Patented Feb. 27, 1923. 1,447,008

UNITED STATES PATENT OFFICE.

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FUEL AND METHOD OF PRODUCING SAME.

No Drawing. Original application filed August 5, 1919, Serial No. 315,497. Divided and this application filed April 9, 1920. Serial No. 372,686.

To all whom it may concern:

Be it known that I, LINDON W. BATES, a citizen of the United States, residing at Mount Lebanon, in the county of Columbia and State of New York, have invented certain new and useful Improvements in Fuel and Methods of Producing Same, of which the following is a specification.

This invention pertains to a fuel as a product and to the process of producing it. More specifically it refers to a mobile fuel, which contains liquid hydrocarbon and particles of carbonaceous substance, so treated that a composite usable for atomizable fuel purposes is produced. The product is designated by the term "colloidal fuel" and the process is called "colloidalizing." The word "colloidal" in these sole instances is not used in a strictly technical sense but is used to conveniently describe the product and process, owing to certain of the fuel's important colloid-like characteristics. This application has been made after complete reduction of the product and process to practice and their adaptation to industrial requirements.

The realm of chemistry herein treated is by no means completely explored, but the chemical explication indicated by the present state of knowledge is given.

In view of the well known economic and operative advantages of atomizable over solid fuel and the high value and comparative scarcity in many places of certain refinable oils, there has long been felt the desirability of evolving a process for combining for purposes of economy, the cheaper or more plentiful sources of carbon with those liquid hydrocarbons in such a fashion as to admit of atomization and simultaneous combustion of the components. The cheaper and more plentiful sources of carbon are generally solids, such as coal and lignites, or are tars and pitches. Attempts have been made in the past to make a liquid fuel of pulverized coal with oil and of tar with oil, but as oil does not ordinarily dissolve coal or tar, comparatively rapid and uncontrolled separation, settling out or sedimentation of some of the components, or complications or cost of the combination treatment developed, has heretofore discouraged industrial use of the product. Fortunately in colloidal fuel the sciences of chemistry and physics have at last been made to disclose a satisfactory, cheap and easy way to produce the desired fuel. Even more has been done, as a whole new range of atomizable fuels has been created.

It is a natural characteristic of solutions, whether the molecules of the particles or droplets actually combine or do not combine with those of the medium, that the dispersed particles or droplets do not settle to the bottom, float to the top or separate under normal conditions. The same is true with respect to colloids provided the particles or droplets are sufficiently within the upper limit of the colloidal state. The requisite margin within the upper limit depends upon the real and apparent specific gravity of the dispersed substance, the characteristics of the medium and other factors. In a composite whose particles are within colloidal limits but are above the size which naturally yields an absolutely stable colloid, the particles form with the medium a colloid of relative stability, which is practically absolute stability when the specific gravity of the particles is close to that of the medium. Of course, solutions and colloids may be so treated as to precipitate, in some cases, the dispersed particles and droplets. With regard to composites in the suspension state, weight and size of dispersed particles and droplets are important factors. There may be a tendency for the particles or droplets to float to the top rather than to settle to the bottom. The word "suspension" as applied to the state of matter, does not by any means imply stability.

In order for a fuel to be atomizable and for its components to be simultaneously combustible, it is necessary that the fuel be mobile and that it enjoy adequate stability to enable it to pass through the pipes, preheater and other apparatus parts without the components congesting therein to such an amount as to prevent the fuel's passage. The degree and duration of the adequate stability desired vary according to the contemplated handling and use of the fuel. When storage is intended, stability not merely for some days but even for months may be desired. To give the utility character required it is essential to prevent or delay settling to the bottom of the medium

or floating to the top by the particles or droplets for a reasonable length of time and to a reasonable extent, depending in duration and degree upon several variable factors, including the length of proposed fuel storage after manufacture and the character of the combustion, conveying and atomizing system. In referring herein to "stability" such adequate or relative stability is meant. Regulation and control, within reasonable limits, of the movement of the dispersed substance to give the fuel a stability of the required degree and duration is sufficient for the practical purposes of fuel utilization. In order to understand how such power over stability may be obtained and exercised it is in order to describe the laws governing the movement of dispersed particles and droplets in a liquid medium.

An investigation of stability is best approached from a consideration of Stokes' law for the terminal velocity of fall of a spherical body in a liquid. According to this law the velocity per second under a constant force such as gravity is derived from the following equation:

$$V=\frac{2r^2(s-s')g}{9\eta}$$

In this expression g is the constant of acceleration per unit mass, that is, gravity; r is the radius of the sphere; s is the specific gravity of the sphere and s' that of the liquid; η is the absolute viscosity coefficient of the liquid. It is obvious, as stated by Hatschek, that the difference $(s—s')$ may be positive, zero or negative, that is the particles may sink, remain stationary or rise, if their specific gravity is greater, equal to, or smaller than that of the liquid.

Droplets of one liquid in another liquid with which the first is immiscible or partially miscible only, disclose somewhat similar stability characteristics. There are, however, lesser deviations from Stokes' law as the droplets are nearly spherical, unless the volume of the disperse phase exceeds 74% of that of the total liquid. Liquid dispersed droplets are stable in a liquid medium when they are of molecular size or when they are sufficiently within colloidal limits.

Although the actual natural rate of settling of particles and droplets corresponding to sizes of the screens mentioned in a medium of liquid hydrocarbon is less than the theoretical, it is too rapid to allow the composite to be used as fuel save in very exceptional cases. In ordinary combinations, for example, of pulverized coal and oil, the particles of coal being heavier than the oil have settled out in the pipes or preheater and have choked these conduits or they have settled to the bottom of the storage tank, somewhat in the fashion of sand in water, which has defeated the purpose of simultaneous combustion of the components of the fuel. There has been a similar experience in the case of tar combined with oil. Resort to constant stirring has been proposed and tried, but even in the case of a short pipe system congestion in the pipes it is understood has occurred. No product adequately stable of itself has heretofore been supplied to industry.

In regard to artificially inducing suspension of particles in liquids there exists some prior experience in connection chiefly with colloids. It is known in chemistry that particles which are normally stable in a liquid may be precipitated by certain substances such as electrolytes. "Protective colloids" possess the property of preventing such precipitation, unless a larger amount of precipitating agent is used. Of protective colloids there are a number enumerated in standard chemistry text books. The list includes such substances as gelatine, glues, casein, gum arabic, sodium oleate, dextrin, silicic acid, and aged stannic acid. Chemists are not agreed whether the action of a protective colloid is to surround the particles with a film, to adsorb with them, or to introduce electrical factors, with resultant effects on surface tension, apparent specific gravity and other characteristics affecting stability. Probably the stabilizing effect is produced by a combination of these and other phenomena.

With regard to suspending carbonaceous particles in liquid hydrocarbon it is known that less than 1% of Acheson graphite, of 2.1 specific gravity, reduced so that the dimension of the particles is 75μμ which is within colloidal limits, is suspended in oil for lubricating purposes with the aid of gallotannic acid. Colloids of charcoal and lampback are known. It is reported that coal may be made into a stable combustible colloid with oil, or brought into a state closely approximating the colloidal condition, when it is reduced therein under high pressure or high speed disk grinding and lengthy trituration, whose duration may be reduced somewhat by adding a colloid to the mixture which assists the endeavor to decompose the coal to molecules.

Turning to the state of the art with respect to stabilizing a composite of two or more immiscible or partially miscible liquid hydrocarbons for fuel purposes, there is little history. It is well known that many liquid hydrocarbons are miscible with others. But there are certain important combustible liquid hydrocarbons that have until now proved refractory to combining,—for instance, fuel oil and tar have been to date immiscible or partially miscible only. Emulsions of immiscible hydrocarbons have been made suitable for creosoting and disinfecting, but no such

emulsions, much less suspensions, involving immiscible liquid hydrocarbons for fuel purposes are recorded.

One may now describe the scientific bases of the present product and process. Reduction of the carbonaceous substance to such a size that the particles enter into a molecular, colloidal, or practically colloidal state with the liquid hydrocarbon is known to promote natural stability. But the manner of so doing is most arduous. The question, however, of diffusion or scattering of the particles through the liquid is also of importance with reference to stability. It has been found as the result of extensive tests that if the components are properly mixed it is not necessary so finely to reduce the particles. The scientific reason is that the size and weight of the particles are not the only factors involved. Initial separation of the particles from each other, adsorption, electrical repulsions, and other mentioned factors have likewises a considerable influence. These are called into operative play in a homogeneous composite.

Certain substances it is found, may be used to induce stability of a suspension of pulverized carbonaceous substance in liquid hydrocarbon. Of these a product containing lime and rosin is cheapest and most effective. Not all colloids or protective colloids will serve. The tannin used by Acheson will not serve, as it apparently lacks sufficient protective strength to stabilize particles above colloidal size. It has been also found that particles considerably above colloidal limits in size may be stabilized and peptized. When a substance is dissolved it gives up a layer to the surrounding liquid, when peptized some dissolving usually takes place but the particles take up a part of the liquid. (Zsigmondy, "The Chemistry of Colloids" 1917, p. 9). It is known in chemistry that resins, caoutchouc and asphalts are peptizable by their own distillates. It has now been ascertained that carbonaceous substances conchoidal in fracture and so seemingly crystalloidal as coal and like carbonaceous substances, are also peptizable by certain coal distillates. Even semi-anthracite pulverized coal is susceptible to some peptization, while bituminous coals and lignites lend themselves readily to such treatment. There are usable as peptizing agents various products, liquid at ordinary temperatures, derived from the destructive distillation of coals. Such distillates not only act upon pulverized carbonaceous substances introduced into liquid hydrocarbons, but also upon the natural carbonaceous impurities, such as asphaltum and free carbons, encountered in some oils and tars. The carbonaceous substance when peptized becomes to a certain extent spongified and cavitated, thereby reducing the apparent specific gravity and hence the tendency to settle. While the chief function of the peptizing agent is to peptize the particles, it has a marked dissolving and stabilizing effect as well, which is an accompaniment of its peptizing action and which is particularly noticeable at temperatures above normal. The stabilizing action may be accounted for by the release into the medium of the resinous content of the coal or other carbonaceous substance upon its peptization. It is of course possible and in some cases it is advantageous, from the economic viewpoint, to introduce some lime-rosin protective agent into the mixture as this reduces the amount of peptizing agent necessary to give the desired adequate stability.

With reference to stabilizing two or more immiscible or partially miscible liquid hydrocarbons in each other the interesting scientific fact has been disclosed that the presence of a considerable percentage by weight of pulverized carbonaceous substance, even well above colloidal limits in size, has the effect, when the components are duly mixed, of stabilizing them. In so doing the particles are themselves stabilized in the liquid. In such a composite there is no need of either a protective agent or a peptizing agent. The ability of charcoal to take up gases, fusel oil, alcohol, dye stuffs and even salts of heavy metals is a well known chemical phenomenon. Substances which greatly lower the surface tension of liquid against liquid are adsorbed by these. In a mixture of oil, tar and pulverized coal, for example, the stabilization effect of the coal and tar upon each other is to a certain extent reciprocal. That is, the coal and the tar together in oil may be stabilized more readily than either alone.

In the case of liquid colloidal fuel, after a completely liquid period of some days or months the fuel tends to gel from the bottom of the container up. The viscosities of the gel or lower stratum and of the so-called "serum" or upper stratum, are different and the gel may carry somewhat more particles, but the fuel retains its atomizable character, and in the case of both strata the several components are present and are simultaneously combustible. Pumping, agitation or heat causes the gel to revert to a liquid, and in some cases this will result even from a tap on the wall of the container. The creation of a gel, even in its early stages, materially assists stabilization, inasmuch as the particles and droplets cannot settle readily through a gel.

Whereas heretofore endeavors to combine pulverized coal and oil and tar and oil have sought only a liquid fuel, the present process offers as a product not only a liquid fuel, but also products between a liquid and a solid, viz.—a mobile paste and a mobile gel,

all of which comply with the requirements that the fuel be atomizable and that the components be simultaneously combustible. Colloidal fuel in liquid form may be made containing up to about 45% by weight of carbonaceous particles. Mobile pastes may be made carrying as much as 75%, more or less, of particles. Mobile gels may be made from liquids or pastes. Colloidal fuel may be a combination of these forms. In these forms and between these approximate ranges, a great number of liquid or other mobile fuels may be prepared.

A judicious and proper selection of the components to be made into colloidal fuel is of great importance to the success of the operation. All classes of carbonaceous substances, susceptible to reduction to particles by pulverization or otherwise, are suitable for combining with liquid hydrocarbon under the process of producing colloidal fuel. For instance, anthracite, semi-anthracite, bituminous and semi-bituminous coals, as well as lignites and peats are usable. Anthracite culm, dust and slush, also bituminous and lignite slack, screenings and dust, and also coal "seam dust" of suitable qualities are all available. To this list may be added pressure still, smelting, and gas house cokes and charcoals. Various grades within these groups have been successfully employed. The type of lignite containing some 20% of water is suitable. Woods, when suitably pulverized, may also be combined under the process with liquid hydrocarbons. Carbonaceous substances of comparatively high ash and sulphur content may be used. When colloidal fuel is burned, the ash in the particles of the carbonaceous substance, as a result of pulverizing and colloidalizing, does not slag, but goes off to a large extent with the gases and the remainder falls to the bottom of the furnace as a fine powder, like pumice. The sulphur content may be averaged down by combining the carbonaceous substance with liquid hydrocarbon containing less sulphur proportionately. Several kinds of carbonaceous substances together may be used.

Among the carbonaceous substances may be included particles which act as fillers to promote stability. These may be of less specific gravity than the oil and must act as nuclei for flocculation, but by reason of their buoyancy operate in the opposite sense to the increased tendency to sedimentation due to flocculated groups of particles. Fillers should have also a fair calorific value and be readily subdivisible. The presence in the filler of a certain amount of water and some hygroscopicity are not a disadvantage when increasing viscosity is involved. Various cellulosic and semi-cellulosic by-products are suitable as fillers, such as waste from starch, corn and flour factories, also wood pulp, wood dust, and disintegrated peat and lignite. Wood dust containing rosin would be usable simultaneously for protective, filler, and objective component purposes. In the materials mentioned, the true density may be somewhat higher than that of oil, but the apparent density is lower by reason of occluded air which gives apparent buoyancy.

The carbonaceous substance or substances heretofore enumerated or described should be reduced by pulverizing or otherwise so that about 95% passes through a 100 mesh screen and 85% through a 200 mesh screen. Finer reduction is advantageous but is not essential to the process. In fact even coarser particles may be temporarily and partially stabilized, adequately for certain fuel uses. The peptizing treatment with its incidental dissolving and the mechanical blending do reduce somewhat further the particle size, but in colloidal fuel as produced many particles are found well above colloidal size. Over peptization, in fact, creates an unstable composite. For the reduction of the carbonaceous substance to the size employed, mechanical, electrical or chemical means may be used, though an ordinary coal pulverizing ball or tube mill is most economical. The word "pulverized" is deemed to embrace carbonaceous substance reduced to the form of particles, either before or during the blending process.

In general all liquid hydrocarbons which are usable as liquid combustible, miscible or not with others, such as oils, tars, and pitches, may be used as a dispersion medium for particles of carbonaceous substance to form colloidal fuel. Such large amount of any one highly viscous liquid as would destroy the atomizable character of the product should not be used. The product has been successfully made with all liquid hydrocarbons tried; including fuel oils, pressure still oil or tar, and coal tar, both by-products of coke ovens and gas houses. By the term "pressure still oil or tar" is meant the residue left after topping and cracking a paraffin base oil in pressure stills. Liquid hydrocarbons of various classes and grades in these groups have been successfully utilized. Liquid hydrocarbons of even higher sulphur and water content than would ordinarily be acceptable for liquid fuel may be used, inasmuch as it is possible on colloidalizing to average down these factors by using carbonaceous substance of proportionately lower content. Solid hydrocarbons when liquefied are also utilizable, provided the liquid falls within the above mentioned groups. Several liquid hydrocarbons may be blended.

In order to carry in liquid from a high percentage of carbonaceous particles, the liquid hydrocarbon should have a viscosity

of about 20° Engler at 20° C. and 10° Engler at 30° C. A lesser viscosity will not prevent the production of colloidal fuel, it merely tends to reduce the percentage of particles which may be introduced into liquid hydrocarbon without changing the relative stability or character of the product. If it is desired to form a colloidal fuel paste or gel, the question of the initial viscosity of the liquid is of lesser moment. An increase in the viscosity of the oil is a means of promoting stability. If the viscosity is less than the figure desired in view of the amount of carbonaceous substance to be introduced and the character of the composite sought, it may be raised by blending with the liquid medium such liquid hydrocarbons as reduced petroleum, petroleum residuals and petroleum or asphaltic pitch. If pitch is used some 5% to 10% by weight will raise the viscosity the desired amount. Standard Navy fuel oil, for example, having a viscosity 7.8° Engler at 20° C. and 4.3° Engler at 30° C. is raised to the above mentioned figures by 12½% of petroleum pitch. Viscosity raising liquids may be combined with the liquid hydrocarbon of the medium by simply blending the two in the manner that such liquids are ordinarily blended. Pitch may be advantageously incorporated in fuel oil by heating it with 25% to 30% of the oil at some 110° C. and then stirring in the remaining oil. Viscosity may be raised also by emulsifying the oil. It is one of the qualities of the protective agent that it increases the viscosity of the oil. The rosin and lime in oil form an emulsoid of viscosity increasing type. The better the quality of the protective agent, the more a given amount increases the viscosity. Viscosity at normal temperatures may be further increased by after treatment of the emulsoid. This consists in heating and cooling it several times. Care should be taken not to ripen too far, as a less stable system may be formed from which the lime-rosin component tends to partially separate.

If the viscosity of the liquid hydrocarbon selected to constitute the dispersion medium is too great to yield a liquid product in view of the amount of particles it is desired to introduce, this quality may be reduced by blending with a liquid a "cut-back" consisting of other suitable liquid hydrocarbon. One may mention, pressure still oil or tar, kerosene and turpentine. In case a liquid of viscosity greater than about 40° Engler at 20° C. is to be used, it is well for practical purposes to introduce less particles than the maximum stabilizable in a liquid form. The manner of blending one or more cut-backs with liquid hydrocarbon is well known.

The composition of the protective agent or fixateur is of importance as it materially affects the amount necessary to give the desired fuel stability and consistency. The fixateur may be prepared in various forms, such as a solid, powder, paste or liquid. The amounts of lime and rosin may vary within certain limits according to the duty to be performed. "1% fixateur" means a lime-rosin composite of such an amount as will add 1% rosin to the fuel. The percentages of lime and other fixateur components are included in the colloidal fuel formulæ under the percentage assigned to a liquid component of the fuel. Various grades of lime-rosin products may be formed. The efficiency of the protective agent depends upon the purity of the ingredients, their quality, and, in the case of soap or grease, in the completeness of the saponification. The content of resinous acids in the rosin is an important factor and counts for more than lightness of color. Rosin may be replaced by balsams, turpentines, and other resinous by-products. Wood pitch particularly from pine, wood tar, and partly distilled pine wood, may also serve, provided the calorific value of the fixateur is not decreased materially. A fresh and somewhat "low-burnt" quick lime may be used. What is known as "fat" lime is desirable. The lime may be replaced by other alkali. Other components may be incorporated.

In general, with a good quality of protective agent, one may regulate stability by varying the amount used. Broadly speaking, the less the degree and duration of the desired stability, the lower the temperature, the fewer particles introduced and the smaller their size, the less fixateur need be employed. The greater the viscosity coefficient of the liquid, the less protective agent is required. If fillers are used, less protective agent may be needed. If a peptizing agent is added to the composite or if other liquid hydrocarbon immiscible with the dispersion medium are joined to the fuel components, then less fixateur is called for. The tendency to early, complete and consistent gel is promoted by somewhat larger amount of protective agent than would be used simply to stabilize the particles in a liquid fuel. If a paste fuel is to be produced less agent than if a liquid fuel is to be made may be required. Some fixateur may, however, be needed to prevent separation of a liquid to the top of the paste. The amount of fixateur used should provide for adequate stability at the temperatures of storage and preheater. The maximum of a good quality of agent practically ever used is an amount which adds by weight some 2% rosin to the fuel. The minimum amount having a perceptible effect is about .1%. Ordinarily between ½% and 1½% is used.

Of the various coal distillates which will serve as peptizing agent the middle frac-

tions, such as creosotes, naphthalene and solvent naphtha tar, are the most operative. The "green" residual after the removal of anthracene is also suitable. The introduction of about 10% by weight into the composite of carbonaceous particles and liquid hydrocarbon will obviate the need of any protective agent. Several peptizing agents may be combined. The amount of peptizing agent required varies with the components and with the stability and fuel character desired. The amount employed will vary between 1% and 10%. If a liquid distillate of coal is selected as a part of the dispersion medium then no further peptizer is needed. But the entire dispersion medium should not be a peptizer if the solids are susceptible to peptization and if the corresponding treatment is given. In the composites including a peptizer stability does not fall off with rise in temperature progressively in extent as it does with composites stabilized with the use of a protective agent alone. But in general, the amount of peptizer varies in the same fashion as does the amount of protective agent heretofore mentioned.

In relation to stabilizing two or more immiscible liquid hydrocarbons with the use of pulverized carbonaceous substance the percentage of necessary carbonaceous particles varies with the nature and relative amounts of liquid hydrocarbons. An adequately stable composite may be made, for example, consisting by weight of about 50% pressure still oil, 20% coke-oven by-product tar, and 30% pulverized coal. If an oil such as that from Texas is used the proportion of coal or other carbonaceous substance to tar has to be increased and the proportion of coal and tar to oil has to be decreased. If a small amount of protective agent is added to the mixture, the highest amount of tar may be stabilized in oil with the aid of coal or other such carbonaceous particles.

Examples of the regulation of the duration and degree of stability by the use of lime-rosin grease fixateur and of coal distillates in liquid fuel are the following: In the examples the carbonaceous substance is pulverized so that 97.5% passes a 100 mesh screen and 95% passes a 200 mesh screen. The viscosity of the fuel oil mentioned is about 20° Engler at 20° C. while that of the pressure still oil is only 8° Engler at 20° C. The specific gravity of the oil in the first full oil example is .924, while in the two last it is .943. That of the pressure still oil is .960. The actual specific gravity of the Pocohontas coal is 1.39, of the anthracite coal 1.6, of the coke 1.7. Stability of over ten days attaches to a composite consisting of 40½% pressure still oil, 3% pressure still wax tailings, 15% road oils, 1½% fixateur and 40% pulverized anthracite coal. Stability of over three months is noted in a composite consisting of 50½% pressure still oil, 3% pressure still wax tailings, 1½% fixateur, 30% pulverized pressure still coke and 15% petroleum pitch. The combination of 67.8% Navy fuel oil, 31.2% pulverized bituminous coal and 1% fixateur is stable for over six months. Stability for over six months is also noted in the case of a composite consisting of ½% fixateur, 3% middle fraction oil, 56½% pressure still oil 5% coke-oven by-product tar, and 35% pulverized Pocohontas high volatile bituminous coal.

In colloidal fuel the amount of settling during the calculated "life" of the composite, or period of assured stability, rarely amounts to 5% of the particles. Usually at the end of the period stated between 95% and 99%, or even 100% of the particles are still in suspense and well scattered through the composite. Thereafter settling begins gradually and proceeds progressively. Temporarily renewed life may be given by stirring with or without more fixateur. The stability mentioned earlier is adequate stability in liquid form. The period of usability of the fuel may be longer as utility is not jeopardized by such small and gradual settlings and there may be further "life" in gel form. The stability mentioned is at a temperature between 20° C. and 30° C. At higher temperatures the period of stability is shorter, save in the case of composites in which a peptizing agent is introduced. The stability is of greater degree or duration than that due to mere high viscosity of the medium, if it is high, and persists under the preheat necessary for atomization. Greater amounts than that required of any mentioned agent will not of themselves, save in an extreme case, prejudice the fuel's utility, while lesser amounts simply decrease the degree and duration of stability or retard formation, lessen the extent and change the consistency of the gel. Either or both agents are embraced in the term "protecting agent."

With reference to the apparatus needed to produce the composite, one may say that it consists chiefly of suitable blending mechanism. Ordinary paint mixing mills, coal pulverizing mills and other known mechanical apparatus may be adapted to this use and serve as a unit in apparatus to make colloidal fuel. If a part of the container in which the components are placed is sufficiently heated, a circulation of the liquid will be set up which will cause the particles to scatter throughout the mixture. If the heat is raised to between 65° C. and 95° C. the homogeneity will become satisfactory. Heat may be combined with mechanical agitation or blending. In case a peptizing agent is used this heat blending treatment may advantageously be utilized with or without a mechanical treatment, and the

product allowed to rest for some hours to advance peptization if storage is intended. When the asphaltum and free carbon particles are to be stabilized one may centrifuge, is desired, the oil initially to lessen the amount of these impurities to stabilize.

The manner of mixing or blending the components of colloidal fuel is simple but important. The carbonaceous substance or substances may be pulverized simultaneously with the blending of the components, or separately. The fixateur may be made beforehand, or its components united when the fuel components are blended. Protective and peptizing agents, viscosity adjusting liquids, and fillers, or any or several of them, may be introduced at any time before the blending is terminated. The duration of the mixing treatment varies with the components and with the stability desired. The introduction of new components and the withdrawal of already mixed components may take place simultaneously in a continuous process. In general the product is satisfactory when on inspection it is seen to have considerable and consistent smoothness to the touch. Suitable tests to determine when blending is sufficient include many known to chemists, such as gravity tests with the fuel at rest and in motion, viscosity tests, atomization tests, centrifugal tests, and dripping tests. Evenness in a drip test tends to show that proper homogeneity has been reached. Only a few minutes total blending time is usually employed to give homogeneity in apparatus of the kind mentioned, although if long stability is required or if the initial viscosity of the liquid component is low a greater duration of treatment or repetition of treatment may be advantageous.

While the components of the protective agent may be added to other components of colloidal fuel before or while the latter are being blended, it is advantageous to prepare the agent beforehand, in a separate step from the colloidalizing or on another occasion and store it until used. The agent hereafter described is simply one form of lime-rosin product, a fixateur grease. Fixateur powder has been made. The fixateur herein given as an example is composed by weight of about 83.5% Navy fuel oil, 10% rosin, 5% lime and 1.5% water. The formula is not inflexible, as different percentages of each of the components may be used. The above percentages, however, yield a suitable grease. The oil used in making the fixateur should have a certain minimum viscosity and flash point. While the emulsification of lime-rosin soap is possible in almost any fraction of mineral oil, yet the stability of the emulsion decreases as the viscosity of the oil becomes less. Since, also, it is necessary to heat the oil up to about 120° C., which is above the melting point of the rosin, the open cup flash point should not be lower than 120° C. The oil should have a viscosity of about 20° Engler at 20° C. and 10° Engler at 30° C. Navy fuel oil, for example, of viscosity 18.1° Engler at 20° C. and 9.3° Engler at 30° C. is suitable. As in the case of oil to be used as dispersion medium for coal particles, the oil used for grease making may be raised or lowered in viscosity to the figure desired. But pitch should not be used as it prevents saponification and grease formation. The grease-making method is as follows: 1. Hydrate the lime before combining it with the other ingredients, unless the lime is obtained already hydrated. 2. Screen it if necessary. The lime powder should mostly be able to pass a 200 mesh screen. 3. Stir the lime with the oil heated to about 120° C. The lime is stirred in with the oil and kept in suspension by agitation while the oil is heated. The stirring should be vigorous and such as will produce proper agitation and mixing. 4. Add the water and hold the heat for saponification. A small amount of water (1 to 5%) is necessary for a consistent grease. It may be incorporated mechanically by pugging with the cold grease, but it is better to add it during the heating, generally just previous to adding the rosin. Sometimes another ½% to 1% may be added just before cooling the grease, if there has been much loss by evaporation. The presence of water leads for a short time to much priming or foaming, so that it is desirable to use a mixing vessel of a volume greater than that of the material used. 5. Melt the rosin and pour it into the lime-oil mixture while this is still hot. The rosin may be separately heated until quite liquid. 6. Add the rosin with constant stirring to the heated mass of lime and oil. Air agitation should be utilized with mechanical stirring or alone to give the required mixing when the priming stage is reached. It may be advantageouly introduced through the lowest part of the mechanical stirrer. The use of preheated air is of value to help maintain and distribute the heat. The water content of the reaction mixture may be held constant by keeping the air saturated with water vapor at the reaction temperature. The water content is otherwise a variable factor difficult to control owing to uncertain evaporation. 7. Run off the grease while still hot and mobile. 8. Allow the grease to cool in order to set, unless immediate use is intended. The duration of the heating and progress of saponification and grease formation are determined by experience. In practice the mass may be withdrawn from the heat or the heat ended when the mass begins to thicken too much for efficient mixing. Small samples should be removed, rapidly cooled,

and their consistency compared with that of a sample of standard grease made under similar conditions. Two connected processes are going on during the heating, namely, the chemical process of saponification of the resinous acids by the lime and the emulsification and solution of the soap in the oil. The product is a protective agent, lime-rosin grease, or fixteur, so-called.

The first example selected to illustrate colloidal fuel is that comprising a Navy fuel oil from Texas combined with pulverized Pocahontas coal. Take such a fuel oil of a viscosity of about 18.7° Engler at 20° C. and 9.3° Engler at 30° C. Take such a coal pulverized so that some 99.7% passes a 100 mesh screen, 98% a 200 mesh screen and 85% a 300 mesh screen. Take a grease in which lime and rosin are incorporated into fuel oil as described so that the grease contains by weight 83.5% fuel oil, 10% rosin, 5% lime and 1.5% water. Use as a blending apparatus an ordinary paint mixing machine, whose wheel weighs about 200 lbs. Rotate the wheel at 70 R. P. M., which is slower than usual. Place in the paint mill a bath of such amounts of components that there will be combined by weight 30.5% coal, 1.5% fixateur and 68% oil. Blend the mixture simply the time necessary for the composite to run through the mill, which is a few minutes only, as in the case of paint mixing. The product is a colloidal fuel which is stable in liquid form for over three months.

A second example of colloidal fuel is that containing by weight: Pressure still oil 50%, coal tar 10%, creosote 2%, pulverized Pocahontas coal 30%, fixateur 1.2%, Texas Navy fuel oil 6.8%. Pulverize the coal in a Fuller mill so that 97.5% passes 100 mesh and 95% passes 200 mesh. As blending apparatus use another ordinary Fuller 37" diameter coal pulverizing mill, in which four 100 lb. balls are present. Rotate these at a speed of 135 R. P. M., which is slower than the usual pulverizing speed of 150 R. P. M. The components, including the pulverized coal, are gradually fed into the blending mill in correct proportions corresponding to the ratio of components, so as to run through it for a few minutes, until a liquid product showing adequate homogeneity upon examination is produced. As components are suitably introduced the finished product flows out in a continuous stream. The product is a colloidal fuel which is stable for over four months in liquid form.

The specific gravity of a composite containing numerous foreign carbonaceous particles is usually from 1.03 to 1.32. Such fuel is therefore heavier than water. This means that such colloidal fuel may be kept under a water seal, and when on fire the flames may be quenched in and by water. Colloidal fuel, furthermore, enables one to give the flame used in metallurgical process the degree of hardness or softness desired. It is well known that coal gives a soft flame while oil gives a hard one. In certain steel and other metal processes the character of the flame, as distinguished from the degree of heat, is of supreme importance. Colloidal fuel gives a new ability to regulate not only the B. T. U. of the fuel but also the nature of the flame. All that is necessary is to make up the composite with such amounts and kinds of components as will give the desired heat units and a flame of the character required. For example, a composite in which a high grade of carbonaceous substance is used has more B. T. U. than one made of a poor grade. A composite containing a high percentage of carbonaceous particles gives a softer flame than one carrying a lesser percentage.

Liquid colloidal fuel, carrying up to 40% of carbonaceous particles, is practically the equivalent, in regard to handling to the preheater stage, of the heavier class of crude oil. At higher temperatures, however, such as obtain in the preheater it may approximate the behavior of the lighter class of oils. The problem of burning colloidal fuel is simply that of burning a viscous oil. In the case of a gel which is liquefied by pumping or which liquefies in the preheater, more pressure is apparently alone required.

Colloidal fuel is not an ordinary coal and oil mixture as it has a stability feature, subject to control. It is a composite in three states of dispersion: solution, colloid and suspension. Some of the particles pass through a filter, many do not. Many are microscopically visible and measurable, others are not. Some display rapid Brownian movement, others slower, others no such movement. In colloidal fuel, a material amount, if not the bulk, of the carbonaceous particles remain in the product when produced greatly above the colloidal size and above the colloid borderland. In view of this condition it has become possible to dispense with the complicated treatment necessary to reduce the particles to molecular or colloidal size, a procedure more suited to the laboratory than to industry. It may be replaced by a brief low speed blending treatment under normal pressure, or by a heat treatment, for homogenizing purposes. The nature of the best and cheapest protective agent has been ascertained and the method for preparing it determined. It artificially induces stability in a composite whose condition would not be stable naturally. The stability is of greater degree or duration than that due to mere high viscosity of the medium. Furthermore, the protective agent is partially or completely

replaceable in certain cases by a peptizing agent. The peptizing agent indicated has as an additional feature certain protective and dissolving action. The viscosity of the liquid hydrocarbon is adjusted to suit the amount and types of components to be used and the product desired. The product is made to give the B. T. U. content, the flame character and the sulphur and water content desired. Finally, immiscible or partially miscible liquid hydrocarbons may now also for the first time be combined with the aid of carbonaceous particles, into an adequately stable atomizable fuel.

No claim is made herein broadly to a stable mobile fuel consisting essentially of liquid hydrocarbon and pulverized solid carbonaceous substance and containing also a smaller proportion of an agent having peptizing qualities sufficient to prevent sedimentation for a predetermined period, or to a method of producing a stable mobile fuel consisting essentially in effecting an admixture of a relatively large quantity of liquid hydrocarbon and pulverized carbonaceous substance, and a relatively smaller quantity of an agent capable of promoting stability, and subjecting the mixture to such heat and mechanical homogenizing action that the main portion of the particles of the carbonaceous substance remain above colloidal size, whereby the composite is stabilized, as such matter forms the subject of my application 315,497, filed on or about the 5th day of August, 1919, Patent 1,390,228, of which this application is a division.

What is claimed is:—

1. A liquid or liquefiable mixed fuel comprising a large proportion of hydrocarbon oil and a substantial proportion of solid carboniferous fuel in the form of a powder, a substantial portion of the powder being adapted to pass a filter which will pass ordinary colloids and a substantial portion of the powder being adapted to be retained on such a filter, said solid carboniferous fuel being adapted to be burned independently as fuel, and said fuel mixture also comprising a medium adapted to hold said powder in suspension a much longer time than results from the viscosity and relative specific gravity of the components of the mixed fuel.

2. A stable mobile atomizable fuel composed essentially of particles of solid carbonaceous substance in an amount which will produce a fuel of specific gravity greater than that of water, which substance is artificially pulverized in a manner which reduces material portions thereof to molecular, colloidal and suspension sizes; a large body of freely flowing liquid hydrocarbon; and a smaller amount of substance which stabilizes the particles both at normal temperature and when the viscosity of the fuel is reduced under the elevated temperature requisite for the fuel's atomization through burners.

3. That method of producing a stable mobile atomizable fuel, which consists essentially in mixing liquid hydrocarbon and particles of solid carbonaceous substance in amounts which will produce a composite of specific gravity greater than that of water without destroying the atomizable character of the composite; and colloidalizing the components.

4. A stable mobile atomizable liquefiable fuel comprising solid particles of carbonaceous substance, liquid hydrocarbon, and saponified resinous matter.

In testimony whereof I have signed my name to this specification.

LINDON W. BATES.