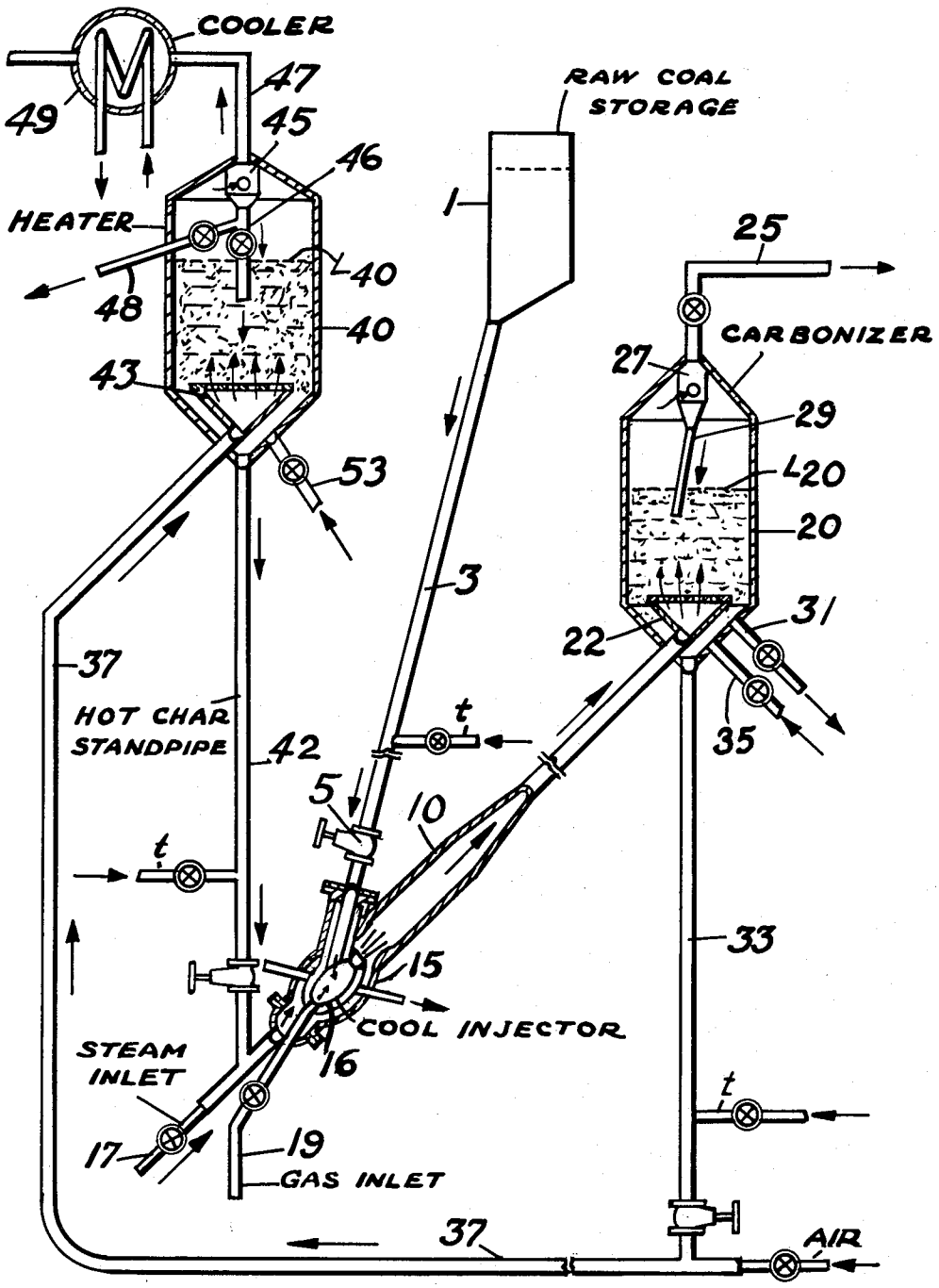
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PROCESS OF CARBONIZING COAL

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# PROCESS OF CARBONIZING COAL

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The present invention relates to the handling of carbonaceous solids. More particularly, the invention is concerned with the treatment of finely divided carbonaceous solids, such as all types of coal, brown coal, lignite, oil shale, tar sands, asphalt, cellulosic materials including lignin, etc. to produce valuable volatile products at temperatures not below their plastic range, wherein the fresh charge is preheated at least to said plastic range by mixing with hot non-plasticizing solids.

This application is a continuation-in-part of my copending application Serial No. 748,796, filed May 17, 1947, now U. S. Patent 2,582,711.

Heretofore, solid carbonaceous materials of the type mentioned above have been treated at elevated temperatures in fixed bed operation to form liquid and gaseous fuels such as light oils, tars, coal gas, producer gas and water gas. However, these processes involve either discontinuous operation or inefficient conversion of the available carbonaceous matter into volatile fuels and heat.

The operation of these processes may be made fully continuous by employing the so-called fluid solids technique in which the reactions take place in dense fluidized beds of finely divided solids maintained in a turbulent ebullient state by means of fluidizing gases. This technique has highly desirable additional advantages including greatly improved heat distribution and ease of solids handling.

However, serious difficulties have been encountered in handling the finely divided raw material. It is well known that most coals below the rank of anthracite and above that of lignite as well as certain types of low temperature coke, shales, etc., undergo some degree of softening when heated. Such materials do not have sharply defined softening points. There is, however, a characteristic temperature range for each coal in which softening will occur. At this temperature range liquid products are formed which may be sufficient to cause the whole mass of coal to coagulate more or less completely. The degree of softening, or "melting" varies widely for different coals from only a slight agglomeration of individual particles to a "melting" so complete that the coal liquefies and all traces of individual particles disappear.

The processing of coals and similar materials exhibiting any appreciable degree of fusion, for example in carbonization, gasification, producer gas operation, etc., is extremely difficult because fusion leads to excessive plugging of the equipment and it contributes to channeling of reactants, as well as appreciable increases in pressure drop through the system. These objections are particularly critical in processes employing the fluid solids technique, which depend on intimate and complete rapid mixing in a turbulent bed of fluidized solids. If any appreciable amount of fusion occurs in the fluid bed, the fluid properties of the bed are lost and the process becomes inoperable.

It has been demonstrated in the "fluid" processing of plasticizing type carbonaceous solids that operable conditions can be maintained if each particle of fresh coal is



completely surrounded and intimately mixed with "dry" processed material, that is, non-plasticizing coke. In its more specific aspects, the present invention relates to improvements of this type of process by which agglomeration, or plugging of the plasticizing carbonaceous solids charge may be completely eliminated in an economical manner.

In accordance with the invention disclosed and claimed in the above-identified parent patent this may be accomplished as follows.

Plasticizing carbonaceous solids of fluidizable particle size are charged to a mixing and preheating zone which is surrounded by, and in open communication with, the relatively dense fluidized mass of carbonaceous solids being processed in a large processing zone at a processing temperature above the plasticization temperature of the charge, while simultaneously causing hot processed solids from said surrounding fluidized mass to enter said mixing zone and to form an intimate mixture with the fresh charge. Gases required for processing and/or heating the charge are passed upwardly through the inner mixing and preheating zone in such a manner as to force "dry" processed solids substantially at processing temperature from said surrounding fluidized mass into said mixing zone through its lower opening and to discharge a mixture of fresh and "dry" material preheated to processing temperature from the upper opening of the mixing zone into said surrounding fluidized mass. The inner mixing zone is operated at relatively high velocities so that the time of residence of solids passing from the bottom to the top of this zone is only sufficient to raise the temperature of the fresh charge to reaction temperature which is normally appreciably above the plastic temperature. This heating takes place under conditions at which each particle of fresh charge is completely surrounded by "dry" coke.

Heat required for processing may be supplied as sensible heat of preheated process materials, or by a partial combustion of combustible process materials within the mixing zone or by burning solid processing residue in a separate heater and returning hot heater residue to the mixing zone. The present invention constitutes a further development of this earlier invention, which is employed with greatest advantage in combination with the last mentioned type of heat supply.

In accordance with the present invention, the mixing zone is arranged outside the enlarged processing zone and has the form of an injector-type transfer line feeding into the lower portion of the processing zone. Hot "dry," i. e. non-plasticizing, solids at a temperature preferably not lower than processing temperature and fresh plasticizing carbonaceous solids are supplied in separate streams to the transfer line and injected into the latter in such a manner that the hot "dry" solids will completely envelop the fresh carbonaceous solids as they are discharged into the transfer line, so as to prevent agglomeration and plugging as a result of plasticization of the fresh charge. This may be accomplished by an injector effect acting on the solids as they are supplied to the transfer line. The feed rates of hot "dry" solids to fresh carbonaceous solids supplied to the transfer line should be such as to establish therein a ratio of these solids not lower than 4.

The fresh carbonaceous solids are instantly heated in the transfer line by the hot "dry" solids and are then conveyed in the fluidized state, completely mixed and enveloped by the "dry" solids, to the processing zone where processing is completed. Normally, the gases and vapors developed by the heating in the transfer line are sufficient to fluidize the solids mixture therein and in the processing zone itself. If desired, additional fluidizing gas, such as steam or product tail gas, may be added to facilitate solids flow and improve fluidization.

The process of the present invention lends itself particularly well to the carbonization of carbonizable solids, but is also applicable to the gasification and other heat treatments of carbonaceous solids with gases, as will become more readily apparent from the following more detailed description read with reference to the accompanying drawing, the single figure of which is a schematical illustration of a system suitable to carry out a preferred embodiment of the invention.

Referring now to the drawing, the system illustrated therein essentially comprises transfer line **10** provided with an injector arrangement **15**, a processing vessel **20** and a separate heater **40**. The functions and cooperation of these elements will be forthwith explained using the carbonization of a bituminous carbonization coal as an example. It should be understood, however, that any other carbonaceous charge previously mentioned may be processed for the same or different purposes in a generally analogous manner.

When employed for the carbonization of a coal having a plastic temperature range of about 700°–850° F., subdivided raw coal of fluidizable particle size is supplied from coal bin **1** through line **3** provided with control valve **5** to transfer line **10** at a point inside of nozzle **16** of the injector arrangement **15**. Line **3** may be either a standpipe aerated through one or more taps *t* or any other means of conveying subdivided solids. The coal may have a particle size of about 8 mesh or ⅜″ by zero, although particle sizes from smaller than 400 mesh to as large as ½″ in diameter may be present.

The coal supplied to nozzle **16** is intimately mixed by injection into the flowing stream of hot "dry," i. e. non-plasticizing, solid residue produced in heater **40** as will appear more clearly hereinafter and supplied through aerated standpipe or other solids conveying means **42**, to a point upstream of injector **15** in transfer line **10**. Simultaneously, a minor amount of a fluidizing gas, such as steam or product tail gas, may be introduced through line **17** upstream of the feed point of line **42** into transfer line **10** to facilitate the flow of the hot heater residue toward injector **15**. A similar gas may be supplied through line **19** directly into nozzle **16** to establish the desired injector effect. The combined effect of the pseudo hydrostatic pressure of the fluidized solids column in line **42** and the injector effect of the solids-in-gas suspension leaving nozzle **16** at a relatively high velocity causes the "dry" solid supplied from line **42** to pass nozzle **16** and thereafter completely to envelop the fresh coal leaving nozzle **16**, so as to form an intimate mixture of fresh coal in "dry" solids and simultaneously to prevent coal agglomeration due to plasticization. The injector arrangement is preferably so designed that most of the mixing takes place immediately upon the discharge of the fresh coal at high velocity from nozzle **16** so that at least the desired minimum mixing ratio of 4 parts of "dry" reactant to one part of plastic material is immediately achieved and no material of higher "plastic" concentration may reach hot equipment parts. In this connection it is important to prevent nozzle **16** itself and the outlet of coal feed pipe **3** from reaching temperatures approaching the plastic range. For this purpose, both nozzle **16** and the outlet of pipe **3** are preferably jacketed as shown in the drawing to permit cooling by means of suitable coolants, such as water, steam, etc. It will be appreciated by those skilled in the art that the injector arrangement shown in the drawing is merely one of numerous means suitable to accomplish the purpose outlined above. For example, a multiple nozzle arrangement may be used. Mechanical stirring may supplement the injector effect described. Other modifications will appear to those skilled in the art.

The heater residue flowing from line **42** is preferably supplied at a temperature about 50°–200° F. higher than the temperature required for carbonization, say at a temperature of about 900°–1200° F. The feed rate of these solids should be a high multiple of, i. e. at least 4 times, depending on the temperature differential, preferably about 8 to 25 times, the raw coal feed rate so as to assure an adequate "dry" to fresh solids weight ratio throughout transfer line **10**. In this manner, the fresh coal will be instantly heated in transfer line **10** to the coking temperature and will be completely surrounded by "dry" char while passing through the plastic range so that plugging and agglomeration are avoided. The ratio of "dry" char to fresh coal may be varied at will depending on the temperature differential between heater **40** and vessel **20**. The use of very high dilution ratios is preferred so that localized concentrations of raw coal are avoided.



The gases supplied and the vapors evolved in the course of this treatment will transport the solids through transfer line **10** in a highly turbulent state involving an apparent density of about 0.5 to 10 lbs. per cu. ft. The suspension so formed enters through a suitable distributing device, such as inverted cone **22**, the lower portion of enlarged coking vessel **20**. The solids in vessel **20** form a turbulent, fluidized mass having a well defined upper level $L_{20}$ and an apparent density of about 15–40 lbs. per cu. ft. Vessel **20** is so designed that the upflowing gases and vapors have a linear superficial velocity of about 0.1–4 ft. per second suitable for proper fluidization and so that a solids residence time is provided which is adequate to complete the carbonization reactions at temperatures of about 800°–1000° F. In many cases, the supply of extraneous fluidizing gas through lines **17** and/or **19** may be substantially eliminated once the liberation of gases and vapors in transfer line **10** has started, because these liberated gases and vapors are sufficient for proper transfer and fluidization of solids, and in most cases no separate supply of fluidizing gas directly to vessel **20** is required.

Volatile carbonization products are withdrawn overhead from level $L_{20}$ and passed through line **25** to a conventional product recovery system (not shown). Solids entrained in the volatile products may be separated in a gas-solids separator **27** and returned through line **29** to vessel **20**. Product coke may be recovered through line **31** in amounts adequate to maintain solids circulation throughout the system in balance. About 0.6 to 0.8 lbs. of product coke per lb. of fresh coal charged may be so recovered.

An amount of solid carbonization residue corresponding to the amount of solids mixture supplied to vessel **20** minus the amount of product coke and volatile products recovered through lines **31** and **25**, respectively, is withdrawn downwardly from vessel **20** through aerated standpipe or similar conveying means **33**. If desired, adhering volatile carbonization products may be stripped off these solids by introducing small amounts of a stripping gas, such as steam, air, flue gas or product gas, through line **35** into the bottom of the annular space formed by cone **22** and the walls of vessel **20**. The stripped solids pass into line **37** in which they are suspended in air which may be preheated to about 100° to 900° F. The amount of air so supplied is that required to maintain by combustion a temperature of about 900°–1200° F. in heater **40**. About 0.3 to 1.5 lbs. of air per lb. of fresh coal are normally adequate for this purpose.

The solids-in-air suspension passes under the combined air pressure and pseudohydrostatic pressure in standpipe **33** to the bottom of heater **40** which it enters through distributing means, such as inverted cone **43**. Heater **40** is so designed that a superficial linear gas velocity of about 0.1–4 ft. per second is established, a fluidized solids mass having a level $L_{40}$, of the type described with reference to vessel **20**, is formed and adequate solids-air contact is afforded to permit maintenance of the desired temperature by combustion. Flue gases are withdrawn

overhead through solids separator **45** and line **47** and may be vented or used for any suitable purpose in the system, if desired after heat recovery in a waste heat boiler **49**. Solids separated in cyclone **45** may be either returned to vessel **40** through line **46** or, if of undesirable particle size, discarded through line **48**.

Hot solid heater residue is withdrawn downwardly from heater **40** via line **42** and supplied to transfer line **10** as described above, if desired after stripping with steam, product gas, etc., supplied through line **53** to the annular bottom space of heater **40**.

The embodiment of the invention described with reference to the drawing will be further illustrated by the following specific example for the carbonization of a Pittsburgh seam bituminous coal.

*Example*

| | | |
|---|---|---|
| Quality of coal: | | |
| Percent moisture | | 5 |
| B. t. u./lb. as received | | 13,500 |
| Solids feed rates, tons/hr.: | | |
| Raw coal to mixer 10 | | 100 |
| Char from heater 40 to transfer line 10 | | 1,200 |
| Solids from transfer line 10 to vessel 20 | | 1,295 |
| Temperatures, ° F. | | |
| Heater | | 1,000 |
| Carbonizer | | 900 |
| Transfer line 10 | | 900 |
| Yields: | | |
| Tar | gals./hr. | 2,750 |
| Gas | MM B. t. u./hr. | 220 |
| Liquid | gals./hr. | 900 |
| Char | tons/hr. | 70 |

The system described with reference to the drawing permits of various modifications. The relative elevations of vessels **20** and **40** and transfer line **10** may be different from those shown in the drawing, solids circulation being accomplished by means well known in the art of fluid solids handing. Screw conveyors, lock hoppers or other conveying means may take the place of the solids conveying lines shown as aerated standpipes in the drawing. Hot carbonizer residue in place of, or together with, hot heater residue may be supplied to transfer line **10** as will be understood by those skilled in the art. The heat required for carbonization may be supplied by a partial internal combustion within vessel **20** in a manner known per se. In this case, heater **40** is eliminated, hot char from vessel **20** is used to dilute and preheat the raw coal in transfer line **10** and air and/or oxygen is supplied to a lower portion of vessel **20** and/or transfer line **10**. A variety of different designs of injection nozzles may be employed in place of injector **15** as shown, provided the criterium of surrounding the coal injection point with hot "dry" char is achieved.



While the foregoing description has primarily referred to the carbonization of coal, it will be understood that the system illustrated may be employed for other types of coal processing, such as gasification with steam, $CO_2$ and/or $O_2$ to produce gas mixtures rich in CO. These gasifying media may be introduced into the lower portion of transfer line **10** and hence into a lower portion of vessel **20** which is then operated at higher temperatures in the range 1700°–2000° F. In addition, the invention is applicable without significant changes to known systems employing three separate vessels, i. e. a coker, a gas generator, and a heater. Other modifications will appear to those skilled in the art.

The above description and exemplary operations have served to illustrate preferred embodiments of the invention. They are not intended to be limiting in scope.

What is claimed is:

1. The method of distilling agglomerative hydrocarbonaceous solids which comprises circulating a stream of gas through a confined mass of finely divided carbonaceous solids under fluidizing conditions, heating said mass to a temperature sufficiently high to effect distillation of said agglomerative solids, continuously withdrawing a portion of said confined mass to a position exterior thereof, injecting a gas-solids suspension consisting of finely divided fresh agglomerative hydrocarbonaceous solids suspended in a second stream of gas into said withdrawn portion at said exterior position, the velocity of said second stream of gas being adequate to create strong turbulence, circulating a cooling medium in heat exchange relation with said suspension of fresh solids to cool said suspension to a temperature below the agglomerating temperature of said solids until the point of injection is reached, returning the mixture so formed to the confined mass in the form of a gaseous suspension, and recovering the products of distillation.

2. Process according to claim 1 wherein the portion of solids withdrawn from the confined mass is further heated before injecting the suspension of fresh solids thereinto.

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