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METHOD AND APPARATUS FOR PREHEATING GASEOUS AND VAPOROUS REAGENTS IN POWDERED FUEL GASIFICATION

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Fig. 1.

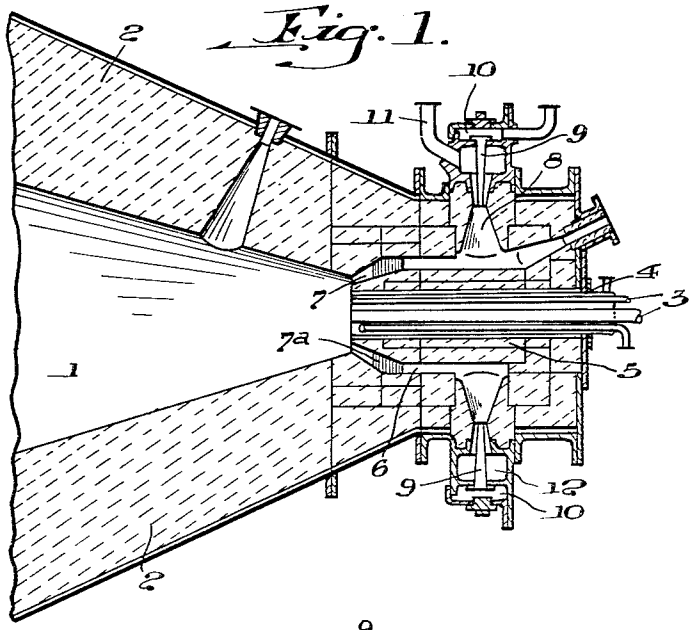
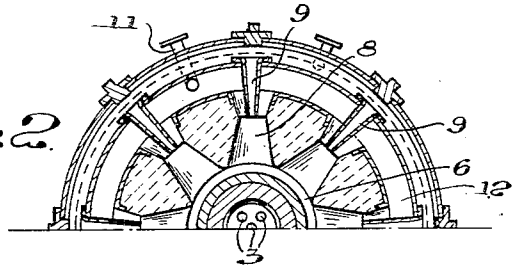


Fig. 2.



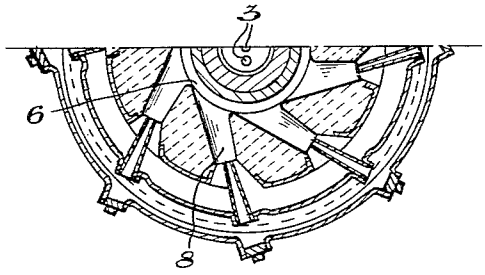


Fig. 3.

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METHOD AND APPARATUS FOR PREHEATING GASEOUS AND VAPOROUS REAGENTS IN POWDERED FUEL GASIFICATION

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Application August 12, 1948, Serial No. 43,954

18 Claims. (Cl. 48—64)

Reference is hereby made to my copending applications Serial Nos. 43,950 and 43,953, both filed concurrently herewith, the latter having issued as Patent No. 2,670,280 on February 23, 1954.

The present invention relates to method and apparatus for the gasification of suspensions of finely-pulverized solid fuel with oxygen, or oxygen-enriched air, and preheated endothermically-reacting fluid, such as, steam or carbon dioxide; it is particularly concerned with method and apparatus wherein the suspensions of finely-pulverized solid fuels move essentially in the same direction as said gaseous and vaporous reactants in contrast to those systems of solid-fuel gasification wherein a stationary bed of such fuel is treated with blasted currents of the reactants.

Any solid fuel can be successfully gasified in suspension by means of reactants that react exothermically and endothermically with the solid fuel, for example respectively oxygen and steam, if the solid fuel is sufficiently finely-divided prior to its gasification. Pure oxygen, or oxygen-enriched air, are preferably employed for promoting the exothermic reaction. The expression "endothermically-reacting fluid" as used in this specification includes not only steam, carbon dioxide but any other suitable fluid, or mixture thereof, that can react with hot carbon accompanied by the absorption of heat.

The progress of the reaction between the solid fuel and the said fluid reactants and the quality of the combustible gas produced and especially its content of carbon monoxide or of carbon monoxide and hydrogen depends largely on the introduction of an endothermically reacting fluid medium into the reaction chamber in a highly heated state that is sufficiently elevated to promote the gasification reaction.

According to my cofiled applications Serial Nos. 43,950 and Serial No. 43,953, there is described a method for gasifying finely-divided fuel in which method the finely-divided fuel is suspended in a free oxygen-containing gas, the oxygen of said gas being present in an amount insufficient to react with all of the suspended fuel. The suspension is then injected axially into a gasification chamber where part of the fuel is burned and the balance of the fuel is heated to the high temperatures necessary for reaction with an endothermic gasifying agent such as steam or carbon dioxide. Simultaneously with the introduction of the suspension, there is introduced into the gasification chamber surrounding the suspension, to flow between the burning suspension and the walls of the gasification chamber, an annular stream of an endothermic gasifying agent. The hot particles of carbon resulting from the partial combustion of the fuel diffuse into the stream of endothermic gasifying agent, thereby producing a gas containing carbon monoxide and, if steam is present in the endothermic gasifying agent, hydrogen.

An object of the present invention is to provide new and improved method and apparatus for heating to preferred temperatures an endothermically-reacting fluid medium used in the gasification process for powdered fuel.

The invention has for other objects such other improvements and such other operative advantages or results as may be found to obtain in the processes or apparatus hereinafter described or claimed.

According to the present invention, the preheating of a fluid that is employed to react endothermically with the hot carbon of a solid fuel that is in suspension in a fluid medium so as to gasify said fuel, is effected by burning any suitable fuel with oxygen, or oxygen-enriched air, and the so-formed highly-heated combustion products are mixed with said endothermically-reacting fluid, for example steam or carbon dioxide, to raise the temperature thereof, and the resultant mixture is then introduced into the gasification chamber to promote the gasification process.

Any fuel can be used for the purpose in the above-described manner. It is advantageous, however, to employ a gaseous fuel and preferably a portion of the combustible gas produced in the gasification process itself. The carbon content of the fuel may, as preferred, be either completely or only partially oxidized during the formation of the combustion products; i. e., it may be completely burned to give only carbon dioxide or incompletely burned to give only carbon monoxide, or so burned as to give mixtures of said gases. The employed fuel can be burned with the oxygen in a separate step after which the resultant hot combustion products are then mixed with the endothermically-reacting fluid or, in the event, that the employed fuel is gaseous or vaporous the combustion reaction can be performed in the endothermically-reacting fluid itself by mixing either the oxygen or the fuel with the endothermically-reacting fluid and thereafter bringing into contact under conditions to promote combustion respectively either the gaseous or vaporous fuel or the oxygen. For example, if steam is used as the endothermically reacting fluid, the combustion reaction can be carried on in the presence of the steam introduced into the combustion apparatus in admixture with either the oxygen or with the employed fuel gas.

In the accompanying drawing forming a part of this specification and showing for purposes of exemplification a preferred apparatus and method in which the invention may be embodied and practised but without limiting the claimed invention specifically to such illustrative instance or instances:

Fig. 1 shows a longitudinal section through the burner-head of gasification apparatus adapted for carrying out reactions according to the present improvement;

Fig. 2 is a section taken along the line II—II of Fig. 1; and

Fig. 3 is a section similar to Fig. 2 taken, however, through a modified form of apparatus.

Referring now to the drawing: in Figure 1 thereof is shown a longitudinal section through the burner-head and a portion of the associated gasification chamber **1** of apparatus adapted for the gasification of powdered fuel according to principles of the present improvement whereby the finely-pulverized solid fuel while it is in substantially homogeneous suspension in oxygen, or in oxygen-enriched air, is introduced as a jet into the preheated gasification chamber and ignited, a substantial portion of the carbon of the solid fuel being thus oxidized principally to carbon monoxide while said jet is surrounded by an envelope of a preheated fluid in an annular stream coaxially of the jet that can react endothermically with the unoxidized portion of the carbon of the fuel of said jet to complete its gasification to combustible gas; the said envelope of endothermically-reacting fluid thus lies between the refractory walls **2** of the gasification chamber and the oxidizing jet of suspended solid fuel to protect the refractory materials of the former from the very high temperatures developed in the jet of the mixture of oxygen and solid fuel. The main body of the gasification chamber can have any preferred shape but in that portion thereof adjacent the burner-head it is preferably circular in cross-section and is tapered toward the inlets for the reactants that are disposed adjacent each other, as shown in the Figure 1. The gasification chamber can also be communicably connected with a dust catcher, scrubbing apparatus, and the like, for additional treatment of the produced gas.

The finely-divided solid fuel to be gasified is suspended in a flow of oxygen, or of oxygen-enriched air by means of apparatus not shown in the drawing thereby forming as nearly as possible a homogeneous suspension which is injected under suitable pressure into the gasification chamber **1** through metallic pipes **3** that are preferably made of copper and are disposed in a cooling-jacket **4**. This cooling-jacket **4** is covered by

heat-insulating refractory material 5 that is so-formed as to provide an annular channel 6 which ports into the gasification chamber 1 as an annular nozzle 7. That end of said refractory material 5, which is adjacent the gasification chamber, is provided with an outer surface that is a truncated cone having disposed thereon a plurality of spaced, parallel rib-like projections 7*a* that divide the annular channel 6 into a plurality of uniformly-sized smaller openings or canals. These parallel rib-like projections are so disposed on the surface of said truncated cone that their extensions intersect its axis at only one point with the result that the said canals formed thereby in the annular channel 6 are double inclined to the longitudinal axis of the gasification chamber 1. The said rib-like projections 7*a*, as can be seen in the drawing, terminate a short distance from the top of the truncated cone of the refractory material 5 so that the endothermically-reacting fluid that is flowed through the canals between them intermingle and unite in the annular nozzle 7, before they enter the gasification chamber, as a whirling, spiral envelope that flows substantially only over the conical walls of the gasification chamber and surrounds its central portion into which the suspension of solid fuel in oxygen, or in oxygen-enriched air, is introduced in the form of jets from the pipes 3.

The annular channel 6 is communicably connected with a series of combustion spaces or burners 8 having frustum-shaped walls of a suitable refractory material, said channel 6 joining with said burners at the points of their greatest cross-section. These burners can, as preferred, be arranged as extensions of radii of the annular channel 6, as clearly shown in Fig. 2; or, they can be disposed as extensions of chords of said annular channel, as shown in Fig. 3, so that combustion products issuing from said burners are introduced tangentially into the channel 6 to provide them therein with a whirling motion. The burners 8 are equipped with injector-nozzle or tuyères 9 that are each communicably connected with a metallic distributing channel 10 which is common to a plurality of the injector-nozzles 9 and is disposed adjacently surrounding the circular periphery of the masonry of the burner-head of the gasification apparatus. Each of the injector-nozzles 9 is arranged to inject oxygen into the combustion space 8 along its axis; the outlet ends of the injector-nozzles 9 are sufficiently less in outside diameter than the inside diameter of the adjacent walls of the combustion spaces 8 to form an annular interspace between them, said interspace serving communicably to connect a said combustion space with the annular conduit 12 whereby fuel gas that is delivered to said conduit from feed-line 11 can be introduced collectively into all the combustion spaces. If preferred, each combustion space can be individually furnished with a feed-line 11 and all such feed-lines can be connected with a common header. In such modification of the invention, annular conduit 12 can be divided by metallic cross-walls dividing said conduit into compartments that supply fuel gas to the combustion spaces individually.

The oxygen employed for combustion of the gaseous fuel in the combustion spaces 8 can be delivered into the latter from annular conduit 10 through injector-nozzle 9, preferably in admixture with the employed endothermically-reacting fluid such as steam, whereas the fuel gas to be burned by such oxygen enters the combustion space 8 from conduit 12 through the illustrated annular opening between a nozzle 9 and the walls of a said combustion space.

In the apparatus shown in the figures of the drawing, the combustion spaces 8 provided for generating the heat required for preheating of an endothermically-reacting fluid are arranged to form an integral part of the gasifier and thus excellent utilization of the heat liberated by reaction between the gaseous fuel and oxygen is assured. However, without departing from the spirit of the invention it is possible to dispose the combustion apparatus at a distance from the gasifier chamber provided the combustion apparatus and the means whereby it communicates with the gasification chamber are highly insulated to prevent as far as possible loss of heat. In addition, it can be of advantage to employ a combustion apparatus that is common to a plurality of the gasification chambers.

The hereinabove-described apparatus is designed especially for the use of a gaseous fuel. However, as hereinbefore mentioned any fuel can be used as the source of heat for preheating the endothermically-reacting fluid for the gasification of the suspended solid fuel and any apparatus known to those skilled in the art for burning liquid or finely-divided solid fuel can be employed to supply the heat for said preheating step; an important feature of the present invention resides in the preparing of highly-heated combustion products which are mixed with the endothermically-reacting fluid that is to be preheated before its introduction into a gasification chamber, for converting a suspension of finely-divided solid fuel into combustible gases, and is in contrast to those methods of preheating which have heretofore employed regenerators and similar apparatus.

The invention as hereinabove set forth is embodied in particular form and manner but may be variously embodied within the scope of the claims hereinafter made.

I claim:

1. Gasification apparatus adapted for the continuous gasification of finely-divided solid fuel in suspension in oxygen, or oxygen-enriched air, said apparatus comprising: a reactor, a burner head therefor, a conduit axially through said burner head for introducing finely-divided solid fuel in suspension in oxygen, or in oxygen-enriched air, axially through said burner head into the reaction chamber in the form of a jet spaced on all sides from the reactor walls; a second conduit in said burner head coaxially around said first conduit for introducing into said gasification chamber preheated fluid oxide that is endothermically reactive with hot carbon of the finely-divided solid fuel through said burner head coaxially around the first conduit in an annular stream discharging along the walls of the reactor chamber so as to surround the jet in the form of a cocurrent flow as the jet issues into and ignites on entering the reactor, and a burner adapted to burn a fuel with oxygen, or with oxygen-enriched air, said burner being directly adjacent said burner head and communicably connected directly with said second conduit that is coaxial in the burner head with the first-mentioned conduit, for flow of hot combustion-products from said burner into said second conduit so that the hot combustion-products can be flowed into the endothermically reactive fluid oxide just immediately preceding its issue into the gasification chamber as the endothermically reactive fluid oxide.

2. Gasification apparatus adapted for gasification of finely-divided solid fuel in suspension in oxygen or oxygen-enriched air, comprising: a truncated cone shaped reactor; a burner head therefor at its smaller end; a conduit axially through said burner head for introducing finely-divided fuel in suspension along with oxygen axially of said burner head into the reactor chamber in the form of a jet spaced on all sides from the reactor walls; a second conduit in said burner head coaxially around said first conduit for introducing preheated fluid oxide endothermically reactive with hot carbon of the finely-divided solid fuel into said gasification chamber through the burner head and coaxially around the jet from the first conduit in an annular stream discharging along the walls of the reactor chamber so as to surround the jet from the first conduit in the form of a co-current flow as the jet from the first conduit issues into and ignites on entering the reactor; and combustion chamber means coaxial of and surrounding the second conduit, and discharging its combustion products directly into said second coaxial conduit for heating the endothermically reactive fluid oxide in its conduit just immediately preceding discharge thereof into surrounding relation with the jet from the first conduit.

3. Apparatus as claimed in claim 2 and in which the combustion chamber means comprises an annular series of combustion zones surrounding the second-mentioned conduit and discharging directly into the annulus of endothermically reactive media in the second-mentioned conduit.

4. Apparatus as claimed in claim 3 and in which the combustion zones discharge radially into the second conduit.

5. Apparatus as claimed in claim 3 and in which the combustion zones discharge tangentially into the second conduit.

6. Apparatus as claimed in claim 3 and in which an annular combustion media feed chamber is provided around the annular series of combustion zones which annular combustion media feed chamber is provided with

outlets for feeding fuel for gaseous combustion into the series of combustion zones.

7. Apparatus as claimed in claim 6 and in which an annular supply feed chamber is provided around the annular combustion-media feed chamber for supply of endothermically reactive media to the second conduit, and in which the annular supply chamber is provided with discharge pipes projecting through the annular combustion media feed chamber and through its outlets and terminating in the combustion zones for discharge of the endothermically reactive media around the combustion fuel media from the outlets during flow of the combustion fuel media and endothermically reactive media from their chambers through the combustion zones on their way to the second conduit for discharge into the reactor.

8. A continuous gasification process comprising flowing from a first conduit a pulverized solid carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of oxygen and oxygen-enriched gas into a reaction chamber, maintained at at least the ignition temperature of said fuel, in the form of a jet spaced on all sides of the jet away from the walls of the reaction chamber in such proportions that only part of the solid fuel is exothermically reacted with the oxygen of said gas and the remainder of the solid fuel is heated to a temperature for effecting the subsequent endothermic reaction of the unreacted fuel with an endothermic gasifying agent therefor selected from the group consisting of steam and carbon dioxide, flowing a mixture of said endothermic gasifying agent and hot combustion gases into an annular second conduit surrounding said first conduit and discharging said mixture from said second conduit into the same end of the reaction chamber coaxially of the jet and in a direction along the walls of the reaction chamber maintaining the endothermic gasifying agent and the unreacted hot solid fuel in the reaction chamber for a period of time sufficiently long to allow them to diffuse in relation to each other and thereby react, and removing the reaction products from the chamber.

9. A continuous gasification process comprising flowing from a first conduit a pulverized solid carbonaceous fuel and a free oxygen-containing gas selected from the group consisting of oxygen and oxygen-enriched gas into a reaction chamber, maintained at at least the ignition temperature of said fuel, in the form of a jet spaced on all sides of the jet away from the walls of the reaction chamber in such proportions that only part of the solid fuel is exothermically reacted with the oxygen of said gas and the remainder of the solid fuel is heated to a temperature for effecting the subsequent endothermic reaction of the unreacted fuel with an endothermic gasifying agent therefor selected from the group consisting of steam and carbon dioxide, preheating said endothermic gasifying agent by admixing it with hot combustion gases and flowing the mixture of said endothermic gasifying agent and hot combustion gases into an annular second conduit surrounding said first conduit and discharging said mixture from said second conduit into the same end of the reaction chamber coaxially of the jet and in a direction along the walls of the reaction chamber, maintaining the endothermic gasifying agent and the unreacted hot solid fuel in the reaction chamber for a period of time sufficiently long to allow them to diffuse in relation to each other and thereby react, and removing the reaction products from the chamber.

10. A process according to claim 9 in which the endothermic gasifying agent is introduced to the reaction chamber through an annular path in a burner head for the chamber while the pulverized fuel and free oxygen-containing gas flows axially and inside of the annular path through the burner head to the chamber and in which the endothermic gasifying agent and the hot combustion products are mixed by flow of the products of combustion directly into the annular path from an annular series of burners surrounding the annular path of flow of the endothermic gasifying agent and discharging directly into said annular path.

11. A process according to claim 10 in which the combustion products are discharged radially into the annular path.

12. A process according to claim 10 in which the combustion products are discharged tangentially into the annular path.

13. A process according to claim 10 in which the series of burners are fed with a mixture of oxygen and the endothermic gasifying agent by an annular flow thereof in an immediately surrounding relation concurrent with feed of fuel by an annular flow thereof, also in immediate surrounding relation therewith.

14. A process according to claim 10 in which the series of burners are fed with oxygen, fuel and endothermic gasifying agent individually.

15. A process according to claim 10 in which a part of the gasified product of the carbonaceous fuel is subjected to combustion to produce the hot combustion products.

16. A continuous gasification process comprising introducing pulverized normally solid carbonaceous fuel in a flow of a gaseous carrier medium along with oxygen into the small end of a truncated cone-shaped reaction chamber in the form of a jet spaced on all sides of the jet away from the walls of the reaction chamber wherein the jet is ignited as it enters the reaction chamber and a substantial portion of the carbon of said fuel is thus oxidized principally to carbon monoxide, leaving a substantial portion of carbon for subsequent endothermic reaction, preheating an endothermically reactive gasifying agent selected from the group consisting of steam and carbon dioxide by admixture with hot combustion gases, flowing the mixture of said endothermic gasifying agent and hot combustion gases into a second annular conduit surrounding said first conduit and discharging said mixture from said second conduit into the same end of the reaction chamber coaxially of the jet and in a direction along the walls of the reaction chamber, maintaining the endothermic gasifying agent and the unreacted hot solid fuel in the reaction chamber for a period of time sufficiently long to allow them to diffuse in relation to each other and thereby react, and removing the reaction products from the chamber.

17. A process according to claim 16 in which the endothermic gasifying agent is steam.

18. A process according to claim 16 in which the endothermic gasifying agent is carbon dioxide.

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