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(71) Applicant: **Kao Corporation**
Chuo-Ku Tokyo 103 (JP)

(72) Inventors:
- **ONO, Reiji**
  Kakogawa-shi, Hyogo 675 (JP)
- **KIMURA, Yoshio**
  Kakogawa-shi, Hyogo 675 (JP)
- **NAKAYA, Takashi**
  Kakogawa-shi, Hyogo 675-01 (JP)
- **MIYAMOTO, Kenichi,**
  Kao Corporation
  Wakayama-shi, Wakayama 640 (JP)
- **MATOBA, Takashi,**
  Kao Corporation
  Wakayama-shi, Wakayama 640 (JP)
- **ICHIMOTO, Takehiko,**
  Kao Corporation
  Wakayama-shi, Wakayama 640 (JP)

(74) Representative:
Kindler, Matthias, Dr. Dipl.-Chem. et al
Hoffmann Eitle,
Patent- und Rechtsanwälte,
Arabellastrasse 4
81925 München (DE)

(54) METHOD FOR IMPROVING CONVEYABILITY OF PULVERIZED COAL

(57) A solid compound having a volume average particle diameter of not more than 5 μm, for example, silicon dioxide, aluminum oxide, calcium carbonate, or silicon cabide, is adhered on a dried fine coal obtained from a raw coal having an average HGI of not less than 30 in such a manner that the value of α falls within the following range to improve the transportability of the fine coal: $k_1 \cdot r^{0.59} \leqq \alpha \leqq 10$ (vol %) wherein $k_1 = 10^{-1.42}$ and r represents the volume average particle diameter (μm) of the solid compound added. As a result, the fine coal is improved in fluidity and thus can be used as an injection fuel for blast furnaces and a fine coal firing boilers.

Further, it is possible to prevent hanging and changing within hoppers and clogging of piping.

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Description

[Technical Field]

The present invention relates to a transportability improver for fine coal which can improve the transportability of fine coal blown through a blowing port of a metallurgical furnace or a combustion furnace to permit a large amount of fine coal to be stably blown, and an operation method for a metallurgical furnace or a combustion furnace using the same.

[Background Art]

In the operation of a metallurgical furnace, for example, a blast furnace, a commonly used method is to alternately feed coke and iron ore from the top of the furnace. In recent years, a method has more and more become used wherein a part of the coke fed from the top of the furnace is replaced by an inexpensive, highly calorific and highly combustible fine coal blown, together with hot air, through a blowing port of the blast furnace. This fine coal blow operation method, as compared with all-coke operation, is advantageous in that the fuel cost can be reduced.

Further, regarding the fuel for a combustion furnace, such as a boiler, coal is reconsidered as a fuel alternative to a heavy oil. In the combustion furnace, the coal is used in the form of CWM (coal-water slurry), COM (coal/heavy oil mixed fuel), fine coal, and the like. Among them, a fine coal-fired combustion furnace has drawn attention because the use of other media, such as water or oil, is not required. This fine coal-fired combustion furnace has, however, the same problems as in the use of fine coal in the operation of the blast furnace.

The blowing of fine coal is carried out through the steps of preparation of fine coal by dry pulverization of raw coal, classification, storage of the resultant fine coal in a hopper, discharge of the fine coal from the hopper, pneumatic transportaion through piping, blowing into a metallurgical furnace or a combustion furnace through a blowing port, and combustion of fine coal in the metallurgical furnace or the combustion furnace. In this case, the discharge of fine coal from the hopper and the pneumatic transportaion of fine coal through piping suffer from the following problems.

Specifically, the fundamental properties of powder, such as fluidity of fine coal, vary greatly depending upon the kind, particle diameter, moisture content of fine coal to be discharged and transported, leading to a great variation in discharge and transportaion conditions. For this reason, when the fundamental properties of fine coal are outside the optimal property range, troubles occur such as the bridging or blow-by in the hopper and the clogging of piping during pneumatic transportaion, making it difficult to stably blow fine coal for a long period of time.

Improving the transportability of fine coal has been considered with a view to solving the above problems, and various methods for this have been proposed in the art. Examples thereof include a method wherein a char is incorporated in an amount of 5 to 20% into fine coal (JP-A 4-268004), a method wherein the content of inerts (the total content of micrinite, 1/3 semifusinite, fusinite, and mineral matter as specified in JIS M 8816-1979) is regulated before pulverization (JP-A 5-9518, JP-A 5-25516, and JP-A 5-222415), a method wherein the kind of coal for the fine coal blown is limited to bring the fluidity index to a value greater than the standard value for a blast furnace used (JP-A 4-224610), a method wherein the coefficient of friction between fine coal and piping is regulated (JP-A 5-214417), and a method wherein the moisture content of fine coal is regulated to an optimal value (JP-A 5-78675). Further, adsorption of a dispersant (JP-A 63-224744) has been proposed for improving the pulverization efficiency of fine coal. This method, however, does not refer to the transportability of fine coal.

The above methods, however, involve problems such that the kind of coal usable in the blowing of fine coal is limited, that the problems of bridging or blow-by in a hopper and clogging of piping could not be satisfactorily solved, and that the provision of an apparatus or equipment for the regulation increases the cost. Thus, any method which is satisfactory from the practical viewpoint has not been proposed in the art.

Further, for example, in the current operation method for a blast furnace, the amount of the fine coal blown through a blowing port is about 50 to 250 kg per ton of pig iron. A further increase in the amount of the fine coal blown is desired for the reason of cost. In the above method, however, since the transportability of fine coal is not always satisfactory, the amount of the fine coal blown cannot be markedly increased.

[Disclosure of the Invention]

Accordingly, an object of the present invention is to solve the above problems of prior art to thereby provide a method which can improve the transportability of fine coal, eliminate the limitation of the kind of the coal used, and prevent the clogging of piping and the bridging in a hopper, thus permitting a large amount of the fine coal to be stably blown.

The present inventors have made intensive studies with a view to attaining the above object and, as a result, have found that when a solid compound having a volume average particle diameter of not more than 5 μm and capable of satisfying particular requirements for the relationship between the volume average particle diameter of the compound and the amount of the compound added is adhered to fine coal obtained from a raw coal having an average HGI of not less than 30, the transportability of fine coal can be markedly improved, which has led to the completion of the present invention.

Thus, according to the present invention, there is provided a method for improving the transportability of dried fine coal obtained from a raw coal having an average HGI of not less than 30, characterized by adding a solid compound having a volume average particle diameter of not more than 5 μm in an amount shown in the following formula α (vol %) to the above shown fine coal and adhering it onto the surface of said fine coal:

$$k_1 \cdot r^{0.59} \leqq \alpha \leqq 10 \text{ (vol \%)}$$

[wherein $k_1 = 10^{-1.42}$ and r represents the volume average particle diameter (μm) of the solid compound added.]

The amount of the solid compound defined by the above formula is expressed in percentage by volume of the solid compound based on the volume of fine coal. In this case, the volume refers to a value determined by dividing the weight by a bulk density in a loosely packed state. The bulk density in a loosely packed state will be described below.

Further, the present invention provides a fine coal mixture comprising a transportability improver for fine coal used in the above method and fine coal having a small diameter, and a method for operating a metallurgical furnace or a combustion furnace, characterized in that fine coal comprising a solid compound, having a volume average particle diameter of not more than 5 μm, adhered in an amount shown by the above α (volume %) to the surface of dried fine coal obtained from a raw coal having an average HGI (pulverizability index) of not less than 30 is blown through a blowing port of the metallurgical furnace or the combustion furnace.

In other words, the present invention is directed to a method for transporting fine coal, wherein a solid compound having a volume average particle diameter of not more than 5 μm is added and adhered in an amount shown by α (volume %) in the above formula to the surface of dried fine coal having an average HGI of not less than 30. Further, the present invention includes the use of the above solid compound for treating fine coal and a method for treating fine coal with the above solid compound.

In the present invention, the solid compound refers to a compound which is solid under the conditions of 1.01×10^5 Pa (1 atm) and 80°C independently of whether or not the solid is crystalline or amorphous.

In the present invention, preferably, the solid compound is insoluble in water, the average HGI of raw coal for producing fine coal is not less than 50, the solid compound is one member or more than two members selected among metal oxides, phosphates, carbonates, silicates, nitrides, silicide, carbides, dust and clay minerals, the solid compound is a fine powder of silicon dioxide, the solid compound has a volume average particle diameter of 0.01 to 5 μm, still preferably 0.1 to 5 μm, particularly preferably 0.1 to 4 μm. The solubility of the solid compound in water is not more than 1, still preferably not more than 0.1, particularly preferably not more than 0.01.

The solid compound is still preferably a metal oxide or dust though the metal oxide is particularly preferred.

The method for operating a metallurgical furnace or a combustion furnace using a transportability improver according to the present invention is characterized in that a transportability improver is added in the amount range shown in the above formula to fine coal to be blown through a blowing port into a metallurgical furnace or a combustion furnace followed by blowing of the fine coal through the blowing port into the metallurgical furnace or the combustion furnace. The amount of the compound added to fine coal is preferably not less than $k_1 \cdot r^{0.59}$ % by volume from the viewpoint of improving the transportability. Addition of the compound in an amount exceeding 10% by weight is not found to result in any improvement of the transportability in proportion to the added amount and hence is economically disadvantageous.

From the viewpoint of improving the transportability, the amount of the solid compound added to be adhered to the surface of fine coal is

preferably

$$k_2 \cdot r^{0.59} \leqq \alpha \leqq 10 \; (k_2 = 10^{-1.10}),$$

still preferably

$$k_2 \cdot r^{0.59} \leqq \alpha \leqq k_3 \cdot r^{0.59} \; (k_2 = 10^{-1.10},\ k_3 = 10^{0.60}).$$

From the viewpoint of the inhibiting of the occurrence of dust and the production cost of the solid compound, the volume average particle diameter of the solid compound adhered to the surface of fine coal is

preferably

$$0.01 \leqq r \leqq 5 \ \mu\text{m},$$

still preferably

$$0.1 \leqq r \leqq 5\ \mu m, \text{ and}$$

particularly preferably

$$0.1 \leqq r \leqq 4\ \mu m.$$

The relationship between the volume average particle diameter (r) and the amount (α) added for the solid compound according to the present invention is shown in Fig. 1.

The solid compound is preferably a water-insoluble solid compound.

The term "water-insoluble solid compound" used herein refers to a solid compound having a solubility (the mass (g) of the solid compound contained in 100 g of a saturated solution) of the solid compound at 25°C of not more than 1, preferably a solid compound having a solubility of the solid compound at 25°C of not more than 0.1, particularly preferably a solid compound having a solubility of the solid compound at 25°C of not more than 0.01.

Upon absorption of moisture by the solid compound adhered to the surface of fine coal, the presence of water causes agglomeration of fine coal, resulting in deteriorated transportability. Therefore, the solubility is preferably not more than 1 from the viewpoint of inhibiting the absorption of moisture by the solid compound.

The fine coal contemplated in the present invention is dried fine coal obtained from a raw coal having an average HGI of not less than 30. The term "dried" used herein means that the moisture content is not more than 10% by weight as measured by "the measuring method for drying loss in air" specified in JIS M 8812-1984. Fine coal having a high moisture content is unsuitable for blowing into a metallurgical furnace or as a fuel for a combustion furnace.

Fine coal obtained form a raw coal having an average HGI of not less than 30 has a poor transportability. The use of the transportability improver according to the present invention has realized smooth transportaion of such fine coal. Further, the present invention is effective for fine coal obtained from a raw coal having an average HGI of not less than 50 which has hitherto been regarded as difficult to transport pneumatically by the current technique.

The "HGI" stands for "Hardgrove Grinding Index" which is a grinding resistance index of coal as defined by ASTM D 409.

The volume average particle diameter is measured with ELZONE Particle Counter 180 XY [manufactured by Particle Data Inc. (USA); measurement range 0.2 to 1200 μm] or Submicron Sizer [manufactured by Brookhaven Instruments(USA); measurement range 0.005 to 5 μm] according to the applicable particle diameter range.

The transportability improver of the present invention may be added before the pulverization of raw coal in order to adhere the improver at the time of pulverization, or alternatively may be added after the pulverization. For both the cases, the same effect can be attained.

Examples of the solid compounds usable as the transportability improver according to the present invention will be listed below.

(1) Metal oxides

Examples thereof include iron oxide, titanium oxide, aluminum oxide, copper oxide, zinc oxide, potassium oxide, calcium oxide, tin oxide, sodium oxide, nickel oxide, magnesium oxide, zirconium oxide, silicon oxide, and composite oxides thereof. The silicon oxide is particularly preferably silicon dioxide. The silicon dioxide may be used either as fine powder or as a colloidal solution such as colloidal silica. Both the cases can offer the effect of the present invention.

(2) Phosphates

Examples thereof include potassium phosphate, calcium phosphate, disodium hydrogenphosphate, iron phosphate, zinc phosphate, magnesium phosphate, potassium dihydrogenphosphate, sodium dihydrogenphosphate, and double salts thereof.

(3) Carbonates

Examples thereof include potassium carbonate, calcium carbonate, potassium hydrogencarbonate, sodium hydrogencarbonate, iron carbonate, copper carbonate, sodium carbonate, lead carbonate, nickel carbonate, magnesium carbonate, manganese carbonate, and double salts thereof.

(4) Silicates

Examples thereof include aluminum silicate, iron silicate, calcium silicate, magnesium silicate, potassium silicate, sodium silicate, and double salts thereof.

(5) Nitrides

Examples thereof include aluminum nitride, silicon nitride, boron nitride, and magnesium nitride.

(6) Silicides

Examples thereof include magnesium silicide, calcium silicide, iron silicide, and potassium silicide.

(7) Carbides

Examples thereof include aluminum carbide, calcium carbide, silicon carbide, iron carbide, and sodium carbide.

(8) Clay minerals

Clay minerals are minerals which are a main constituent of clay. Examples thereof include sericite, talc, mica, bentonite, kaolinite, halloysite, montmorillonite, illite, vermiculite, chlorite, and heat treatment products thereof. Fumes and the like derived from clay minerals in the coal are also preferred.

(9) Dust

The term "dust" used herein refers to a solid compound collected with an electric precipitator or the like from "smoke and soot" specified in the Air Pollution Control Law. Specific examples of the dust include dust collected from smoke and soot discharged from a fine coal-fired boiler, a heavy oil-fired boiler, a converter and the like.

Solid compounds having a solubility in water at 25°C of not more than 1 include the above solid compounds except for the following compounds:

aluminum oxide, potassium phosphate, disodium hydrogenphosphate, potassium dihydrogenphosphate, sodium dihydrogenphosphate, potassium carbonate, potassium hydrogencarbonate, sodium hydrogencarbonate, sodium carbonate, nickel carbonate, magnesium carbonate, sodium silicate, and sodium carbide.

Among the above solid compounds, the metal oxides (1) and dust (9) are preferred from the viewpoint of the volume average particle diameter and the cost and the metal oxides (1) are still preferred.

The inorganic solid compounds listed in the above categories (1) to (9), when used in combination with various water-soluble polar organic compounds exemplified by ionic surfactants or fatty acid salts, can also offer favorable effects.

The fluidity index and the pressure drop in the piping test which will be described in detail in the following Examples are used as the transportability index of fine coal. The fluidity index can simulate the discharge characteristics in a hopper or the like, while the pressure drop can simulates the flow characteristics in piping during pneumatic transportaion. An improvement of at least three points in fluidity index and a 3 mmH_2 O/m or more reduction in pressure drop are a measure of the inprovement in transportability. For fine coal having very poor transportability, the fluidity index and the pressure drop should be brought to not less than 40 and not more than 16 mmH_2 O/m, respectively.

Bringing the fluidity index and the pressure drop to not less than 42 and not more than 13 mmH_2 O/m, respectively, is still preferred because the transportability exceeds that of the fine coal having the best transportability in current use.

Examples of the metallurgical furnace and the combustion furnace contemplated in the present invention include furnaces using fine coal as a fuel and/or a reducing agent, such as a blast furnace, a cupola, a rotary kiln, a melt reduction furnace, a cold iron source melting furnace, and a boiler, and dry distillation apparatuses using fine coal, for example, a fluidized bed dry distillation furnace and a gas reforming furnace.

According to the present invention, the transportability of fine coal obtained from a raw coal having an average HGI of not less than 30 can be improved, permitting a large amount of the fine coal to be transported. Further, the addition of the transportability improver of the present invention to coal having a poor transportability can improve the same, here again permitting a large amount of the fine coal to be transported. This can expand the kinds of coal usable for blowing fine coal.

At the same time, since the treatment of the fine coal to be blown through a blowing port with the transportability improver of the present invention can realize a good fluidity of fine coal, the treated fine coal does not cause bridging in a hopper and, in addition, can greatly reduce a variation in the amount of the fine coal taken off from the hopper with the elapse of time and a deviation of the amount of dispensing.

[Brief Description of the Drawings]

Fig. 1 is a diagram showing the relationship between the volume average particle diameter of a solid compound and the amount of the solid compound added;
Fig. 2 is a schematic diagram showing an apparatus for measuring transport characteristic in piping;
Fig. 3 is a schematic diagram showing an actual fine coal blowing device of a blast furnace used in Example 46;
Fig. 4 is a chart showing the results of measurement of the transporting time in Example 46;
Fig. 5 is a chart showing the results of measurement of the pressure drop in piping in Example 46;
Fig. 6 is a chart showing the results of measurement of the pressure drop in piping in Example 46;
Fig. 7 is a schematic diagram showing a fine coal-fired boiler used in Example 47; and
Fig. 8 is a chart showing the results of measurement of the pressure drop in piping in Example 47.

[Description of Reference Numerals]

1: fine coal, 2: table feeder, 3: flowmeter, 4: horizontal pipe, 5: cyclone, 6: blast furnace, 19: boiler combustion chamber, and 20: burner.

[Examples]

The present invention will be described with reference to the following Examples, though it is not limited to these Examples only.

Examples 1 to 51 and Comparative Examples 1 to 20

[1] Pulverization of raw coal and preparation of fine coal for evaluation

The pulverization of raw coal and the addition of a fluidity improver were conduced according to the following procedure.

(i) Raw coal and a fluidity improver specified in Tables 1 to 6 are put into a pulverizer [a small-size pulverizer SCM-40A (manufactured by Ishizaki Denki Seisakusho)], fine and mixed together. In this case, the pulverization time is regulated so that a required particle diameter is provided. Further, at that time, the fluidity improver is added in an amount based on the fine coal as specified in the Tables while pulverizing the raw coal.

(ii) The mixture is dried at 105°C for one hour to regulate the moisture content of the fine coal to 0.5 to 1.0%.

(iii) The fine coal is then sieved (106 μm sieve) to prepare a fine coal having a particle diameter of not more than 106 μm. The fine coal samples were regulated to the same moisture content (0.5 to 1.0%) and the same volume average particle diameter (75 μm).

(iv) The volume average particle diameter is defined by the following equation:

$$d = \frac{\Sigma n_i d_i^{\ 4}}{\Sigma n_i d_i^{\ 3}}$$

wherein

d_i: particle diameter, and
n_i: number of particles having particle diameter d_i.

[2] Transportability improver for fine coal

Transportability improvers used in the Examples are summarized below.

- Silicon dioxide: special grade reagent
- Colloidal silica: RM-5, manufactured by Mizusawa Industrial Chemicals Ltd.
- Aluminum oxide: special grade reagent
- Titanium oxide: special grade reagent
- Zirconium oxide: special grade reagent
- Calcium phosphate: special grade reagent
- Calcium carbonate: special grade reagent
- Magnesium carbonate: special grade reagent
- Aluminum silicate: special grade reagent
- Silicon carbide: special grade reagent
- Silicon nitride: special grade reagent
- Sericite
- Talc
- Mica
- Bentonite
- Dust (silica fume) from fine coal-fired boiler:
  the dust collected from smoke and soot discharged from a fine coal-fired boiler with an electric precipitator equipped with a multi-cyclone in the front stage thereof, and having a volume average particle diameter of 1.0 μm.
- Dust from heavy oil-fired boiler:
  the dust collected from smoke and soot discharged from a heavy oil-fired boiler with an electric precipitator equipped with a multi-cyclone in the front stage thereof, and having a volume average particle diameter of 0.12 μm.
- Dust from converter:
  the dust collected from smoke and soot discharged from a converter with an electric precipitator equipped with a multi-cyclone in the front stage thereof, and having a volume average particle diameter of 0.21 μm.

The above compounds except for colloidal silica were regulated to have a predetermined particle diameter by gravitational force, inertial force, centrifugal force or filtration, or with an electric precipitator.

[3] Evaluation of fine coal

The fine coal thus obtained was examined for the effect of additives on the fluidity index and transport characteristic in piping thereof by the following methods.

⟨Measurement of fluidity index⟩

The fluidity index is an index for evaluating the fluidity of powder which is determined by expressing four factors of powder (angle of repose, degree of compaction, spatula angle, degree of agglomeration) in terms of respective indexes and summing up the indexes. The measurement method and the index for each factor are described in detail in "Funtai Kogaku Binran" (edited by the Society of Powder Technology and published by Nikkan Kogyo Shimbun Ltd.), pp. 151-152 (1987). The measurement methods for respective factors will now be described.

1. Angle of repose: The powder is passed through a standard sieve (25 mesh) and further put through a funnel on a disk having a diameter of 8 mm, and the angle of inclination of the resultant deposit is measured.
2. Degree of compaction: A cylindrical container (capacity: 100 cm^3) for packing powder is used to measure the bulk density of powder in a loosely packed state, ρ_5 (g/cm^3), and the density of powder in a densely packed state, ρ_c (g/cm^3), after tapping a predetermined number of times (180 times), and the degree of compaction, ψ (%), is determined by the following equation:

$$\psi = (\rho_c - \rho_s) \times 100/\rho_c \ (\%)$$

3. Spatula angle: A spatula having a given width (22 mm) is inserted into a powder deposit and raised to measure the angle of inclination of the powder put on the spatula. A slight impact is then applied to the spatula to measure, the angle of inclination of the powder, and the average of the two values is taken as the spatula angle.
4. Degree of agglomeration: Three sieves different from one another in opening (60 meshes for the upper sieve,

100 meshes for the middle sieve, and 200 meshes for the lower sieve) are put on top of the another and 2 g of the powder is put on the uppermost sieve. The sieves are simultaneously vibrated and, after the stopping of the vibration, the amount of the powder left on each of the sieves is measured, followed by the following calculation:

$$(\text{amount of powder on upper sieve}/2\text{g}) \times 100,$$

$$(\text{amount of powder on middle sieve}/2\ \text{g}) \times 100 \times 3/5, \text{ and}$$

$$(\text{amount of powder on lower sieve}/2\text{g}) \times 100 \times 1/5$$

to determine the degree of agglomeration by summing up the three calculated values.

In the case of the fine coals used in the present invention, there is no difference in the amount of the fine coal left on each sieve, so that the comparison of the degree of agglomeration alone is meaningless. For this reason, in the present invention, the fluidity index was evaluated in terms of the total point of the three factors, i.e., angle of repose, degree of compaction, and spatula angle.

〈Measurement of transport characteristic in piping〉

The transport characteristic in piping of fine coal was evaluated by measuring the pressure drop using an apparatus shown in Fig. 2 according to the method described in detail in "CAMP-ISIJ," vol. 6, p. 91 (1993). In Fig. 2, numeral 1 designates fine coal, numeral 2 a table feeder, numeral 3 a flowmeter, numeral 4 a horizontal tube having a diameter of 12.7 mm, and numeral 5 a cyclone. In this apparatus, the fine coal 7 discharged from the powder feeder 8 is pneumatically transported with the aid of a transporting gas, and the pressure drop between pressure measuring holes (P_1, P_2) is measured. Experimental conditions are as follows.

Fine coal feed rate: 0.8 kg/min
Transporting gas: nitrogen (N_2)
Flow rate of transporting gas: 4 Nm^3/hr (67 ℓ/min)
Transporting time: 6 min

Evaluation was performed for the following items.

1. Pressure drop

In the pressure gauge P_1, P_2, sampling is performed at 500 Hz. The pressure drop is given in terms of the overall average of P_1-P_2 during the transporting time (6 min).

$$\Delta P = \frac{\sum_{n=1}^{N} (P_{1n} - P_{2n})}{N}$$

For Examples 1 to 51 and Comparative Examples 1 to 20, the fine coal, the transportability improver, the fluidity, and the pressure drop are summarized in Tables 1 to 6. For the fluidity index and the pressure drop, the degree of increase or decrease relative to the results obtained in Comparative Example 4, wherein no transportability improver has been added, is also given in the Tables.

It is apparent that, among the fine coal samples containing silicon dioxide added thereto of Comparative Examples 5 to 20, Examples 11 to 21 and 46 to 51, all the samples wherein the amount of silicon dioxide added falls within $10^{-1.42} \cdot r^{0.59} \leqq \alpha \leqq 10$ have a fluidity index of not less than 40 and a pressure drop of not more than 16 mmH_2O/m (Examples 11 to 21 and 46 to 51). Further, it is apparent that the fine coal samples wherein the amount of silicon dioxide added falls within $10^{-1.10} \cdot r^{0.59} \leqq \alpha \leqq 10$ (Examples 2 to 8, 10 to 15, 18 to 21, and 46 to 51) have a fluidity index of not less than 42 and a pressure drop of less than 13 mmH_2O/m, demonstrating that the addition of silicon dioxide in this amount range is more effective. Furthermore, it is apparent that, for the fine coal samples wherein $\alpha > 10^{0.60} \cdot r^{0.59}$ (Examples 6 to 8, 14, 15, and 51), the effect of improving the transportability is not increased.

Furthermore, it is apparent that regarding the volume average particle diameter of the transportability improver, a further improvement in the effect of improving the transportability is attained when the volume average particle diameter is 4 μm (Examples 16 to 21 and 46 to 51).

Table 1

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH_2O/m)		Clogging in actual device
	Feed coal		Particle diameter (μm)	Compound	Solubility	Amt. added (vol%)	Particle diameter (μm)	Angle of repose	Degree of compaction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop	
	Kind	HGI													
Comp. Ex. 1	a Coal	42	81	Free	-			16	9	16	41	-	13.0	-	Not clogged
Comp. Ex. 2	b Coal	48	72	Free	-			15	9	16	40	-	16.0	-	Not clogged
Comp. Ex. 3	c Coal	67	74	Free	-			12	8	15	35	-	24.0	-	Clogged
Comp. Ex. 4	d Coal	96	75	Free	-			12	7	15	34	-	29.0	-	Clogged
Comp. Ex. 5	d Coal	96	75	Silicon dioxide	0.01 or below	0.005	0.10	13	7	15	35	1	27.3	1.7	
Ex. 1	d Coal	96	75	Silicon dioxide	do.	0.01	0.10	15	9	16	40	6	15.9	13.1	
Ex. 2	d Coal	96	75	Silicon dioxide	do.	0.05	0.10	16	9	17	42	8	12.1	16.9	
Ex. 3	d Coal	96	75	Silicon dioxide	do.	0.1	0.10	17	10	18	45	11	10.3	18.7	
Ex. 4	d Coal	96	75	Silicon dioxide	do.	0.5	0.10	19	11	19	49	15	9.9	19.1	
Ex. 5	d Coal	96	75	Silicon dioxide	do.	1	0.10	19	12	20	51	17	9.0	20.0	
Ex. 6	d Coal	96	75	Silicon dioxide	do.	3	0.10	20	13	20	53	19	8.9	20.1	
Ex. 7	d Coal	96	75	Silicon dioxide	do.	5	0.10	20	14	21	55	21	8.5	20.5	
Ex. 8	d Coal	96	75	Silicon dioxide	do.	10	0.10	20	14	21	55	21	8.5	20.5	

Note) The particle diameter of the transportability improver is expressed in terms of volume average particle diameter (the same shall apply hereinafter).

Table 2

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH_2O/m)	
	Feed coal		Particle diameter (µm)	Compound	Solubility	Amt. added (vol%)	Particle diameter (µm)	Angle of repose	Degree of compaction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop
	Kind	HGI												
Comp. Ex. 6	d Coal	96	75	Silicon dioxide	0.01 or below	0.005	1.0	13	7	15	35	1	28.5	0.5
Comp. Ex. 7	d Coal	96	75	Silicon dioxide	do.	0.01	1.0	13	8	15	36	2	27.2	1.8
Ex. 9	d Coal	96	75	Silicon dioxide	do.	0.05	1.0	15	9	16	40	6	16.0	13.0
Ex. 10	d Coal	96	75	Silicon dioxide	do.	0.1	1.0	16	9	17	42	8	12.0	17.0
Ex. 11	d Coal	96	75	Silicon dioxide	do.	0.5	1.0	17	10	18	45	11	11.2	17.8
Ex. 12	d Coal	96	75	Silicon dioxide	do.	1	1.0	19	11	19	49	15	10.3	18.7
Ex. 13	d Coal	96	75	Silicon dioxide	do.	3	1.0	19	12	20	51	17	9.0	20.0
Ex. 14	d Coal	96	75	Silicon dioxide	do.	5	1.0	20	13	20	53	19	8.0	21.0
Ex. 15	d Coal	96	75	Silicon dioxide	do.	10	1.0	20	13	20	53	19	8.0	21.0
Comp. Ex. 8	d Coal	96	75	Silicon dioxide	do.	0.005	5.0	12	7	15	34	0	28.8	0.2
Comp. Ex. 9	d Coal	96	75	Silicon dioxide	do.	0.01	5.0	13	7	15	35	1	27.2	1.8
Comp. Ex. 10	d Coal	96	75	Silicon dioxide	do.	0.05	5.0	13	8	15	36	2	27.0	2.0
Ex. 16	d Coal	96	75	Silicon dioxide	do.	0.1	5.0	15	9	17	41	7	16.0	13.0

Table 3

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH$_2$O/m)	
	Feed coal		Particle diameter (μm)	Compound	Solubility	Amt. added (vol%)	Particle diameter (μm)	Angle of repose	Degree of compaction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop
	Kind	HGI												
Ex. 17	d Coal	96	75	Silicon dioxide	0.01 or below	0.5	5.0	16	9	17	42	8	15.0	14.0
Ex. 18	d Coal	96	75	Silicon dioxide	do.	1	5.0	17	10	18	45	11	12.0	17.0
Ex. 19	d Coal	96	75	Silicon dioxide	do.	3	5.0	19	11	19	49	15	10.2	18.8
Ex. 20	d Coal	96	75	Silicon dioxide	do.	5	5.0	19	12	20	51	17	9.5	19.5
Ex. 21	d Coal	96	75	Silicon dioxide	do.	10	5.0	20	13	20	53	19	8.8	20.2
Comp. Ex. 11	d Coal	96	75	Silicon dioxide	do.	0.1	10	12	7	15	34	0	28.8	0.2
Comp. Ex. 12	d Coal	96	75	Silicon dioxide	do.	0.5	10	12	7	15	34	0	28.6	0.4
Comp. Ex. 13	d Coal	96	75	Silicon dioxide	do.	1	10	13	7	15	35	1	28.5	0.5
Comp. Ex. 14	d Coal	96	75	Silicon dioxide	do.	3	10	13	7	15	35	1	28.3	0.7
Comp. Ex. 15	d Coal	96	75	Silicon dioxide	do.	5	10	13	8	15	36	2	28.1	0.9
Comp. Ex. 16	d Coal	96	75	Silicon dioxide	do.	10	10	13	8	15	36	2	27.8	1.2
Comp. Ex. 17	d Coal	96	75	Colloidal silica	do.	0.005	0.10	13	7	15	35	1	27.2	1.8
Ex. 22	d Coal	96	75	Colloidal silica	do.	0.01	0.10	15	9	16	40	6	16.0	13.0

Table 4

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH$_2$O/m)	
	Feed coal		Particle diameter (μm)	Compound	Solu-bility	Amt. added (vol%)	Particle diameter (μm)	Angle of repose	Degree of com-paction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop
	Kind	HGI												
Ex. 23	d Coal	96	75	Colloidal silica	0.01 or below	0.05	0.10	16	9	17	42	8	12.0	17.0
Ex. 24	d Coal	96	75	Colloidal silica	do.	0.1	0.10	17	10	18	45	11	10.2	18.8
Ex. 25	d Coal	96	75	Colloidal silica	do.	0.5	0.10	19	11	19	49	15	9.8	19.2
Ex. 26	d Coal	96	75	Colloidal silica	do.	1	0.10	19	12	20	51	17	9.0	20.0
Ex. 27	d Coal	96	75	Colloidal silica	do.	3	0.10	20	13	20	53	19	8.8	20.2
Ex. 28	d Coal	96	75	Colloidal silica	do.	5	0.10	20	14	21	55	21	8.5	20.5
Ex. 29	d Coal	96	75	Colloidal silica	do.	10	0.10	20	14	21	55	21	8.5	20.5
Ex. 30	d Coal	96	75	Aluminum oxide	do.	0.1	1.0	16	9	17	42	8	11.9	17.1
Ex. 31	d Coal	96	75	Titanium carbonate	do.	0.1	1.0	16	9	17	42	8	11.8	17.2
Ex. 32	d Coal	96	75	Zirconium oxide	do.	0.1	1.0	16	9	17	42	8	11.5	17.5
Ex. 33	d Coal	96	75	Calcium phosphate	do.	0.1	1.0	16	9	17	42	8	11.6	17.4
Ex. 34	d Coal	96	75	Calcium carbonate	do.	0.1	1.0	16	9	17	42	8	11.9	17.1

Table 5

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH$_2$O/m)	
	Feed coal		Particle diameter (µm)	Compound	Solu-bility	Amt. added (vol%)	Particle diameter (µm)	Angle of repose	Degree of com-paction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop
	Kind	HGI												
Ex. 35	d Coal	96	75	Magnesium carbonate	24	0.1	1.0	16	9	17	42	8	11.9	17.1
Ex. 36	d Coal	96	75	Aluminum silicate	0.01 or below	0.1	1.0	16	9	17	42	8	11.3	17.7
Ex. 37	d Coal	96	75	Silicon carbide	do.	0.1	1.0	16	9	17	42	8	11.9	17.1
Ex. 38	d Coal	96	75	Silicon nitride	do.	0.1	1.0	16	9	17	42	8	11.2	17.8
Ex. 39	d Coal	96	75	Sericite	do.	0.1	1.0	16	9	17	42	8	11.4	17.6
Ex. 40	d Coal	96	75	Talc	do.	0.1	1.0	16	9	17	42	8	11.5	17.5
Ex. 41	d Coal	96	75	Mica	do.	0.1	1.0	16	9	17	42	8	11.8	17.2
Ex. 42	d Coal	96	75	Bentonite	do.	0.1	1.0	16	9	17	42	8	11.9	17.1
Ex. 43	d Coal	96	75	Dust from pulverized coal-fired boiler	do.	0.1	1.0	17	10	18	45	11	10.2	18.8
Ex. 44	d Coal	96	75	Dust from heavy oil-fired boiler	do.	0.1	0.12	17	10	18	45	11	10.3	18.7
Ex. 45	d Coal	96	75	Dust from converter	do.	0.1	0.21	17	10	18	45	11	11.3	17.7

Table 6

	Fine coal			Transportability improver				Fluidity					Pressure drop (mmH$_2$O/m)	
	Feed coal		Particle diameter (μm)	Compound	Solubility	Amt. added (vol%)	Particle diameter (μm)	Angle of repose	Degree of compaction	Spatula angle	Fludity index	Increase in fluidity index		Decrease in pressure drop
	Kind	HGI												
Comp. Ex. 18	d Coal	96	75	Silicon dioxide	0.01 or below	0.005	4.0	13	7	15	35	1	28.6	0.4
Comp. Ex. 19	d Coal	96	75	Silicon dioxide	do.	0.01	4.0	13	8	15	36	2	27.2	1.8
Comp. Ex. 20	d Coal	96	75	Silicon dioxide	do.	0.05	4.0	14	9	15	38	4	17.0	12.0
Ex. 46	d Coal	96	75	Silicon dioxide	do.	0.1	4.0	16	9	17	42	8	12.0	17.0
Ex. 47	d Coal	96	75	Silicon dioxide	do.	0.5	4.0	17	10	17	44	10	11.5	17.5
Ex. 48	d Coal	96	75	Silicon dioxide	do.	1	4.0	18	11	18	47	13	11.0	18.0
Ex. 49	d Coal	96	75	Silicon dioxide	do.	3	4.0	19	12	19	50	16	10.0	19.0
Ex. 50	d Coal	96	75	Silicon dioxide	do.	5	4.0	19	12	20	51	17	9.0	20.0
Ex. 51	d Coal	96	75	Silicon dioxide	do.	10	4.0	20	13	20	53	19	8.5	20.5

Example 52

An example of application to a fine coal blowing device in a blast furnace will be described.

Conditions

Fine coal blowing rate: 40 t/hr
Transportability improver: silicon dioxide (particles having a volume average particle diameter of not more than 5 μm account for 80%)
Amount added: 0 or 1.0 vol %
Fine coal:

Volume average particle diameter 74 μm
Moisture content 1.5%
Average HGI of raw coal 45, 55, 70

The fine coal blowing device in a blast furnace used in this example is schematically shown in Fig. 3. In Fig. 3, numeral 6 designates a blast furnace, numeral 7 a blowing port, numeral 8 a blowing piping, numeral 9 a dispensing tank, numeral 10 a valve, numeral 11 an equalizing tank, numeral 12 a valve, numeral 13 a fine coal storage tank, numeral 14 a coal pulverizer, numeral 15 an additive spraying nozzle, numeral 16 a belt transporting for coal, numeral 17 a coal receiving hopper, and numeral 18 an air/nitrogen compressor.

Coal is introduced into the receiving hopper 17 and fed through the transporting 16 into the pulverizer 14, during which time a transportability improver is added by spraying through the nozzle 15. The coal is fine by means of the pulverizer 14 to prepare a fine coal having the above particle diameter, which is then sent to the storage tank 13. At the outset, the valve 12 is opened in such a state that the internal pressure of the equalizing tank 11 is equal to the atmospheric pressure, permitting a predetermined amount of the fine coal to be fed from the storage tank 13 into the equalizing tank 11. Next, the internal pressure of the equalizing tank 11 is increased to become equal to the internal pressure of the dispensing tank 9. The valve 10 is opened in such a state that the internal pressure of the tank 9 is equal to that of the tank 11, so that the fine coal is dropped by gravitational force. The fine coal is pneumatically transported from the dispensing tank 9 into the blowing port 7 through the blowing pipe 8 by blowing air fed by means of the compressor 18 and blown into the blast furnace 6 through the blowing port 7.

⟨Effect of adding transportability improver⟩

In transporting the fine coal under the above conditions, a difference in tank-to-tank transporting time (time taken for transporting the fine coal from the tank 11 to the tank 9) and pressure drop in piping (the pressure drop in the blowing piping 14, that is, a difference in pressure between the tank 9 and the blast furnace 6) between the presence of the transportability improver and the absence of the transportability improver was evaluated. The results are shown in Figs. 4, 5 and 6.

In Figs. 4 and 5, (a) represents the results in the case where no transportability improver has been added, and (b) represents the results in the case where the transportability improver has been added. In Fig. 6, A represents the upper limit for the equipment.

As can be seen from Figs. 4 and 5, the use of a raw coal having an average HGI of 45 could reduce the pressure drop in piping and the tank-to-tank transporting time, enabling the amount of the fine coal blown to be increased in the same apparatus. Further, the use of a simpler apparatus has become sufficed for offering the same blowing capability. For both Figs. 4 and 5, the results are relatively evaluated by presuming the result for the absence of the transportability improver to be 1.

Fig. 6 shows how the pressure drop in piping changes when the average HGI of the raw coal is changed to 45, 55, and 70. From the drawing, it is apparent that the addition of the transportability improver could reduce the pressure drop in the piping to a value lower than the upper limit value even when high HIG coal was used. This can expand the kinds of usable coals, making it possible to use inexpensive coal. For Fig. 6, the results are relatively evaluated by presuming the result for the absence of the transportability improver in the fine coal having an average HGI of 45 to be 1.

Example 53

An example of application to a fine coal-fired boiler will be described.

Transportability improver: silicon dioxide (particles having a volume average particle diameter of not more than 5

μm account for 80%)
Amount added: 0 or 1.0 vol %
Fine coal:

Volume average particle diameter 74 μm
Moisture content 1.5%
Average HGI of raw coal 45, 55, 65, 75

The fine coal-fired boiler used in this Example is schematically shown in Fig. 7. In Fig. 7, numeral 19 designates a boiler combustion chamber, numeral 20 a burner, numeral 21 a blowing piping, numeral 22 a fine coal storage tank, numeral 23 a coal pulverizer, numeral 24 an additive spraying nozzle, numeral 25 a belt transporting for coal, numeral 26 a coal receiving hopper, and numeral 27 an air/nitrogen compressor.

Coal is introduced into the receiving hopper 26 and fed through the transporting 25 into the pulverizer 23, during which time a transportability improver is added by spraying through the nozzle 24. The coal is fine by means of the pulverizer 23 to prepare a fine coal having the above particle diameter, which is then sent to the storage tank 22. The fine coal is then pneumatically transported by means of air blown by means of the compressor 27, fed into the burner 20, and burned.

〈Effect of adding transportability improver〉

In transporting the fine coal under the above conditions, a difference in pressure drop in piping (the pressure drop in the blowing piping 27, that is, a difference in pressure between the tank 22 and the burner 20) between the presence of the transportability improver and the absence of the transportability improver was evaluated. The results are shown in Fig. 8. In Fig. 8, A represents the upper limit for the equipment and x represents that clogging in piping occurred. For Fig. 8, the results are relatively evaluated by presuming the result for the absence of the transportability improver in the fine coal obtained from a raw coal having an average HGI of 45 to be 1.

When the average HGI of the raw coal was changed to 45, 55, 65, and 75, the pressure drop in the piping was lower than the upper limit of the pressure drop for the equipment even in the case of high HGI coal, permitting the kinds of usable coal to be expanded.

Claims

1. A method for improving the transportability of dried fine coal obtained from a raw coal having an average HGI of not less than 30, characterized by adding a solid compound having a volume average particle diameter of not more than 5 μm in an amount shown in the following formula α (volume %) to the above shown fine coal and adhering it onto the surface of said fine coal.

$$k_1 \cdot r^{0.59} \leqq \alpha \leqq 10 \text{ (vol \%)}$$

[wherein $k_1 = 10^{-1.42}$ and r represents the volume average particle diameter (μm) of the solid compound added.]

2. A method according to claim 1, wherein the solid compound is insoluble in water.

3. A method according to claim 1, wherein an average HGI of the raw coal for fine coal is not less than 50.

4. A method according to claim 1 wherein the solid compound is one or two or more compounds selected among metal oxides, phosphates, carbonates, silicates, nitrides, silicide, carbides, dust and clay minerals.

5. A method according to claim 1 wherein the solid compound is a fine powder of silicon dioxide.

6. A method according to claim 1 wherein the solid compound has a volume average particle diameter of 0.01 to 5 μm.

7. A method according to claim 1 wherein the solubility of the solid compound is not more than 1 in water at 25 °C.

8. A method according to claim 1 wherein the solid compound is a metal oxide.

9. A method according to claim 1 wherein the solid compound is a dust.

10. A transportability improver of fine coal used in the method described in claim 1 which is one or two or more solid compounds having a volume average particle diameter of not more than 5 μm, selected from among metal oxides, phosphates, carbonates, silicates, nitrides, silicides, carbides, dust and clay minerals.

11. A transportability improver according to claim 10, wherein the solid compound is insoluble in water.

12. A transportability improver according to claim 10, wherein the solid compound is a fine powder of silicon dioxide.

13. A fine coal in which the solid compound having a volume-average particle diameter of not more than 5 μm in an amount shown in the formula α defined in claim 1 (volume %) is adhered to the surface of dried fine coal obtained from a raw coal having an average HGI of not less than 30.

14. A fine coal according to claim 13 wherein the solid compound is insoluble in water.

15. A fine coal according to claim 13 wherein an average HGI of the raw coal is not less than 50.

16. A fine coal according to claim 13 wherein the solid compound is one or two or more compounds selected among metal oxides, phosphates, carbonates, silicates, nitrides, silicides, carbides, dust and clay minerals.

17. A fine coal according to claim 13 wherein the solid compound is a fine powder of silicon dioxide.

18. A method for operating a metallurgical furnace or a combustion furnace characterized by blowing in through a blowing port the fine coal in which a solid compound having a volume average particle diameter of not more than 5 μm is adhered in an amount of α shown by the formula described in Claim 1 (volume %) onto the surface of dried fine coal obtained from a raw coal having an average HGI of not less than 30.

19. A method according to claim 18 wherein the solid compound is insoluble in water.

20. A method according to claim 18 wherein an average HGI of the raw coal for the fine coal is not less than 50.

21. A method according to claim 18 wherein the solid compound is one or two or more selected among metal oxides, phosphates, carbonates, silicates, nitrides, silicides, carbides, dust and clay minerals.

22. A method according to claim 18 wherein the solid compound has a volume-average particle diameter of 0.01 to 5 μm.

23. A method according to claim 18 wherein the solubility of the solid compound in water at 25 °C is not more than 1.

24. A method according to claim 18 wherein the solid compound is a metal oxide.

25. A method according to claim 18 wherein the solid compound is a dust.

26. A method according to claim 18 wherein the solid compound is a fine powder of silicon dioxide.

Figure 1

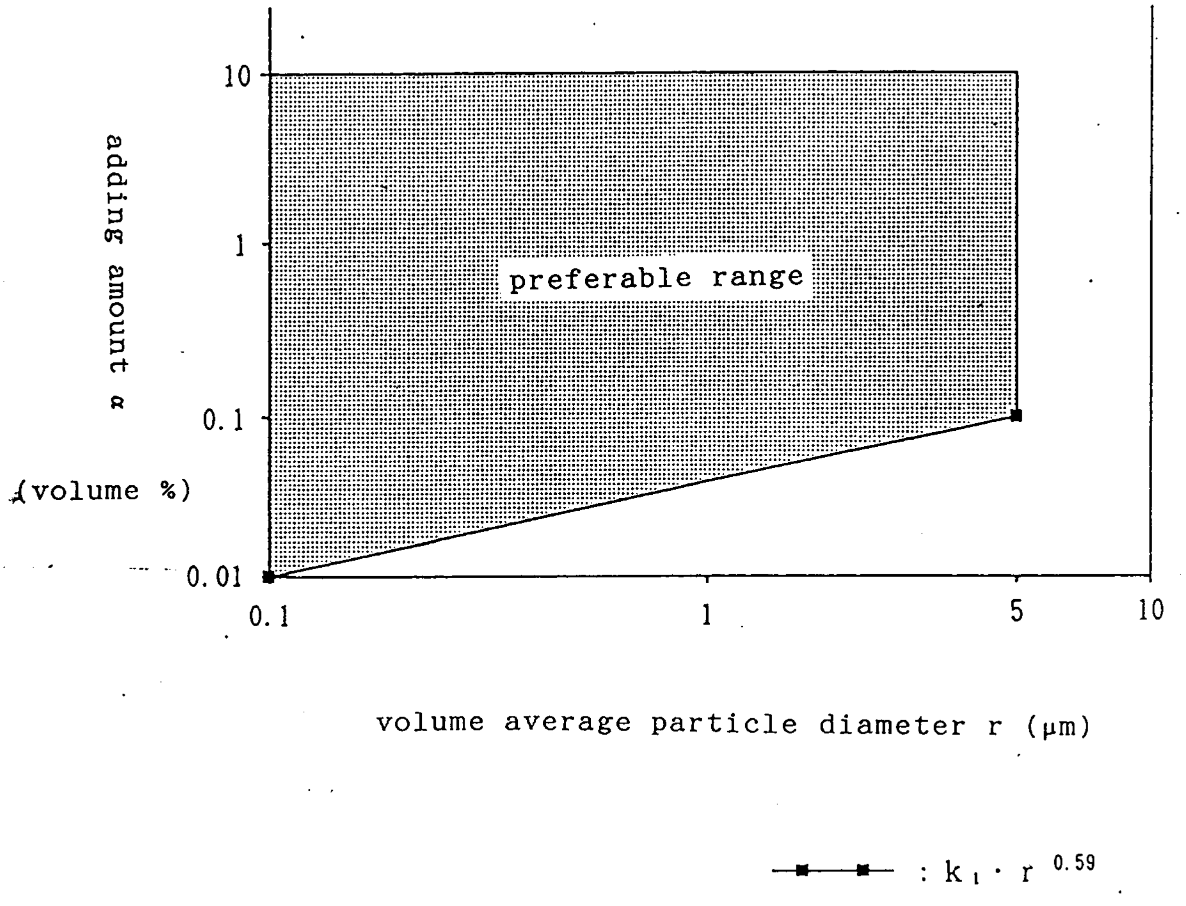

10
1
0.1
0.01
adding amount α
(volume %)
preferable range
0.1
1
5
10
volume average particle diameter r (μm)
: $k_1 \cdot r^{0.59}$

Figure 2

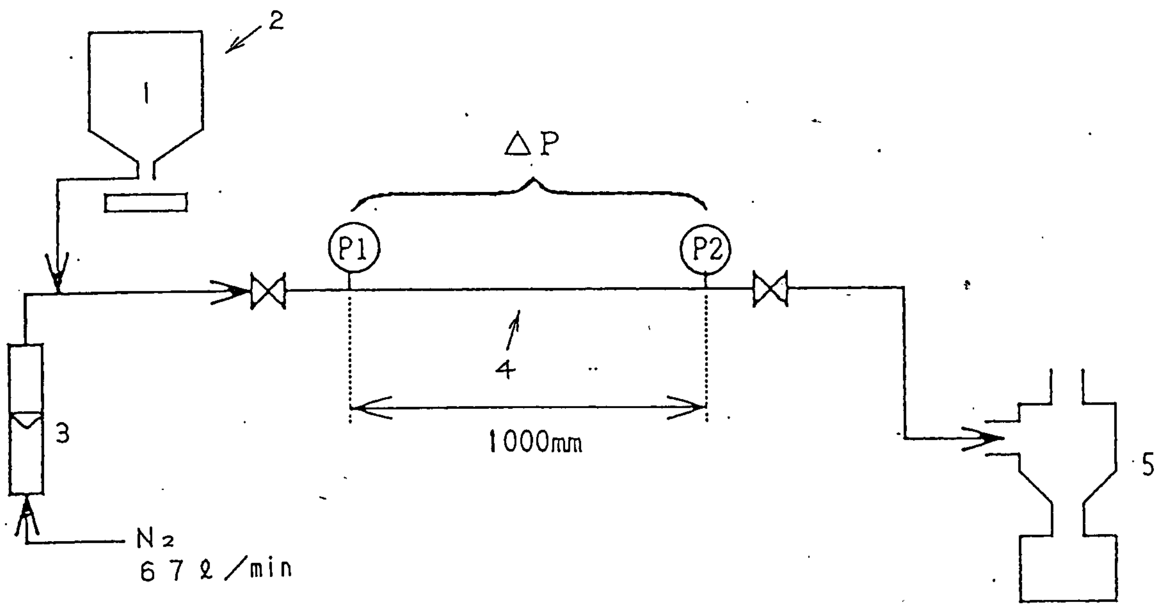


Figure 3

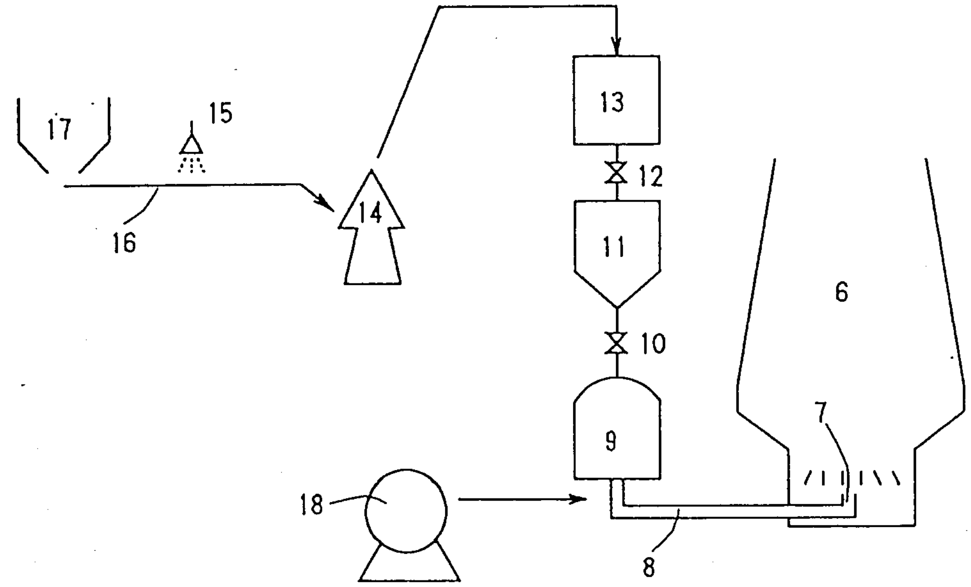


Figure 4

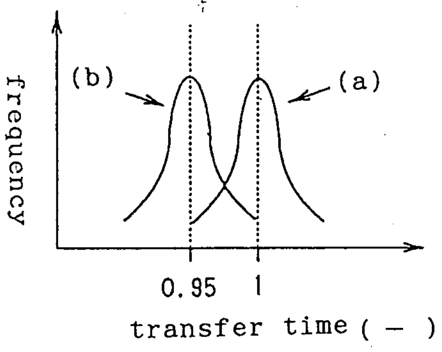


Figure 5

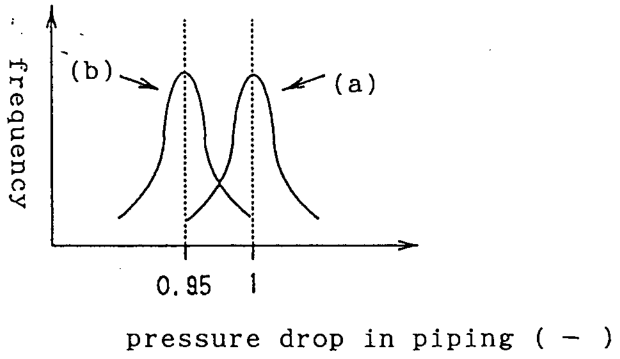


Figure 6

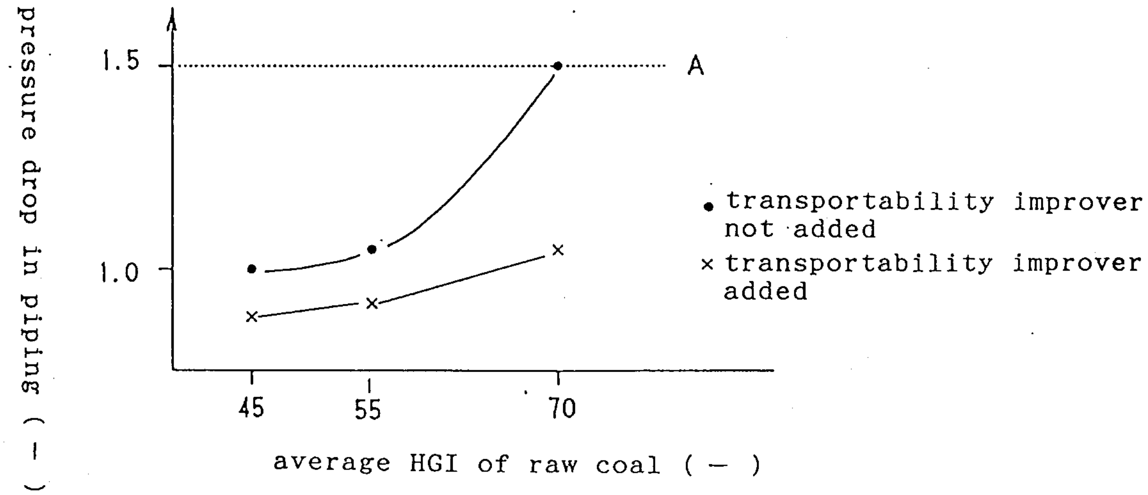


Figure 7

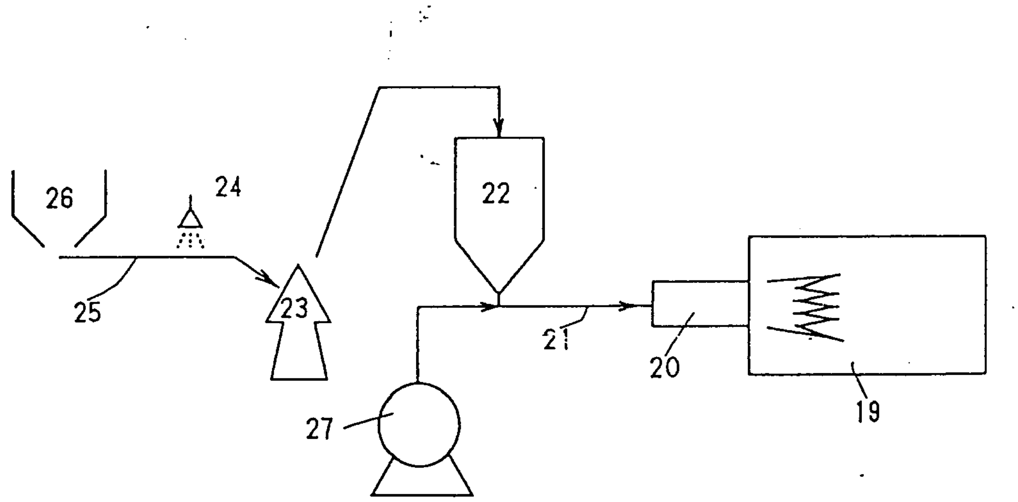
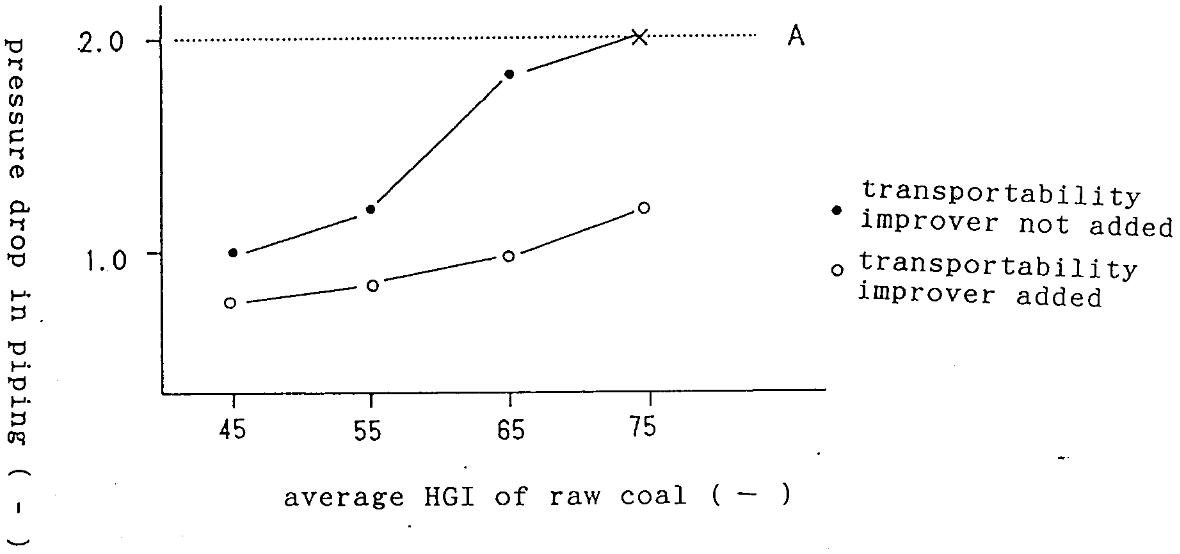


Figure 8



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/01875

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 C21B5/00, F23K3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 C21B5/00, F23K3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1996
Kokai Jitsuyo Shinan Koho	1971 - 1996
Toroku Jitsuyo Shinan Koho	1994 - 1996

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP, 63-224744, A (Mitsubishi Heavy Industries, Ltd.), September 19, 1988 (19. 09. 88), Page 1, lower left column, lines 5 to 11; page 2, lower left column, lines 6 to 12 (Family: none)	1-3, 6, 7, 13-15, 18-20, 22, 23 4, 5, 8-12, 16, 17, 21, 24-26
Y A	Microfilm of the specfication and drawings annexed to the written application of Japanese Utility Model Application No. 25726/1982 (Laid-open No. 132343/1983)(Mitsui Engineering & Shipbuilding Co., Ltd.), September 6, 1983 (06. 09. 83), Page 1, line 12 to page 2, line 4 (Family: none)	1-3, 6, 7, 13-15, 18-20, 22, 23 4, 5, 8-12, 16, 17, 21, 24-26
Y A	JP, 4-268004, A (Nippon Steel Corp.), September 24, 1992 (24. 09. 92), Column 1, lines 8 to 10, 30 to 35 (Family: none)	1-3, 6, 7, 13-15, 18-20, 22, 23 4, 5, 8-12, 16, 17, 21, 24-26

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search September 30, 1996 (30. 09. 96)	Date of mailing of the international search report October 8, 1996 (08. 10. 96)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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