding or pulverizing procedure using a rod.
In the above-described process, $R_w$ representing a ratio of $F_1/F_2$ wherein $F_1$ means a feed rate (by weight) of the coarse solid fuel supplied to the first step, and $F_2$ means a feed rate (by weight) of the coarse solid fuel particles supplied directly to the second step is preferably in the range of 0.4 to 2.4, more preferably 0.6 to 1.6. Further, a ratio of $R_s/R_w$ preferably is in the range of 1 to 3. Furthermore, the particle size distribution of the solid fuel contained in the solid fuel-water slurry obtained at the second step preferably has a geometric standard deviation ($6_g$) in the range of 6 to 12.

The above process comprising the two pulverizing (or grinding) steps is described more in detail hereinbelow, referring to the flow sheet illustrated in Fig. 1.

First Step

Water and additives such as a dispersant and/or a pH adjusting agent are supplied to mixing vessel 1 through line 15 and then sent to wet mill 6 through line 16, pump 2, line 17, flowmeter 3 and line 13. A coarse solid fuel is supplied to wet mill 6 through line 19, hopper 13, line 20, constant feeder 4, line 21, crushe 5 (optionally installed to crush the supplied coarse solid fuel, if desired), and line 22. The amounts of water and solid fuel particles supplied to the wet mill 6 are controlled to give a solid fuel-water slurry having a solid particle content in the range of 30 to 80 wt.%. In the wet mill 6, the solid fuel particles, water and the additives are mixed and simultaneously pulverized to give a solid fuel-water slurry containing pulverized particles which have a geometric mean diameter in the range of 30 to 149 μm. A portion of the solid fuel-water slurry can be circulated through line 23, pump 7, line 24 and line 25 to return into the wet mill 6.

Second Step

The solid fuel-water slurry prepared in the first
step is supplied to mill 11 such as a rod mill through line 23, pump 7, line 24, line 26, flowmeter 8 and line 27. A coarse solid fuel is supplied to the mill 11 through line 28, hopper 14, line 29, constant feeder 9, line 30, crusher 10 (optionally installed to crush the supplied coarse solid fuel, if desired) and line 31.

Water and additives such as the above-mentioned agents are supplied to a mixing vessel 50 through line 38 and then sent to the mill 11 through line 39, pump 44, line 40, flowmeter 51 and line 41. In the mill 11, the fine pulverizing procedure is carried out to prepare a solid fuel-water slurry having a desired particle size distribution.

The solid fuel-water slurry prepared in the mill 11 is introduced into slurry tank 12 through line 32 and taken out through line 33, pump 43, line 34 and line 35. A portion of the solid fuel-water slurry can be circulated through line 36 to return to the mill 11 and/or through line 37 to return to the wet mill 6.

As described above, the solid fuel-water composition of the invention can contain an appropriate additive such as a dispersant for suppressing increase of viscosity which is likely caused by increase of the solid fuel concentration. As the dispersant, a known dispersant can be employed. Examples of the dispersants include naphthalene sulfonic acid and its salts, petroleum sulfonic acid and its salts, lignin sulfonic acid and its salts, and formaldehyde condensation products thereof; polyoxyethylene-alkylethersulfuric acid ester and its salts; polyoxyethylenealkylarylethersulfuric acid ester and its salts; polyglycerol sulfate; melamine resin sulfonic acid and its salts; and coal extract sulfonic acid and its salts.

The dispersant is preferably employed in an amount of 0.01 to 3 weight parts per 100 weight parts of the solid fuel-water slurry. The dispersant can be incorporated into the solid fuel-water slurry at any step of the process of the preparation of the slurry. Otherwise, the
dispersant can be added to the previously prepared solid fuel-water slurry.

The solid fuel-water composition of the invention may also contain appropriate additives such as a pH adjusting agent. As the pH adjusting agent, a known pH adjusting agent can be employed. Examples of the pH adjusting agent include sodium hydroxide, potassium hydroxide and ammonium hydroxide.

The solid fuel-water slurry composition of the invention shows a lower viscosity such as approx. 800 mPa·s or lower (determination of this viscosity shall be described hereinafter), though it contains not less than 70 weight % of solid fuel.

The solid fuel-water slurry composition of the invention can be in the form of a slurry composition comprising 100 weight parts of solid fuel-water slurry containing 50-80 weight parts of solid fuel particles of coal and/or petroleum coke, 0.01-3 weight parts of a dispersant and 0.01-0.5 weight part, preferably 0.02-0.3 weight part, of a stabilizer which comprises 1-20 weight %, preferably 2-10 weight % of at least one water-soluble polymer selected from the group consisting of natural gum, modified natural gum, polyvinyl alcohol, polyacrylamide, carboxymethyl cellulose and hydroxyethyl cellulose and 80-99 weight %, preferably 90-98 weight %, of fine particles of at least one inorganic material selected from the group consisting of bentonite, attapulgite, sepiolite and chrysotile asbestos.

The solid fuel-water slurry composition containing the above stabilizer which comprises a combination of the specific organic material and the specific inorganic material shows more improved stability in the storage or transportation of the slurry composition.

In the above water-soluble polymer, the natural gum preferably is guar gum, xanthane gum, locust bean gum, karaya gum, sodium alginate or a modified product of said
natural gum.

The stabilizer can be incorporated into a solid fuel-water slurry at any step of the process of the preparation of the slurry, and it is preferably incorporated into the taken out slurry through line 35.

The present invention is further illustrated by the following examples.

The method for measuring particle size distribution of solid fuel particles and the method for measuring viscosity of solid fuel-water slurry employed in the following examples are set forth below.

(1) Method for measuring particle size distribution of solid fuel particles

The measurement was done using a centrifugal particle size analyzer manufactured by Shimazu Seisakusho Co., Ltd., Japan, in combination with standard sieves.

(2) Method for measuring of viscosity of solid fuel-water slurry

A solid fuel-water slurry was subjected to measurement of viscosity using a Brookfield rotating viscometer (manufactured by Tokyo Keiki Co., Ltd., Japan, No. 3 rotor was used) just after the slurry was prepared. The measurement was done at 27°C and rotation rate of 12 r.p.m., and a value measured at one minute after the beginning of the measuring procedure was detected.

**Example 1**

A solid fuel-water slurry was prepared according to the flow sheet of Fig. 1 using a ball mill as the wet pulverizer 6.

To the ball mill 6 were continuously supplied a solid fuel (coarsely crushed coal having a geometric mean diameter of approx. 8 mm through the line 22 and an aqueous dispersant (water containing a formalin condensate of sodium β-naphthalenesulfonate) through the line 18. In the ball mill 6, the crushed coal was pulverized in the
dispersant solution to produce a solid fuel-water slurry containing solid particles of a geometric mean diameter (Dp50) of 53.4 μm.

The solid fuel-water slurry was then supplied continuously to the rod mill 11 through the line 27. Simultaneously, another portion of the coarsely crushed coal and another portion of the dispersant solution were supplied to the rod mill 11 through the lines 31 and 41, respectively. In the rod mill 11, the supplied solid fuel was finely pulverized to prepare a solid fuel-water slurry having characteristics value set forth in Table 1. Thus prepared slurry was then taken out continuously through the line 35.

Comparison Examples 1 & 2

The procedures of Example 1 were repeated using the same apparatus but varying the pulverizing conditions to prepare a solid fuel-water slurry containing solid particles which had particle diameter distribution values set forth in Table 1, the values being outside of the range of the invention. The characteristic values of the resulting slurry are also set forth in Table 1.
Table 1

<table>
<thead>
<tr>
<th></th>
<th>Example 1</th>
<th>Com. Ex. 1</th>
<th>Com. Ex. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q [kg/h·m²]</td>
<td>325</td>
<td>311</td>
<td>256</td>
</tr>
<tr>
<td>Rw</td>
<td>0.90</td>
<td>0.95</td>
<td>0.34</td>
</tr>
<tr>
<td>Rs</td>
<td>1.21</td>
<td>0.79</td>
<td>1.44</td>
</tr>
<tr>
<td>Rs/Rw</td>
<td>1.34</td>
<td>0.85</td>
<td>4.31</td>
</tr>
<tr>
<td>Final slurry product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dp50²</td>
<td>44.1</td>
<td>27.4</td>
<td>31.6</td>
</tr>
<tr>
<td>50 Mesh pass ratio [%]</td>
<td>99.8</td>
<td>99.9</td>
<td>99.9</td>
</tr>
<tr>
<td>6g</td>
<td>6.1</td>
<td>5.1</td>
<td>5.5</td>
</tr>
<tr>
<td>Slurry Concentration [wt. %]</td>
<td>70.1</td>
<td>69.5</td>
<td>69.9</td>
</tr>
<tr>
<td>Viscosity [mPa·s]</td>
<td>730</td>
<td>1,200</td>
<td>1,150</td>
</tr>
</tbody>
</table>

Remarks: "Q": rate of material (to be pulverized) being supplied to rod mill (weight of supplied material per effective area)

"Rw": F1/F2, namely, weight of coarsely crushed solid fuel supplied to the first step /weight of coarsely crushed solid fuel supplied to the second step

"Rs": Dp50¹/Dp50², namely, geometric mean diameter of solid fuel particles in solid fuel-water slurry prepared in the first step (Dp50¹)/geometric mean diameter of solid fuel particles in solid fuel-water slurry prepared in the second step (Dp50²)

As is apparent from the results set forth in Table 1,
the solid fuel-water slurry containing solid fuel particles which are so prepared as to have particle diameter distribution values within the specifically defined range shows a relatively low viscosity value, as compared with a solid fuel-water slurry containing almost the same amount of solid fuel particles whose particle diameter distribution values are outside of the range of the invention.

**Example 2**

A de-ashed coal having the below-mentioned components and property was wet-ground in a ball mill and classified to remove all above No.50 sieve size to obtain various samples of particles having different sizes. The geometric mean diameters (Dp50), (Dp+6), and (Dp-6) of the obtained samples are set forth in Table 2.

**Analytical data of deashed coal**

<table>
<thead>
<tr>
<th>Proximate analysis (wt.%)</th>
<th>moisture 5.1</th>
<th>ash 2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(JIS M8813)</td>
<td>volatile matter 40.8</td>
<td>fixed carbon 51.8</td>
</tr>
<tr>
<td>Calorific value (kcal/kg, JIS M 8814):</td>
<td>7410</td>
<td></td>
</tr>
<tr>
<td>Ultimate Analysis (wt.%)</td>
<td>carbon 79.6</td>
<td>hydrogen 5.2</td>
</tr>
<tr>
<td>(JIS M8813)</td>
<td>nitrogen 1.7</td>
<td>sulfur 0.5</td>
</tr>
<tr>
<td></td>
<td>oxygen 10.6</td>
<td>ash 2.4</td>
</tr>
</tbody>
</table>
Sixty four weight parts of Sample A, 28 weight parts of Sample C and 8 weight parts of Sample D were uniformly mixed to prepare a coal particle mixture having a geometrical mean diameter and a particle size distribution set forth in Table 3.

Seventy weight parts of the coal particle mixture, 29.5 weight parts of water and 0.5 weight part of a dispersant (formaldehyde condensation product of β-naphthalene sulfonic acid, sodium salt) were placed in a mixing vessel at room temperature and then stirred manually. Thus obtained mixture was stirred at a rotation speed of 3,000 r.p.m. for 3 min. by means of a labo disper (manufactured by Tokushu Kiko Kogyo Co., Ltd., Japan) to prepare a solid fuel-water slurry having 70 wt.% of the fuel particles.

The measured viscosity is set forth in Table 3.

**Example 3**

A solid fuel-water slurry was prepared in the same manner as in Example 2 except that a coal particle mixture were prepared by mixing 72 weight parts of Sample B, 21 weight part of Sample C and 7 weight parts of Sample D.

The geometric mean diameter and particle size distribution of the obtained solid fuel-water slurry is set forth in Table 3. The measured viscosity is also given in
Table 3.

**Comparison Examples 3 & 4**

A solid fuel-water slurry was prepared in the same manner as in Example 2 except for using coal particles having a geometric mean diameter and a particle size distribution outside of the range of the present invention. The geometric mean diameter and particle size distribution of the obtained solid fuel-water slurry is set forth in Table 3. The measured viscosity is also given in Table 3.

<table>
<thead>
<tr>
<th>Example</th>
<th>Arithmetic mean value</th>
<th>Ratio</th>
<th>Geometric mean diameter [μm]</th>
<th>Viscosity [mPa·s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example 2</td>
<td>6.2</td>
<td>0.25</td>
<td>32</td>
<td>80</td>
</tr>
<tr>
<td>Example 3</td>
<td>6.1</td>
<td>0.26</td>
<td>44</td>
<td>110</td>
</tr>
<tr>
<td>Com. Ex.3</td>
<td>6.1</td>
<td>0.71</td>
<td>16</td>
<td>84</td>
</tr>
<tr>
<td>Com. Ex.4</td>
<td>6.0</td>
<td>0.71</td>
<td>22</td>
<td>110</td>
</tr>
</tbody>
</table>

**Remarks:** Arithmetic mean value is an arithmetic mean value of upper geometrical standard deviation (6g+) and lower geometrical standard deviation (6g-), namely (6g+ + 6g-)/2; and Ratio is a ratio of 6g+ to 6g-, namely 6g+/6g-; Geometrical mean diameter is Dp50 (μm).

Examples 4-6

A coal particle mixture having the same geometric
mean diameter and particle size distribution as those of Example 2 was prepared in the same manner as in Example 2 except that the coal particle mixture was prepared from a deashed coal having the following components.

<table>
<thead>
<tr>
<th>Analytical data of deashed coal</th>
<th>moisture (wt.%)</th>
<th>ash content (wt.%)</th>
<th>volatile matter (wt.%)</th>
<th>fixed carbon (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximate analysis (JIS M8812)</td>
<td>5.3</td>
<td>0.7</td>
<td>38.8</td>
<td>55.2</td>
</tr>
</tbody>
</table>

The coal particle mixture, water, a dispersant (formaldehyde condensation product of 8-naphthalene sulfonic acid, sodium salt), and a pH adjusting agent (ammonium hydroxide) were placed in a mixing vessel at room temperature and then stirred manually. The dispersant is used in an amount of 0.5 weight part per 100 weight parts of the solid fuel-water slurry. The obtained mixture was stirred at a rotation speed of 3,000 r.p.m. for 3 minutes by means of the labo disper to prepare a primary solid fuel-water slurry having 70 wt.% of the fuel particles and having a viscosity of 800 mPa·s and pH 8.0.

A stabilizer was then added to the primary solid fuel-water slurry, and the slurry was manually stirred. Subsequently, the slurry was stirred at approx. 3,000 r.p.m. for 3 min. by means of the above labo disper to give a solid fuel-water slurry having a viscosity of approx. 1,000 mPa·s.

**Comparison Examples 5-10**

The procedures of Example 4 were repeated except for replacing the stabilizer with a single compound (Comparison Examples 5-9) or with a mixture having a composition outside of the present invention (Comparison Example 10), to obtain a solid fuel-water slurry having a viscosity of approx. 1,000 mPa·s.
Evaluation of Storage Stability and Transportation Stability

The solid fuel-water slurries obtained in Examples 4-6 and Comparison Examples 5-10 were evaluated with respect to storage stability and transportation stability in the following manner.

Method for determination of storage stability

The solid fuel-water slurry was placed in a 100 ml-glass sample tube, and then allowed to stand for 7 days. At the end of the 7 days storage, a glass rod was inserted into the slurry to detect if solid fuel particles were sedimented on the bottom or a consolidated particles were formed on the bottom.

The results were marked in the following manner:

AA: neither sedimented particles nor consolidated particles were observed;
BB: sedimented particles were observed but no consolidated particles were formed; and
CC: consolidated particles were formed.

Method for determination of transportation stability

The solid fuel-water slurry was placed in a 100 ml-glass sample tube, and then subjected to horizontal vibration (amplitude: 40 mm, frequency: 90 min⁻¹) for 5 hours. At the vibration was terminated, a glass rod was inserted into the slurry to detect if solid fuel particles were sedimented on the bottom or a consolidated particles were formed on the bottom.

The results were marked in the following manner:

aa: neither sedimented particles nor consolidated particles were observed;
bb: sedimented particles were observed but no consolidated particles were formed; and
cc: consolidated particles were formed.

Results are set forth in Table 4.
Table 4

<table>
<thead>
<tr>
<th>Stabilizer (weight ratio)</th>
<th>Amount (wt.%) of Added Stabilizer</th>
<th>Storage Stability</th>
<th>Transportation Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Example</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 xanthane gum (6)</td>
<td>0.106</td>
<td>AA</td>
<td>aa</td>
</tr>
<tr>
<td>5 attapulgite (94)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 polyvinyl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 alcohol (5)</td>
<td>0.084</td>
<td>AA</td>
<td>aa</td>
</tr>
<tr>
<td>10 bentonite (95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 hydroxyethyl cellulose (5)</td>
<td>0.100</td>
<td>AA</td>
<td>aa</td>
</tr>
<tr>
<td>6 bentonite (95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Com. Example</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 5 xanthane gum (100)</td>
<td>0.006</td>
<td>CC</td>
<td>bb</td>
</tr>
<tr>
<td>6 polyvinyl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 alcohol (100)</td>
<td>0.004</td>
<td>CC</td>
<td>bb</td>
</tr>
<tr>
<td>7 hydroxyethyl cellulose (100)</td>
<td>0.005</td>
<td>CC</td>
<td>bb</td>
</tr>
<tr>
<td>20 8 attpulgite (100)</td>
<td>0.130</td>
<td>AA</td>
<td>cc</td>
</tr>
<tr>
<td>9 bentonite (100)</td>
<td>0.135</td>
<td>BB</td>
<td>cc</td>
</tr>
<tr>
<td>10 polyvinyl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 alcohol (22)</td>
<td>0.018</td>
<td>BB</td>
<td>bb</td>
</tr>
<tr>
<td>10 bentonite (78)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remark: The amount of added stabilizer is based on the amount of the solid fuel-water slurry.
The claims defining the invention are as follows:

1. A solid fuel-water slurry composition containing 50-80 weight % of solid fuel particles of coal and/or petroleum coke wherein a geometric mean diameter \( \text{Dp}_{50} \) of the particles is not more than 74 \( \mu \text{m} \), and a particle size distribution is adjusted in such manner that an arithmetic mean value of a upper geometric standard deviation \( \sigma_{g+} \) and a lower geometric standard deviation \( \sigma_{g-} \) in logarithmic normal distribution is in the range of 6-12, and a ratio thereof \( \sigma_{g+}/\sigma_{g-} \) is not more than 0.6.

2. The solid fuel-water slurry composition as claimed in claim 1, which contains 65-75 weight % of the solid fuel.

3. The solid fuel-water slurry composition as claimed in claim 1, wherein the geometric mean diameter \( \text{Dp}_{50} \) of the solid fuel particles is in the range of 20-53 \( \mu \text{m} \).

4. The solid fuel-water slurry composition as claimed in claim 1, wherein the ratio of the upper geometric standard deviation and the lower geometric standard deviation \( \sigma_{g+}/\sigma_{g-} \) is a value of not more than 0.4.

5. The solid fuel-water slurry composition as claimed in claim 1, wherein a dispersant is contained in the slurry.
6. The solid fuel-water slurry composition as claimed in claim 1, wherein a dispersant selected from the group consisting of naphthalene sulfonic acid and its salts, petroleum sulfonic acid and its salts, lignin sulfonic acid and its salts, and formaldehyde condensation products thereof; polyoxyethylenealkylether sulfuric ester and its salts; polyoxyethylenealkylarylether sulfuric ester and its salts; polyglycerol sulfate; melamine resin sulfonic acid and its salts; and coal extract sulfonic acid and its salts.

7. The solid fuel-water slurry composition as claimed in claim 1, which comprises 100 weight parts of solid fuel-water slurry containing 50-80 weight parts of solid fuel particles of coal and/or petroleum coke and 0.01-0.5 weight part of a stabilizer which comprises 1-20 weight % of at least one water-soluble polymer selected from the group consisting of natural gum, modified natural gum, polyvinyl alcohol, polyacrylamide, carboxymethyl cellulose and hydroxyethyl cellulose and 80-99 weight % of fine particles of at least one inorganic material selected from the group consisting of bentonite, attapulgite, sepiolite and chrysotile asbestos.

8. A solid fuel-water slurry composition which comprises 100 weight parts of solid fuel-water slurry containing 50-80 weight parts of solid fuel particles of coal and/or petroleum coke, 0.01-3 weight parts of a dispersant and 0.01-0.5 weight part of a stabilizer which comprises 1-20 weight % of at least one water-soluble polymer selected from the group consisting of natural gum, modified natural gum, polyvinyl alcohol, polyacrylamide, carboxymethyl cellulose and hydroxyethyl cellulose and 80-99 weight % of fine particles of at least one inorganic material selected from the group consisting of bentonite, attapulgite, sepiolite and chrysotile asbestos.
9. The solid fuel-water slurry composition as claimed in claim 8, wherein the water-soluble polymer is a natural gum selected from the group consisting of guar gum, xanthane gum, locust bean gum, karaya gum, sodium alginate and a modified product of said natural gum.

10. The solid fuel-water slurry composition as claimed in claim 8, wherein the stabilizer comprises 2-10 weight % of the water-soluble polymer and 90-98 weight % of fine particles of inorganic material.

11. The solid fuel-water slurry composition as claimed in claim 8, wherein 0.02-0.3 weight part of the stabilizer is contained in 100 weight parts of the solid fuel-water slurry.

12. The solid fuel-water slurry composition as claimed in claim 8, which contains 65-75 weight % of the solid fuel.

13. The solid fuel-water slurry composition as claimed in claim 8, wherein a dispersant selected from the group consisting of naphthalene sulfonic acid and its salts, petroleum sulfonic acid and its salts, lignin sulfonic acid and its salts, and formaldehyde condensation products thereof; polyoxyethylenealkylether sulfuric ester and its salts; polyoxyethylenealkylarylether sulfuric ester and its salts; polyglycerol sulfate; melamine resin sulfonic acid and its salts; and coal extract sulfonic acid and its salts.
14. A process for the preparation of a solid fuel-water slurry composition according to claim 1 which comprises:

   a first step for pulverizing a solid fuel comprising coarse particles of coal and/or petroleum coke which have a geometric mean diameter of not more than 20 mm in an aqueous solution of an additive to prepare a solid fuel-water slurry having solid fuel particles of a geometric mean diameter $D_{p50}^1$ in the range of 30 to 149 $\mu$m; and

   a second step for mixing the solid fuel-water slurry prepared in the first step with the above-mentioned coarse particles of coal and/or petroleum coke and an aqueous solution of an additive, and subjecting the resulting mixture to wet grinding using a rod mill, to prepare a solid fuel-water slurry which has solid fuel particles having a geometric mean diameter $D_{p50}^2$ of not more than 74 $\mu$m, and having such a relationship with the geometric mean diameter $D_{p50}^1$ of the solid fuel particles of the solid fuel-water slurry obtained in the first step that $R_s$ representing a ratio of $D_{p50}^1/D_{p50}^2$ is in the range of 0.8 to 4, that $R_w$ representing a ratio of $F_1/F_2$ wherein $F_1$ means the feed rate of the coarse solid fuel supplied to the first step, and $F_2$ means the feed rate of the coarse solid fuel particles supplied to the second step is in the range of 0.4 to 2.4, and that a ratio of $R_s/R_w$ is in the range of 1 to 3.

15. The process as claimed in claim 14, wherein the first step is performed to give a solid fuel-water slurry having solid fuel particles of a geometric mean diameter $D_{p50}^1$ in the range of 44 to 149 $\mu$m.

16. The process as claimed in claim 14, wherein the second step is performed to give a solid fuel-water slurry showing the $R_s$ value in the range of 0.8 to 3.

17. A solid fuel-water slurry composition substantially as hereinbefore described with reference to any one of Examples 1-6.

18. A process for the preparation of a solid fuel-water slurry composition substantially as hereinbefore described with reference to any one of Examples 1-6.

DATED this TWELFTH day of APRIL 1991

Ube Industries, Ltd.

Patent Attorneys for the Applicant
SPRUSON & FERGUSON

rhk/0388E