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ART OF COMBUSTION OF CARBONACEOUS FUELS AND FUEL PRODUCTS USED THEREIN

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It has already been proposed to employ many substances as an admixture with coal or the like carbonaceous fuel matters, for the purpose of controlling the combustion thereof. A usual purpose of such procedures and compositions is to permit the efficient combustion of fuels in open or closed furnaces under particular conditions of operation. Thus, in some cases the natural coal or like fuel contains a high percentage of non-combustible matter (commonly denominated "ash") and therefore its rate of combustion is so low that a continuous progressive consumption of the combustible matter does not occur without assistance by forced draft, at a rate sufficient for the economic employment of the grate space and volume required for the fuel: and it has therefore been proposed to introduce materials for accelerating the rate of combustion of such fuels.

The use of many such substances, however, has been accompanied by two primary difficulties. The first of these is the difficulty of assuring that a proper dosage or proportioning of the material is provided at each point of the combustion zone, throughout the entire course of combustion. Thus, many such substances are water-soluble or otherwise subject to separation from the coal during the course of its transportation or storage: while others tend to separate and establish local excessive accumulations of such material while leaving other portions of the coal in uncontrolled state. In recent years, power plants of efficient type have been established, in which heat is developed in furnace constructions which employ powdered coal. This coal is burnt within the furnace space, with the development of a high temperature of the walls of the space and of the combustion gases. These gases are then led over water tubes or other elements for establishing a heat exchange and thereby deriving an effective employment of the heat produced. The walls of such furnace structures must be protected by refractory materials, and usually are further protected by cooling jackets which may for example be composed of pipes through which feed water flows on its way to the boiler tubes.

When such furnaces are operated at a temperature below the fusion point of the ash components of the fuel, a large proportion of the light feathery or dusty ash is carried forward into the boiler spaces, and is deposited on the boiler tubes and in the flues, and sometimes is emitted from the stack itself, in a manner regarded as objectionable under sanitary regulations.

It is not, however, possible to burn all coals in such furnaces at the high temperature required for fusion of the ash, owing to difficulties of construction, such as the difficulties of maintaining a proper refractory lining and of sealing the combustion space.

When the coal has an ash component which is fusible at the temperature of combustion, this feathery or dusty ash nuisance is eliminated, as the ash fuses and collects in drops which fall to the bottom of the combustion chamber, or which adhere to the refractory lining and flow downward to the bottom of the combustion chamber. In such cases, further, another difficulty arises with types of coal which contain pyrites, that is, minerals of the sulphide type. Many coals contain iron sulphide, for example. At an efficient rate of introduction of air for combustion, these sulphides are fused but are not oxidized to sulphates. They therefore collect on the refractory walls, and ultimately cause a perforation of these walls and of the water pipes aforesaid, so that the furnace goes out of service, and a considerable expense is always involved in maintaining the walls of the combustion chamber. Organic sulphur causes a similar trouble.

A further difficulty in the employment of combustion controlling agents has been the cost. It is sometimes required to employ twenty to one hundred pounds of combustion-controlling agent per ton of coal, for example: and yet the mixture must be sold in competition with coals which naturally have the desired combustion properties. Since the price of coal, for competitive sale, must be kept low, it is obvious that expensive controlling agents, or those which require peculiar procedures for their introduction and maintenance, must be regarded as economically unsatisfactory at present price levels of the coal and agent.

It has now been found that an advantageous control of the combustion temperature can be effected by using a cheap waste product of the phosphate industry. This is the material known as "waste gypsum," and results from the treatment of phosphate rock with sulphuric acid. This treatment liberates the major portion of the phosphorous as calcium phosphate along with phosphoric acid, usually in the form of an acid phosphate. The sulphuric acid combines with other portions of calcium present in the phosphate rock, to produce calcium sulphate or gypsum. Owing to the commercial necessities of cheap operations, the calcium phosphate is not entirely separated from the gypsum, so that the

latter contains varying percentages of phosphates. A normal constitution of this "waste gypsum" is around 2% of so-called calcium superphosphate: although other percentages result from differing conditions of treatment, particularly in the phase of operations involving the separations of the soluble calcium phosphates from the relatively insoluble gypsum matters.

This material is available at a very low cost per ton, and in the quantities employed it adds but a small amount to the coal cost: and usually the mixture can be sold at substantially the same price per ton as the price quoted for untreated coal.

Furthermore, it has been found that this material, during the course of the combustion, has a very effective action in respect to the fusion point of the ash constituents of the coal or other fuel. Thus, it has been found that coals having an ash content of 6% to 9% of total ash, with a fusion point of this ash at around 2900° F., can be brought to a condition in which the product has an ash fusion point around 2400° F., which is sufficiently below the customary operating temperature of 2500° F., at which a "slag bottom" or fused ash furnace chamber is operated: and this result can be attained by employing not over 2% of the above material, that is, about one-fifth to one-third of the weight of the ash as a maximum.

Further, it has been found that the presence of the calcium phosphate material assists the action, and that the action can be further promoted in a highly advantageous manner by employing also a small percentage of trisodium phosphate or like neutral heat-dissociable compound which yields off acid vapors and leaves an alkaline ash. A presently preferred composition is to employ 90% of waste gypsum (including around 2% of calcium superphosphate) with 10% of trisodium phosphate: of this mixture, about ½% to 2% is employed upon the basis of the coal used.

It has been found that a composition of this type has the further advantageous action of eliminating corrosion due to the presence of iron sulphide or other pyrites compounds. The definite evolution of acid vapors from the composition means that the alkalinity of the ash is increased, and hence the sulphur is eliminated and the iron is usually brought down in elemental, oxide or sulphate form: and hence the refractory linings and water pipes are safeguarded.

It is preferred, in selecting the "waste gypsum," to obtain a material which is derived from phosphate rock which has been cleaned as carefully as possible with respect to clay or other aluminous compounds, as it has been found that the presence of such aluminous compounds tends to counteract the desired effect of the composition in reducing the fusion point of the ash.

The composition may be introduced by dosage directly at the furnace, or it may be introduced into coal which is passing through a ball mill crusher incident to its pulverization for combustion in a powdered-coal burning furnace. Further, it may be mixed with a "wetting" oil which is now often employed at the rate of around one gallon per ton for preventing the dirtiness by floating coal dust. It is particularly advantageous to avoid the use of water, owing to possibilities of freezing, and to the loss of efficiency due to the latent heat absorbed during combustion.

In the actual combustion itself, it has been found that apparently only about one-half of the phosphate is dissociated and driven off as vapor, and hence normally around half of this phosphate remains unchanged in the ash: but the effectiveness of a promoting agent, in forming a glaze or flux at the temperatures involved, stabilizes the action and assures the capacity of operating a "slag bottom" furnace without fly ash, even though the coal originally had a fusion point far above the operating temperature.

As pointed out above, 3% of the mixture is regarded as an extreme upper limit, and it is usually preferred to employ between ½% and 2% of the material with normal coals, as the higher percentages usually represent no increase in effectiveness in reducing the fusion point, and percentages in excess of 2% usually represent an actual increase of fusion point, apparently due to the relative proportion of undissociated gypsum which is carried down with the ash.

In operating such furnaces, it is found that the iron pyrites is converted to sulphate under reducing conditions in the furnace, and is brought down as metallic iron or as iron oxide under neutral or oxidizing conditions.

While the above example sets out a preferred composition and proportion for employment, this composition may be varied according to the ash constitution of the coal or like carbonaceous fuel: and the ratio of ingredients may be modified, always giving due regard to the question of economy in price of the materials employed. It is possible to introduce lime, in a proportion of say equal parts or less, compared to the gypsum present, but in such instances, it is usually desirable also to augment the proportion of phosphate employed as a promoter.

Although the above composition has been selected as a commercial example, on the basis of modifying the ash fusion point so that a high-fusion-ash coal can be employed in a slag bottom furnace, yet it is also found in practice that this material constitutes a highly advantageous and satisfactory substance for controlling the combustion of the coal, so that it may be employed, though in lesser percentages of composition, for this purpose alone.

This action of controlling the rate of combustion of the coal may be utilized for establishing an accurate determination of the optimum proportion to be employed.

It is well known that coal begins to glow at temperatures from say 350° to say 600° F., according to the relative percentage of ash and carbon, and to the form in which the carbon is present. Further, it has been found that for a particular sample of coal, the introduction of the fusion controlling material has an effect of substantially proportionate nature in reducing the glow point. Hence, with the coal from a given mine (that is, with substantially the same ash content and analysis), it is possible from time to time to effect a quick and simple determination of the glow point, and introducing sufficient amount of material for reducing this glow point to a predetermined temperature: and it is then found that the originally high fusion point for the ash has been reduced correspondingly to a temperature which is sufficiently low for the employment of the coal in a slag bottom furnace at the particular operating temperature thereof as desired.

In analytic work, the "glow point" is the point at which a standard quantity (one gram of the fuel) takes on a red glow under the conditions of

test. This glow point is considerably lower than the ignition point, and is very much easier to ascertain. The ignition point itself is a function of the softening point of a coal or of the flash point of a hydrocarbonaceous fuel. At the softening point or flash point, inflammable gases are evolved from the fuel body: and hence the lower the ignition point, the sooner these gases appear.

As a specific example, using a coal which is known commercially as C-prime (C') coal, the coal itself was determined on analysis to have the following characteristics: glow point, 545° F.; ash fusion point, 2620° F.; ash fluid at 2730° F.; total ash 8%, with analysis 43.6 silica, 29.3 alumina, 19.9 ferric oxide, 1.4 calcium oxide, 1.4 alkali, 1.05 pyritic sulphur. This is an acid ash.

Knowledge of the fact that coal comes from this common source, and has the general characteristics of the above fuel, permits a simple determination by determining the glow point of a particular lot. The above coal, for example, is high in iron, average in alkali and low in lime. The above quantity of pyritic sulphur will be slagged by substantially an equal amount of the mixed phosphate matter.

When it is sought to operate a slag bottom furnace at a temperature of around 2400° to 2500° F., with this coal, a primary test is made, by adding the mixture of phosphates and sulphates, increasing the amount by ¼ of 1% for each test; and observing the glow point of the coal and the fusion and fluid points of the ash. An illustrative set of tests on the above coal is:

	Glow point	Fusion	Fluid pt.
	° F.	° F.	° F.
½% mixed phosphates and sulphates	450	2490	2645
¾% mixed phosphates and sulphates	442	2465	2625
1% mixed phosphates and sulphates	439	2450	2570
1¼% mixed phosphates and sulphates	433	2435	2540
1½% mixed phosphates and sulphates	421	2405	2470

In interpreting these results, it is found that ½% of the mixed reagents lowers the glow point of the coal, and the fluid temperature of the ash is reduced to a point where nodulizing, but hard clinker would not be formed. This therefore would be a satisfactory addition for stoker practice or hand firing of any kind. The glow point has been reduced from 545° F. to 450° F. Hence, with other coals from this source and of like characteristics, the analyst need only determine the glow point of the coal as mined, and then add a quantity of the mixed phosphates and sulphates in a proportion to effect a reduction of the glow point to a temperature which has been established as standard for the particular coal when employed for a particular purpose: and his work will then result in the production of a fuel product which will have a nodulized or fused ash. That is, if a particular specimen shows a glow point of 580° F., then around 1½% of the mixture would be added: while with a glow point of 500° F., the quantity of mixture could be decreased.

If the fuel is to be used in a slag bottom furnace, however, 1½% will be added in order to bring the fusion temperature of the specific above coal, down to 2405° F., at which a slagging furnace operator desires to operate. It will be noted that this, further, is above the 1% of mixture which is required to compensate for the pyritic sulphur present.

It is obvious that the procedure can be employed with colloidal fuels, in which fine coal particles are suspended in a vehicle which itself comprises a combustible oil. The like advantages are present of controlling the combustion of the coal, of avoiding difficulties by corrosion due to organic and pyritic sulphur, and by avoiding the escape of fly ash or the like.

The percentages of addition of such basic phosphate and sulphate matters is substantially within the limits of one-tenth of 1% to 2%. In the majority of the cases, the proportion is from ¼% to ½% for controlling the combustion of hydrocarbonaceous oil fuels, around ¼% to 1% for colloidal fuels, and from ½% to 2% for fuels of the nature of coal.

The heat-dissociation of the materials added has the advantage of giving an acid vapor which assists in the combustion control, and an alkaline solid, plastic or fluid residue which further promotes the course of combustion, and leads to the formation of an ash which is fragile, as opposed to the hardness of a silica-alumina-iron ash which usually is of clinker type and may give trouble in furnace combustion.

It is believed that the action of the agent is to act by the emitted acid vapors to modify the heat conductivity of the offcoming vapors as a whole, so that the gases are burnt with a greater heat and completeness and also there appears to be an intruding action into the coal molecule, so that the hydrogen bonds are loosened and a depolymerization of the higher hydrocarbons in the fuels is occasioned, and the lower hydrocarbons are evolved at a greater rate.

It is obvious that the invention may be employed in other ways, and in other mixtures and with other proportions than those specifically set out above.

I claim:

1. A fuel material comprising a solid carbonaceous fuel having an ash high in silica and alumina and with a low total content of lime and alkali and containing sulphur in pyritic form, and an admixture consisting of basic phosphate and sulphate matters, the weight of the admixture being at least equal to the weight of the pyritic sulphur present and between ½ percent and 2 percent of the weight of the fuel and effective to fix at least the major part of the sulphur as sulphate and to avoid the presence of iron sulphide in the ash produced.

2. A combustible fuel material comprising a solid carbonaceous fuel having an ash high in silica and alumina and with a low total content of lime and alkali and a high normal ignition point and between ½ percent and 2 percent of the product known as "waste gypsum" and obtained from the acid treatment of phosphate rock and containing phosphate matter, said product being effective to reduce the ignition point of the fuel.

3. A fuel material comprising a solid carbonaceous fuel having an ash high in silica and alumina and with a low total content of lime and alkali and a high normal ignition point and between ½ percent and 2 percent of an admixture consisting of waste gypsum and lime and containing a phosphate, said admixture being effective to reduce the ignition point of the fuel.

4. A fuel material comprising coal having an ash high in silica and alumina and with a low total content of lime and alkali and a high normal ignition point and substantially ½ percent to 2 percent of an admixture consisting of substantially 90 percent of waste gypsum and 10 percent

of trisodium phosphate, said product being effective to reduce the ignition point of the coal.

5. A pulverulent fuel material consisting of powdered coal having an ash high in silica and alumina and with a low total content of lime and alkali and a high normal ignition point with admixture of waste gypsum and an alkaline phosphate, the quantity of admixture being from one-tenth to 3 percent, substantially one-eighth thereof being phosphate, said admixture being effective to reduce the ignition point of the coal.

6. A fuel product containing hydrocarbons with an ash high in silica and alumina and with a low total content of lime and alkali and having a high normal ignition point, and also containing a mixture of waste gypsum and phosphate matter in quantity substantially equivalent to one-third to one-fifth the weight of the ash, said admixture being effective to reduce the ignition point of the fuel.

7. The method of burning powdered coal having an ash high in silica and alumina and with a low total content of lime and alkali and a normal high ignition point, which comprises the step of mixing the coal prior to combustion with waste gypsum and additional phosphate as a promoter in the proportion of ½ percent to 2 percent of the weight of the coal, said gypsum and sulphate being effective to reduce the ignition point of the fuel.

8. The method of operating a slag-bottom furnace with a coal which as a natural product has a normal high ignition point and an ash high in silica and alumina and with a low total content of lime and alkali with a fusion point above the desired temperature of operation of the furnace, which comprises the step of adding a mixture of basic phosphate and sulphate matters to the coal in proportion equivalent to approximately one-third to one-fifth the weight of the coal ash and effective for lowering the ignition point of the coal and for bringing the fusion point of the ash to said desired temperature.

9. The method of producing a coal mixture having an ash fusion point of substantially predetermined value which is lower than the fusion point of the ash of the coal itself, from coals of similar characteristics and source and of normal high ignition point but of varying fusion point of the ash thereof, ash high in silica and alumina and with a low total content of lime and alkali so that the mixture may be employed in a slag bottom furnace at a combustion temperature lower than the normal ash fusion point of the coal itself, which comprises the steps of determining the glow point of the coal itself, and mixing with the coal a quantity of mixed basic phosphate and sulphate matters selected from the group consisting of calcium sulphate and phosphates of the alkali metals and calcium in amount sufficient to reduce the glow point of the mixture to a predetermined standard for coal of the given characteristics and source.

10. The method of producing a coal mixture having an ash fusion point of a substantially predetermined value which is lower than the fusion point of the ash of the coal itself, from coals of similar characteristics and source and of normal high ignition point but of varying fusion of the ash thereof, ash high in silica and alumina and with a low total content of lime and alkali which comprises determining the glow point of the coal itself, and mixing with the coal a quantity of waste gypsum and additional phosphate sufficient to reduce the glow point of the mixture to a predetermined standard for coal of the given characteristics and source.

11. A pulverulent fuel material for use in powdered coal furnaces comprising particles of a carbonaceous fuel having an ash high in silica and alumina and with a low total content of lime and alkali and normal high ignition point and containing sulphur in pyritic form, and an admixture of particles of basic phosphate and sulphate matters therewith in proportion of substantially ½ to 2 percent of the fuel, said admixture being effective to reduce the ignition point of the fuel and to fix at least the major part of the sulphur thereof as sulphate and to avoid the presence of iron sulphide in the ash produced.

12. A pulverulent fuel material for use in slag-bottom powdered coal furnaces comprising particles of a coal having a normal high ignition point, a glow point in excess of substantially 500 degrees F. and an ash high in silica and alumina and with a low total content of lime and alkali having a fusion point in excess of substantially 2600 degrees F. and containing sulphur in pyritic form; and an admixture of particles of basic phosphate and sulphate matters therewith in proportion of substantially ½ to 2 percent of the coal and likewise being substantially equivalent to one-fifth the weight of the normal ash of the coal; said admixture being effective to reduce the glow point of the fuel material to a temperature not exceeding 450 degrees F. and the ash fusion point to a temperature not exceeding 2500 degrees F., and to fix the sulphur and avoid the presence of iron sulphide in the ash produced.

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