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PROCESS FOR PRODUCING GAS TURBINE FEED

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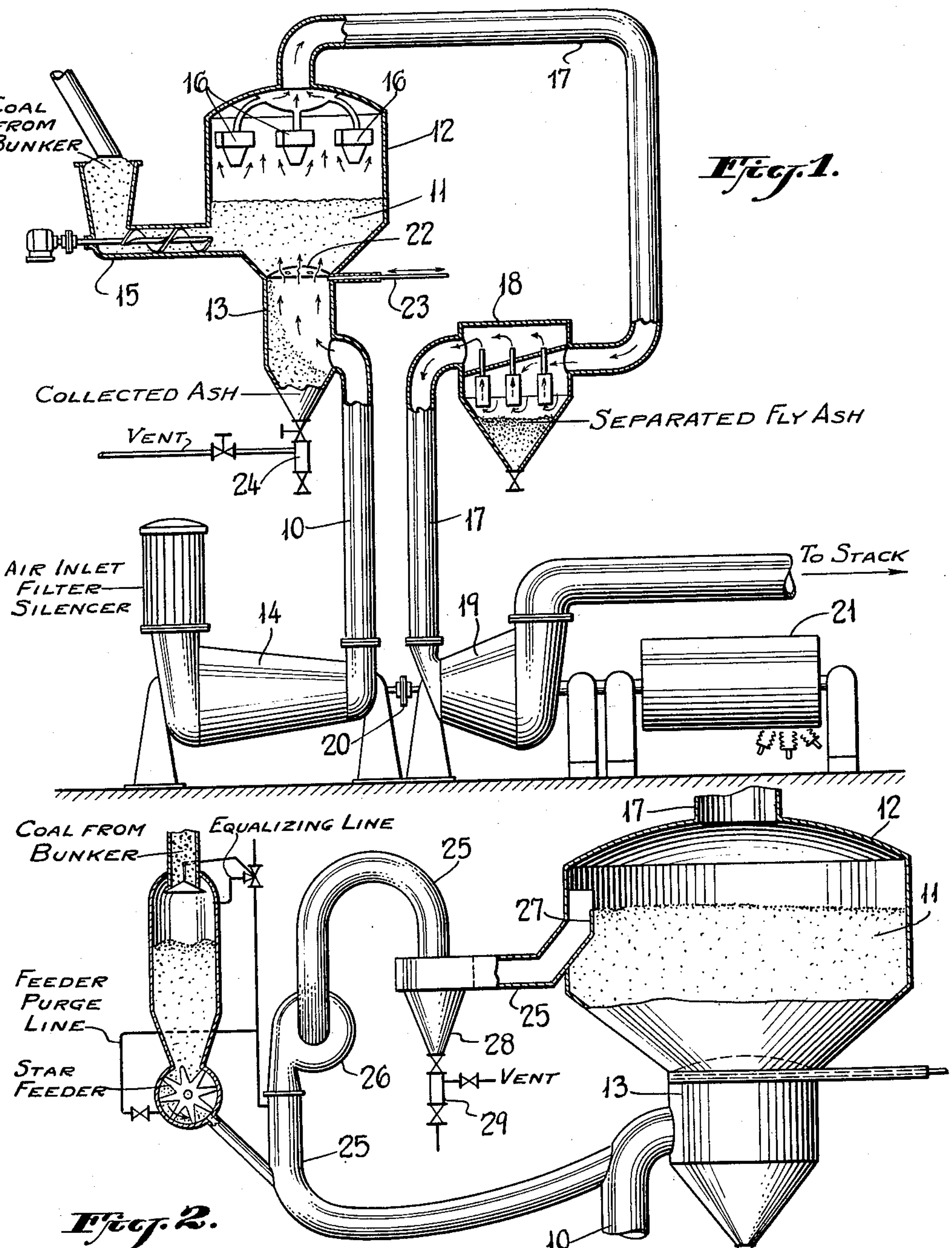


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# PROCESS FOR PRODUCING GAS TURBINE FEED

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This invention relates to a process for producing a hot, high-pressure gas stream suitable for use as the work medium for a gas turbine. More particularly, it is directed to a process for burning a finely divided solid carbonaceous fuel in the presence of air under pressure for producing such a stream.

Pulverized coal has been used heretofore as a fuel in the combustor of a gas turbine assembly, in which instance the coal and air are blown into a simple "can" type combustor similar to that originally developed for aviation gas turbines. To assure complete burning in such equipment the coal must be very finely divided, usually of the order of 95% through U.S. Sieve No. 200, or of a particle size smaller than about 74 microns, which of course requires extensive, high cost milling operations. Because of the extremely fine subdivision of the fuel, substantially its entire ash content is entrained in the hot gas stream leaving the combustor. To avoid erosion of the turbine blades, this fine ash must be removed from the gas stream. The required ash removal apparatus between the combustor discharge and the turbine is thus one or more large, unwieldy and expensive pieces of equipment. Because of this fine ash problem, firing of gas turbines with pulverized coal is still in the experimental stage.

The present invention eliminates many of the disadvantages of the "can" type combustor and burning effected in impinging air and pulverized fuel streams by providing a process whereby coal or other solid carbonaceous fuel of considerably larger size is burned in a fluidized bed in the combustor. The solid material in this fluidized bed consists primarily of inert material such as coal ash but also contains a small proportion of solid fuel dispersed throughout the inert material. The fuel in the bed is of course burned in the air passing through the bed so that all stages of its consumption are represented in the bed, from freshly introduced raw fuel to completely burned out ash. By burning in a fluidized bed as distinguished from in an open air stream, and because of the larger particle size of the fuel a much larger portion of the fuel ash is retained in the combustor, and the amount of fly ash leaving the combustor with the exit gases is greatly reduced. The establishment of a uniform diffuse dispersion of fuel particles in the generally inert solid material of the bed tends to maintain a uniform temperature therein.

In the drawings:

Fig. 1 is a diagrammatic sketch or flow sheet of apparatus arranged for carrying out the process of the present invention; and

Fig. 2 is a similar sketch illustrating a preferred method for removing inert material or ash from the fluidized bed and injecting finely divided solid fuel thereto.

In accordance with the present invention, a bed of finely divided solid material **11** is provided in a combustor **12** of generally cylindrical shape with a hopper portion **13** preferably of lesser diameter at its base, see Fig. 1. Initially the material making up the bed may be ash from the fuel to be burned, or a relatively inert material such as alumina or silica. In any event a noncombustible material is chosen that has a softening point in air at least as high as that of the ash of the coal to be used, which softening temperature will preferably be between about 1900° and about 2700° F. The material thus may be said to be inert and will be so referred to hereinafter. The inert material is of a particle size to permit fluidization of the bed. The terms "fluid" and "fluidized" are intended to denote the appearance of the bed under the influence of an upwardly rising gas stream passing therethrough. The bed appears to flow as a fluid, although composed only of solid particles. Obviously the degree of fine subdivision of the inert material will depend upon the bed density desired, the pressure of the air rising upwardly therethrough and to some extent upon its distribution through the bed, as well as upon the dimensions of the combustor.

The fluidizing air stream compressed to between about 60 and 150 p.s.i. in a rotary compressor **14** is introduced through a line **10** into the hopper above its base and flows upwardly into the combustor and through the bed. During compression the temperature of the air is of course raised substantially, for example, at a compressor discharge of about 90 p.s.i.a. the temperature of the air entering the combustor will be approximately 530° F.

With the bed in a fluidized condition, solid carbonaceous fuel in finely divided form is introduced below the upper surface of the bed, for example, through a worm feeder **15** or by other conventional solid fuel feeding means. It is important that the fuel be introduced below the upper surface of the fluidized bed in order to avoid substantial surface burning. Furthermore, the fuel is introduced at a rate such that the bed is predominantly inert material, containing only a minor portion of the solid fuel. The intense agitation of the particles making up the fluidized bed effects complete mixing of fuel and inert material, and the fuel is dispersed substantially uniformly throughout the bed. The fuel is then initially ignited by external means such as an auxiliary gas burner, and burns within the bed. Combustion of the fuel raises the temperature of the material making up the bed, and because of complete agitation bed temperature becomes substantially uniform throughout. Once the temperature has reached the ignition point of the fuel particles therein, the gas burner is cut off and the fuel being introduced burns readily.

Initially air introduced to the combustor, which is always in excess of that required to support complete combustion of the fuel, is substantially below bed temperature, however, it is heated through contact with and by radiation from the particles thereof. Uniform bed temperature effects even heating of the upwardly rising air, and the gases rising from the bed are at or about bed temperature.

The rate at which fuel is fed and ash or inert material removed from the bed are substantially the same, and the fuel particles are retained sufficiently long for their combustible content to be completely consumed. They are thus burned to dry ash particles, which ultimately replace the original inert material supplied to the bed at start-up. Once the fuel feeding rate has been established and the volume of upwardly flowing air maintained, bed temperature remains substantially constant. The temperature of the bed is preferably controlled by increasing or decreasing the rate of fuel feed rather than by control of the air, because the volume of air to be heated is governed by the turbine requirements, and flow through the bed is always in excess of that required to support complete combustion of the fuel.

Since combustion occurs in the bed containing a major portion of inert particles, the bed provides an effective ash filter, and the hot gas collecting near the combustor discharge contains substantially less entrained ash than gases produced by direct burning of pulverized fuel in a high velocity air stream. Nevertheless, the hot gases rising from the fluidized bed will entrain some dust, which may be separated by means of one or more cyclone separators **16** positioned in the upper portion of the combustor. The heated gas is discharged from the combustor through a line **17** in which, if desired, there may be placed a secondary dust separator **18**. Where such a separator is employed, it is considerably smaller than those now required in installations firing pulverized coal, for example, into an air stream. Clean, hot, high-pressure gas in line **17** is now available for expansion through a turbine **19**, which is provided with an output shaft **20** which drives a generator **21** for example. The turbine shaft also serves to drive air compressor **14**.

Again referring to the apparatus illustrated for practicing the process of the present invention, combustor **12** is provided with a perforated plate **22** in its base above the hopper portion thereof for distributing the upwardly rising air stream uniformly through the bed. The combustor is also provided adjacent and below the perforated distributor plate, with a simple gate device illustrated at **23** for gravity removal of ash from the bed to the hopper. The hopper is provided at its base with a conventional lock mechanism **24** through which collected ash is withdrawn from the system.

An essential feature of the process of the present invention is introduction of the solid fuel below the surface of the bed, as illustrated in Fig. 1. The specific gravity of the fuel is lower than that of the ash particles resulting from its combustion, and since the upwardly rising air stream is capable of keeping ash particles in partial suspension, introduction of fuel particles at or very near the surface of the bed results in the fuel being lifted completely out of the bed. It is also important that the fuel be so introduced as to avoid over-concentrations of fuel anywhere in the bed, thus avoiding hot spots where the temperature of the ash may exceed its softening temperature and clinkers may be formed. While multiple fuel feeders positioned about the combustor below the surface are generally satisfactory, the fuel is preferably introduced to the bottom of the bed by way of the upwardly rising air stream.

In the preferred process, a portion of the heated gas above the bed together with some of the material from the surface of the bed are withdrawn from the combustor through line **25** by means of an auxiliary blower **26** therein, see Fig. 2. In order to remove the desired quantity of material from the upper part of the bed, the combustor is desirably provided with an overflow weir **27**. A cyclone separator **28** or other suitable means are provided in line **25** intermediate the combustor and auxiliary blower for collecting the solids withdrawn, which are then removed separately as through bottom lock port **29**. Beyond the auxiliary blower, fuel is introduced to the rapidly moving gas in line **25** by means of a suitable feeder such as that illustrated in Fig. 2. The fuel now in line **25** is introduced to the upwardly rising pressurized air stream in line **10** before the same enters the combustor. Fuel is thus introduced to the bottom of the fluidized bed along with the incoming air. By introducing fuel to the coolest part of the bed, there is no danger of ignition before the fuel particles have become substantially uniformly dispersed throughout the bed. If desired, fuel may be introduced directly into the high-pressure air stream in line **10**. However, the method which employs a side stream for ash removal and indirect fuel feeding is preferred, not only for the reasons just noted but also because said method provides for positive ash removal from a part of the fluidized bed where little combustion is occurring, i.e., the portion of the bed which has the lowest concentration of combustion material, with bottom fuel feeding. Furthermore, it is not necessary that ash separation be complete in separator **28**, only that substantially the same volume of ash be removed from the bed as is equal to the ash produced from the fuel added to the system. Ash not separated is reintroduced to the combustor.

The process of the present invention permits the use not only of anthracite coal and lignite, which are free-burning fuels, but also of the agglutinating fuels, bituminous and sub-bituminous coals. The high concentration of ash or inert material in the fluidized bed acts as an interfering phase and prevents agglomeration of the agglutinating fuels. As indicated, the degree of subdivision of the fuel and inert material is not merely so fine as that required in the direct firing of coal into an air stream. In accordance with the present process the fuel need not be smaller than through U.S. Sieve No. 20 (particle diameter about 840 microns) up to as large as about 3/16 inch in diameter, depending of course upon bed density, air pressure and volume and other factors affecting fluidization of the bed. Of course fuel smaller than through U.S. Sieve No. 20 may be used if desired, but it must be remembered that the smaller the particle size of the fuel and consequently the inert material of the bed, the less efficient the filtering action of the bed, and the more complex the problem of separating ash from the heated gases.

As an illustration of the present process, where it is desired to produce a gas stream for introduction to a turbine at about 1450° F., about 98 pounds per second of air at about 94 p.s.i.a. (20,800 c.f.m.) and about 530° F. is introduced through a bed of material in the combustor and fluidization is effected. Coal (8000 B.t.u./lb.) is introduced to the bottom of the fluidized bed at about 3.2 lbs./sec., and ash is removed from the upper surface of the bed. Through combustion of fuel, which is approximately 95% complete, the temperature of the air is raised about 920° to 1450° F. Under these conditions, gas flow from the combustor outlet is approximately 100 pounds per second (47,400 c.f.m.) at a temperature of 1450° F.

What is claimed is:

1. A process for producing a hot, high pressure turbine gas stream, which comprises providing a bed of finely divided inert material in a combustor, introducing finely divided solid carbonaceous fuel to said bed below the upper surface thereof, introducing an upwardly directed stream of high pressure air adjacent the bottom of said bed, thereby fluidizing the bed, the quantity of air thus introduced being in excess of that required to provide complete combustion of said solid fuel and the volume of said air per unit time being substantially constant, burning the fuel in said bed thereby raising the temperature of said air, collecting the thus heated upwardly moving air and combustion gases above said bed, separating entrained non-combustibles therefrom, discharging the thus heated gases from the combustor, controlling the temperature of the discharging gases by controlling the rate at which said solid fuel is fed to the bed, and withdrawing from the combustor at the upper surface of the bed a stream consisting of a minor portion of the heated upwardly moving air and combustion gases and a minor portion of the solid material from the bed, separating a major portion of the solids from said stream and returning the gaseous stream with still entrained solids to said combustor.

2. A process as set forth in claim 1 wherein the returning gaseous stream with entrained solids is introduced to the upwardly directed high pressure air stream below said bed.

3. A process as set forth in claim 2 wherein the solid carbonaceous fuel is introduced to said returning gaseous stream prior to merger with the upwardly directed high pressure air stream.

4. A process for producing a hot, high pressure turbine gas stream of substantially constant volume per unit time,

which comprises providing a bed of finely divided inert material in a combustor, introducing finely divided solid carbonaceous fuel to said bed below the upper surface thereof in amount such that said solid fuel constitutes only a minor portion of the bed, introducing a stream of high pressure air upwardly through the bed thereby fluidizing the same, the quantity of air thus introduced being greatly in excess of that required to effect complete combustion of said solid fuel and the volume of said air per unit time being substantially constant, burning the solid fuel in the fluidized bed thereby raising the temperature of said air, collecting heated gases consisting of a major portion of air and a minor portion of combustion gas above said bed and discharging said heated gases from the combustor at substantially constant volume per unit time, controlling the temperature of the discharging heated gases by controlling the rate at which said solid carbonaceous fuel is introduced to said bed while maintaining substantially constant the volume of air per unit time introduced upwardly therethrough, and withdrawing



from the combustor a minor portion of the solid material of the fluidized bed at a rate so related to the rate of introduction of solid carbonaceous fuel thereto as to maintain the volume of said bed substantially constant.

5. A process as set forth in claim 4, wherein the minor portion of solid material withdrawn from the combustor is withdrawn at the upper surface of the fluidized bed along with a minor portion of heated gases above said bed.


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