

[54] **PROCESS WITH FLUIDIZED COMBUSTOR AND FLUIDIZED HEAT EXCHANGER FOR AIR**

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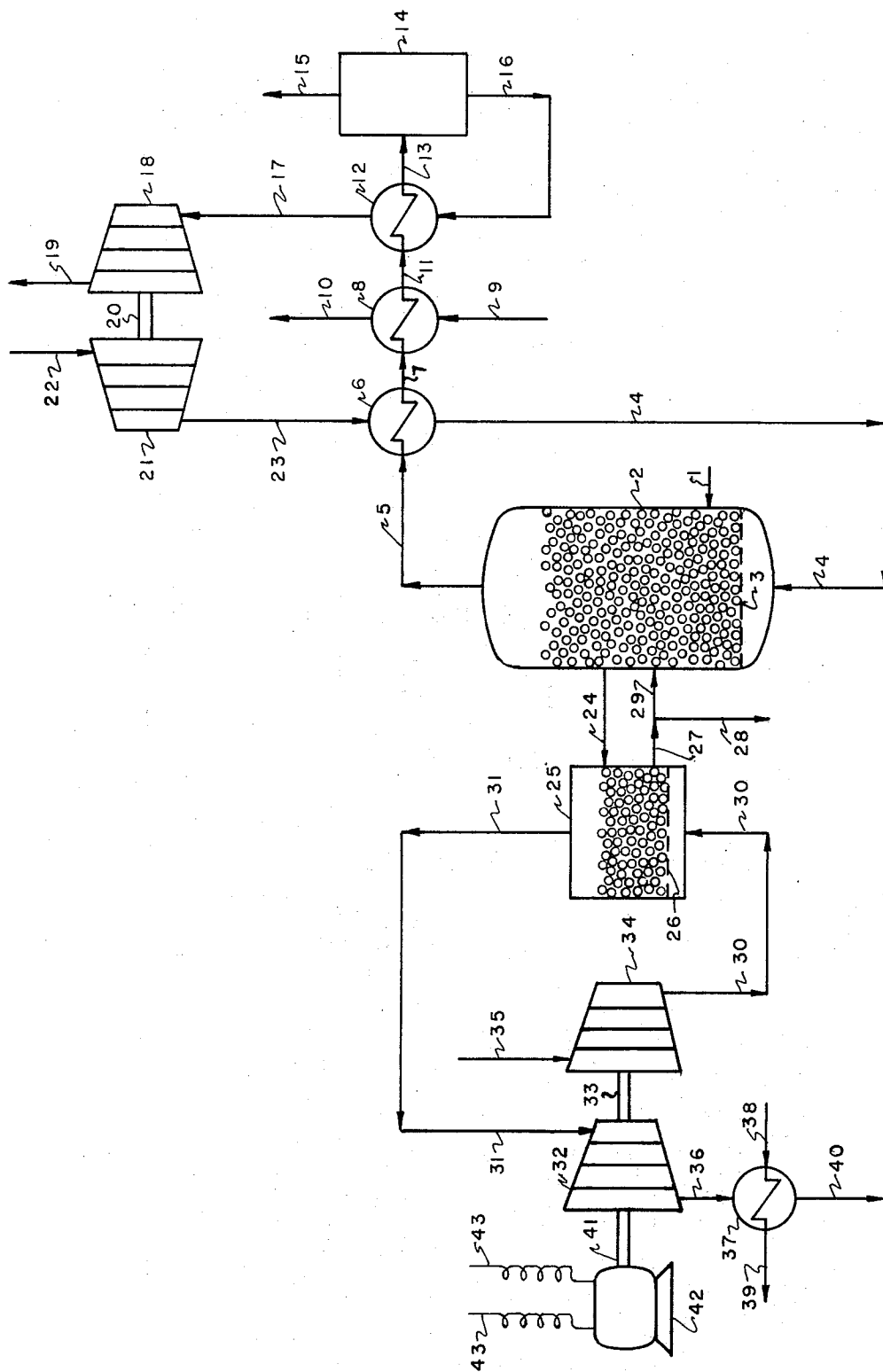
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[57] **ABSTRACT**

Carbonaceous fuels are burned in a high pressure fluidized bed combustor to produce a hot sinter or ash which is passed to a fluidized bed heat exchanger for direct contact with pressurized air. The resultant heated pressurized air is expanded through a gas turbine which drives an electrical generator.

10 Claims, 1 Drawing Figure



PROCESS WITH FLUIDIZED COMBUSTOR AND FLUIDIZED HEAT EXCHANGER FOR AIR

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The invention relates to the production of electrical power by the combustion of ash-containing carbonaceous fuels.

2. Description of the Prior Art:

The production of electrical power by burning carbonaceous fuels such as coal to generate steam, which is expanded through steam turbines which drive electrical generators and thereby produce electrical power, is a well established commercial procedure widely practiced in steam power plants. The combustion of carbonaceous solids in a fluidized bed is described in U.S. Pat. No. 3,171,369.

SUMMARY OF THE INVENTION

In the present invention, a carbonaceous fuel such as coal is burned in a pressurized fluid bed combustor, under conditions which produce agglomeration of the ash particles which join the fluidized bed. A portion of the hot ash or sinter is withdrawn from the fluid bed combustor and passed in direct heat exchange fluid bed contact with compressed air which is thereby heated. The heated compressed air is expanded through a gas turbine which drives an electrical generator to produce power.

The combustion of coal in an agglomerating bed under pressure produces a combustion effluent gas containing a minimum of fly ash, but the ash loadings are still above the levels allowable for existing gas turbines. In the present invention, a modification of this approach gives a clean gas which can be used to run a turbine. The hot sinter from the combustor moves to a fluid bed direct contact heat exchanger, and the hot sinter cascades through the exchanger. Compressed air fluidizes the sinter and is heated towards 1100°C. The hot air is expanded through a gas turbine which drives an electrical generator to produce power. The gas turbine may also drive one or more air compressors. The hot expander or gas turbine outlet gas may be passed in indirect heat exchange with water to make steam, or may be used to superheat the compressed air. The hot sinter from the combustor can be dedusted by flowing against a portion of the combustor feed air if necessary. This may be necessary as a general rule as a guard against combustor upset and poor ash agglomeration.

The net result and advantage of the invention is that the heat liberated from coal combustion produces very hot clean pressurized air using a very cheap fluid bed direct contact heat exchanger, and the hot air is usefully employed by expansion through a gas turbine to drive an electrical generator and thereby produce electrical power.

It is an object of the present invention to provide an improved process for producing electrical power by the combustion of a carbonaceous fuel.

Another object is to provide clean hot compressed air in an improved manner for the actuation of a gas turbine.

A further object is to heat compressed air in an improved manner using combustion of an ash-containing carbonaceous fuel as a heat source.

Another object is to generate heat for the elevation of the temperature of compressed air in an improved manner.

Still another object is to effectively utilize hot sinter from a fluid bed combustor in which carbonaceous fuel is burned to produce an agglomerate sinter or ash.

These and other objects and advantages of the present invention will become evident from the description which follows.

DESCRIPTION OF THE DRAWING AND PREFERRED EMBODIMENTS

Referring now to the drawing, a flowsheet of a preferred embodiment of the invention is presented. Carbonaceous fuel stream 1 is passed into a fluid bed consisting essentially of agglomerated ash within the fluid bed combustor 2. Stream 1 may consist of an ash-containing liquid fuel such as crude oil, liquid asphalt, a residual oil derived from petroleum refining, a fuel oil or gas oil. In other instances stream 1 may consist of a solid fuel such as various types of coal including anthracite, bituminous, sub-bituminous or lignite or the like, or coke, slack, solid asphalt or pitch. In any case, stream 1 is passed into the fluid bed within unit 2 above lower foraminous grate 3. The fluid bed consisting of a fluidized combustion zone within unit 2 is generally maintained at an elevated pressure, typically in the range of about 5 kg./sq. cm. to 20 kg./sq. cm., and an elevated temperature, generally in the range of about 1000°C to 1300°C, is maintained within unit 2 by the combustion of stream 1 with compressed air stream 4, which is admitted into unit 2 below grate 3 at a pressure typically in the range of about 5 kg./sq. cm. to 20 kg./sq. cm.

The process air stream 4 rises through the fluid bed within unit 2 and maintains fluidization of the bed. In addition, the combustion of stream 1 within the bed serves to generate heat and maintain elevated temperature within the bed, as well as forming an ash which becomes sticky or tacky and at least partially agglomerated in the fluid bed within unit 2. The agglomeration of the ash within unit 2 serves to effectively curtail or prevent the entrainment of fine ash particles in the hot gas containing gaseous combustion products such as carbon dioxide and sulfur dioxide, which rises from the bed within unit 2 and is withdrawn via upper hot product gas stream 5.

Stream 5 is withdrawn from the top of unit 2 at an elevated temperature typically in the range of about 1000°C to 1300°C, and stream 5 contains only a very minor proportion of entrained fine ash particles. In some instances, stream 5 may be essentially devoid of ash. In any case, stream 5 is also at an elevated pressure typically in the range of 5 kg./sq. cm. to 20 kg./sq. cm., and stream 5 is now processed for heat and power recover as well as sulfur dioxide removal.

Stream 5 passes through indirect heat exchanger 6, which is typically of shell and tube configuration or the like, and stream 5 is cooled by heat exchange with compressed process air, which is discharged from unit 6 via stream 4 at an elevated temperature typically in the range of 200°C to 500°C. The partially cooled gas stream 7 which is also discharged from unit 6 is passed into boiler or steam generator 8, and is further cooled by indirect heat exchange with liquid water stream 9, which is thereby heated and vaporized to form steam stream 10.

The further cooled gas stream 11 discharged from unit 8 now passes through gas-to-gas heat exchanger 12 and is fully cooled by heat exchange with gas which has been treated for sulfur dioxide removal, as will appear infra. The fully cooled gas stream 13 discharged from unit 12 is now at a reduced temperature typically in the range of 50°C to 200°C, and stream 13 is passed into sulfur dioxide removal unit 14, which is provided in order to remove sulfur dioxide from the gas stream and thereby prevent air pollution. Unit 14 is typically a scrubbing tower or venturi scrubber or the like in which the gas stream is contacted with an aqueous alkaline solution or slurry, containing an alkaline compound of sodium, potassium, calcium, magnesium, barium or the like, which absorbs sulfur dioxide from the gas stream in the form of an alkali sulfite or bisulfite. Typical procedures of this nature are described in U.S. Pat. Nos. 3,653,823; 3,650,692; 3,632,306; 3,622,270; 3,617,212; 3,607,033; 3,607,001; 3,600,131; 3,577,219; 3,542,511 and 3,533,748. Typical types of venturi apparatus configurations for attaining contact of the gas stream 13 with a scrubbing liquid or slurry in unit 14 are described in U.S. Pat. Nos. 3,638,925; 3,584,440; 3,567,194; 3,544,086; 3,440,803 and 3,085,793. The operation of sulfur dioxide removal in unit 14 will also serve to remove substantially all of the fly ash or dust particles from the gas stream.

Separated sulfur dioxide is passed to product utilization or sales via stream 15. In some instances, sulfur dioxide-containing stream 15 may be passed to a sulfuric acid production facility for conversion to sulfuric acid. In other instances, stream 15 may be cooled via refrigeration to condense product liquid sulfur dioxide for sales.

The resulting cooled and substantially sulfur dioxide-free gas stream 16 produced by unit 15 is at elevated pressure, and stream 16 is now reheated and expanded through mechanical power recovery means to generate usable power. Stream 16 is reheated in unit 12 by indirect heat exchange with stream 11, and the resulting reheated clean gas stream 17 is expanded to atmospheric pressure through gas turbine 18 and is then discharged to atmosphere via stream 19. Turbine 18 is connected via shaft 20 with air compressor 21, which compresses ambient air stream 22 to form compressed air stream 23 which is passed through unit 6 and heated to form stream 4.

Returning to unit 2, a hot solids stream 24 consisting of agglomerated ash particles at an elevated temperature typically in the range of about 1000°C to 1300°C is withdrawn from the fluid bed within unit 2 and utilized in accordance with the present invention. Stream 24 is passed into a fluidized bed of ash particles within the fluidized heat exchange zone 25, which is provided with a lower support grate 26. The hot ash particles are cooled in the fluid bed within unit 25 by direct contact heat exchange with air, as will appear infra. Cooled ash particles are withdrawn from the fluid bed within unit 25 via lower outlet stream 27, which is typically at a temperature in the range of about 150°C to 350°C. Stream 27 is divided into bleed stream 28, which is removed from the system and passed to disposal to prevent buildup of excessive solid ash in the system, and stream 29 which is recycled to the fluid bed within unit 2.

The counter current heat exchange between air and hot solids may be achieved by several routes such as

fluidized beds operating in series, a single fluid bed operating just above minimum fluidization velocity, a moving bed or combinations of the above. The preferred mode is operation at just above minimum fluidization velocities where the bed moves downward without mixing yet evenly over its cross section because of its liquid like behavior.

Compressed air stream 30, which is at an elevated pressure typically in the range of about 5 kg./sq. cm to 20 kg./sq. cm and a temperature generally in the range of about 100°C to 300°C, is passed into unit 25 below grate 26 in accordance with the present invention, and the air stream rises through unit 25 and is heated by contact with the hot agglomerated ash particles. Essentially none of the ash is entrained in the air, and a high temperature air stream 31 is withdrawn from the upper end of unit 25 at a temperature typically in the range of about 900°C to 1200°C. Stream 31 is thus produced at high temperature and pressure and is essentially devoid of entrained solid particles, and stream 31 is eminently suitable for utilization in a gas turbine for power generation.

Stream 31 is now passed through mechanical power recovery means, which in this embodiment of the invention consists of the gas turbine 32. The hot high pressure air expands within turbine 32 and drives unit 32 which produces useful power. Unit 32 is also preferably connected via shaft 33 to air compressor 34, which compresses ambient air stream 35 to elevated pressure to form stream 30.

Returning to unit 32, the resulting low pressure hot air stream 36 is discharged from gas turbine 32 and passed through heat exchanger 37 for the recovery of available heat. In this embodiment of the invention unit 37 is a steam boiler, and water stream 38 is passed into unit 37 for indirect heat exchange with the hot air. The water stream 38 is thus heated and vaporized to form steam stream 39. The cooled low pressure air stream 40 discharged from unit 37 may be passed to atmosphere discharge.

In accordance with the present invention, unit 32 is connected via shaft 41 to electrical generator 42 and drives unit 42 to generate usable electric power which is passed to utilization via power lines or wire 43.

Numerous alternatives within the scope of the present invention will occur to those skilled in the art. Streams 9 and/or 38 may consist of steam which would be superheated in the respective units 8 or 37. The steam streams 10 and/or 39 may be expanded through a steam turbine or turbines to generate power, or streams 10 or 39 may be employed for heating purposes, process usage or the like. Streams 36 or 5 or both may be passed in indirect heat exchange with stream 30 in order to superheat the compressed air stream 30. The hot sinter stream 24 from the combustor can be dedusted by flowing against a portion of the combustor feed air stream 4 if necessary. This may be necessary as a general rule as a guard against combustor upset and poor ash agglomeration. Unit 42 converts the energy in excess of the process requirements to electric power. Alternate modes of interlocking the several compressors and expanders will be obvious to those familiar with combined cycle power applications.

An example of commercial application of the present invention will now be described.

EXAMPLE

Following are point values for a typical installation. Heat fluxes are thermal energy above 100°F.

Stream No.	Temp. °F	Pressure psig.	Heat Flux 10 ³ BTU/hr	Flow Rate Tons/hr
1				200
4	1000	180	11	154,000*
5	2000	170	23	
7	1450			
10	900	600	10.5	
11	1100			
13	320	150		
15				6**
16	120	140		
17	900	125	9.7	
19	300	0	2.4	
23	450	185	4	
24	2000			5,000
27		600		
28				18
30	450	185	8.5	335,000*
31	1950	170	45	
36	1000	5		
39	900	600	22	
40	300	0	5	

*mols

**as elemental sulfur

Note: In this design for a commercial facility, compressor 21 was omitted and compressor 34 furnished both streams 28 and 30. Steam streams 10 and 39 were combined and expanded through a steam turbine, not shown, which was connected with generator 42 on a shaft linked with shafts 41 and 33.

We claim:

1. A process for producing electrical power by the combustion of a carbonaceous fuel which comprises
 - a. introducing said carbonaceous fuel into an elevated pressure fluidized combustion zone, said fluidized combustion zone containing at least one bed of fluidized ash particles,
 - b. passing a first compressed air stream into said combustion zone, whereby said bed is fluidized and said fuel is burned in said fluidized bed to produce a substantially solids-free hot gas containing combustion products, and whereby ash from fuel combustion is agglomerated and added to said bed,
 - c. withdrawing said hot gas from said combustion zone,
 - d. passing hot solids from said fluidized combustion zone to a fluidized heat exchange zone,
 - e. passing a second compressed air stream into said fluidized heat exchange zone, whereby said second air stream is heated and said hot solids are cooled,

f. recycling the cooled solids produced by step (e) to said combustion zone,

g. expanding the heated second air stream through mechanical power recovery means, said mechanical power recovery means being connected with and driving an electrical generator, and

h. withdrawing electrical power from said electrical generator.

2. The process of claim 1, in which said carbonaceous fuel is an ash-containing liquid fuel selected from the group consisting of crude oil, liquid asphalt, petroleum refining residual oil, fuel oil, and gas oil.

3. The process of claim 1, in which said carbonaceous fuel is a solid fuel selected from the group consisting of coal, lignite, coke, slack, anthracite, solid asphalt, and pitch.

4. The process of claim 1, in which said fluidized combustion zone and said fluidized heat exchange zone are maintained at a pressure in the range of about 5 kg./sq. cm. to 20 kg./sq. cm.

5. The process of claim 1, in which said fluidized combustion zone is at a temperature in the range of about 1000°C to 1300°C, said second air stream is heated from an initial temperature in the range of about 100°C to 300°C to a higher temperature in the range of about 900°C to 1200°C, and said cooled solids are recycled at a temperature in the range of about 150°C to 350°C.

6. The process of claim 1, in which said hot gas withdrawn from said combustion zone is cooled by indirect heat exchange with a fluid selected from the group consisting of compressed air, steam and water.

7. The process of claim 6, in which said fluid is compressed air, and the heated compressed air is passed to said fluidized combustion zone to fluidize said bed and support combustion.

8. The process of claim 1, in which said mechanical power recovery means is a gas turbine.

9. The process of claim 1, in which said mechanical power recovery means is connected with a drives a compressor, the input fluid to said compressor being ambient air which is compressed to form said second compressed air stream.

10. The process of claim 6 in which the cooled gas produced by said indirect heat exchange is expanded through a gas turbine, said gas turbine being connected with and driving a compressor, the input fluid to said compressor being ambient air which is compressed to form said first compressed air stream.

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