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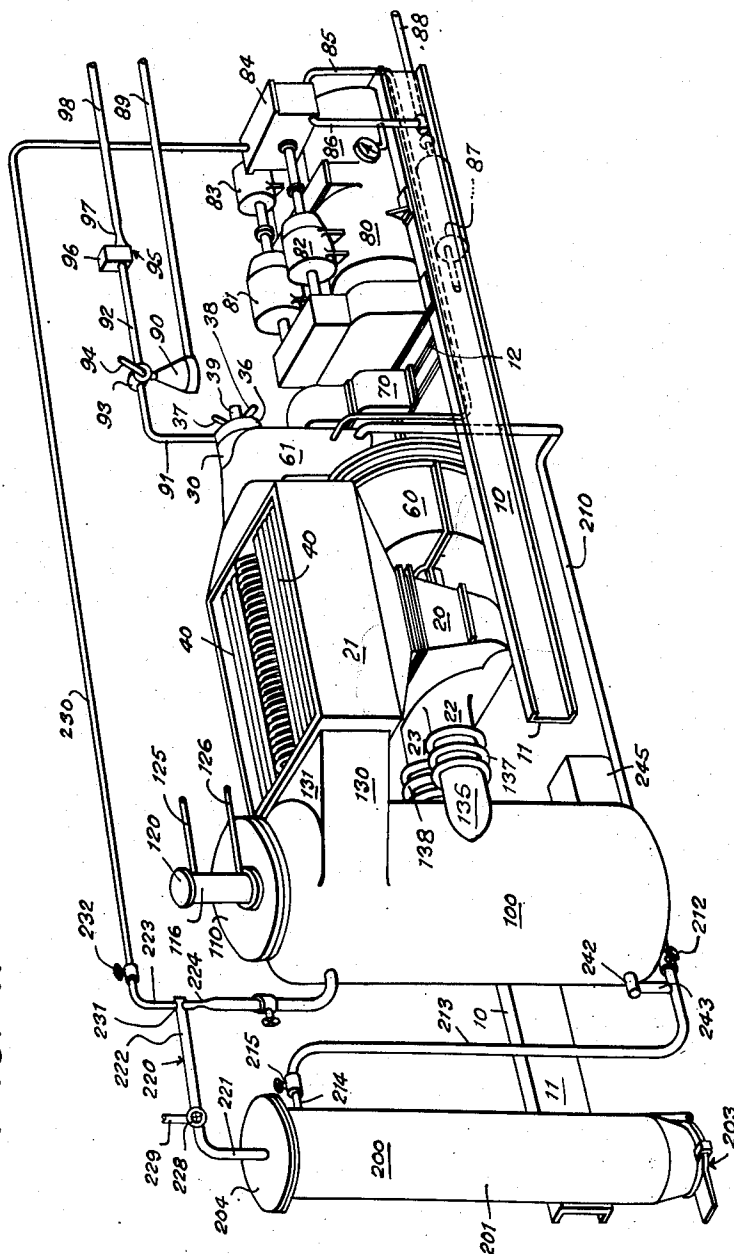
J. I. YELLOTT
ASH HANDLING SYSTEM FOR HIGH-PRESSURE
COMBUSTION OF PULVERIZED SOLID FUELS

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2 Sheets-Sheet 1

FIG. 1.



INVENTOR.
JOHN I. YELLOTT
BY
Frederick A. Norton
ATTORNEY

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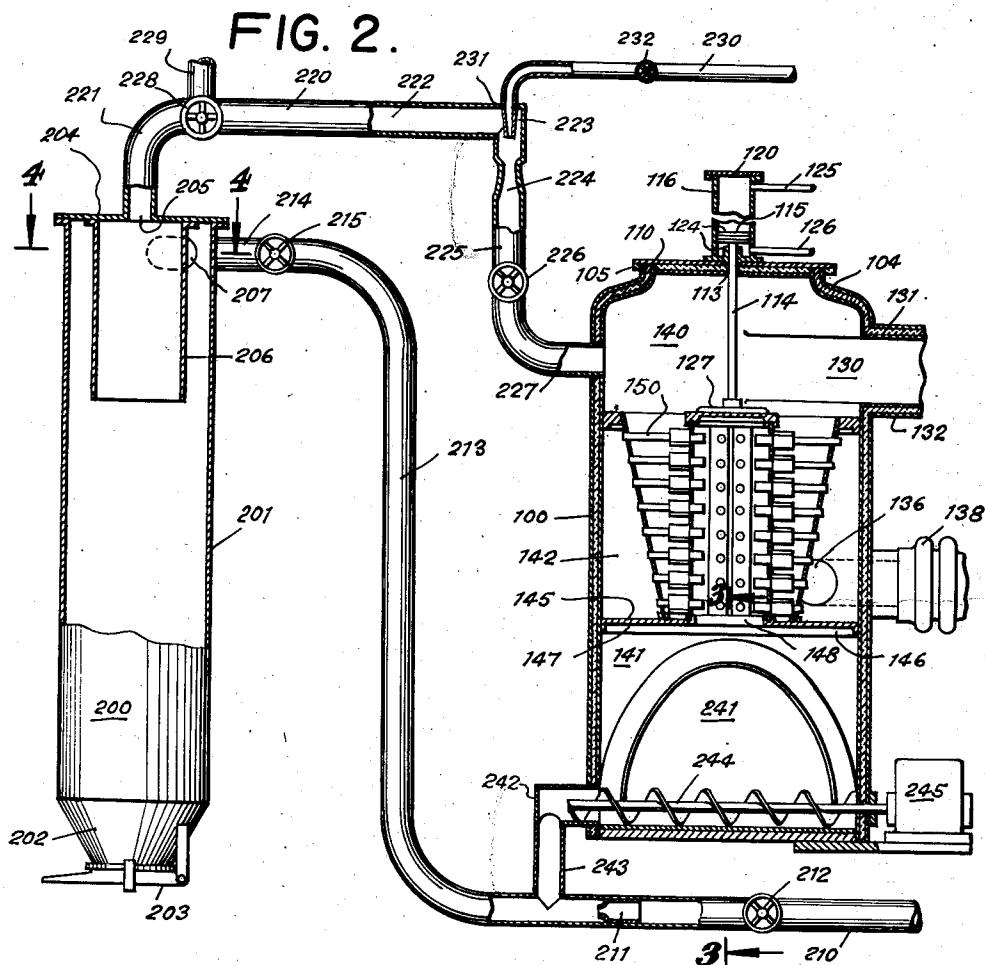


FIG. 3.

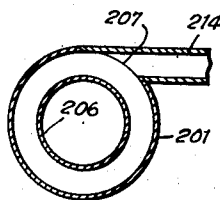
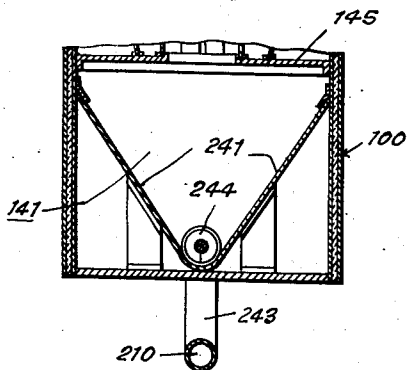


FIG. 4.

INVENTOR.
JOHN I. YELLOTT
BY
Frederick A. Norton
ATTORNEY

UNITED STATES PATENT OFFICE

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ASH HANDLING SYSTEM FOR HIGH-PRESSURE COMBUSTION OF PULVERIZED SOLID FUELS

John I. Yellott, Cockeysville, Md., assignor to
Bituminous Coal Research, Inc., Washington,
D. C., a corporation of Delaware

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5 Claims. (Cl. 60—39.46)

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This invention relates to improvements in the pressurized combustion of pulverulent solid fuels, and, more particularly to a novel system and apparatus for cooling and conveying hot fly-ash separated from the gaseous products of combustion of pulverulent fuel.

In my Patent No. 2,583,921 of January 29, 1952, I have shown and claimed a special pressurized combustion system, including novel means for separating fly-ash from the gaseous products of combustion of pulverulent fuel.

I have now found that the fly-ash derived from the pressurized combustion of pulverulent fuel should be cooled as rapidly as possible to a temperature below the ignition temperature of any uncombusted oversize fuel particles and of the unburned carbon which is commonly contained in fly-ash.

It is, therefore, among the features of novelty and advantage of the present invention to provide a fly-ash cooling and treating system which will permit the continuous removal of superheated fly-ash from a fly-ash separator and discharge of the same in a pressurized stream of relatively cool air into a container, the coolant air with the heat units derived from the now cooled fly-ash being returned to the system as added motive gases, or discharged to the atmosphere, while the stored fly-ash, being relatively cool, is not subject to burning or clinkering.

The features of novelty and advantage of the present invention which have been indicated hereinabove, will be more readily comprehended by reference to the following specification and accompanying drawings, wherein there is disclosed a generating electric power plant embodying a pulverized coal-fired gas turbine installation incorporating a novel fly-ash separator, and in which like numerals refer to similar parts throughout the several views, of which

Fig. 1 is a perspective view of a generating electric power plant embodying a gas turbine, a fly-ash separator, coal-fired combustor, and a fly-ash cooling device;

Fig. 2 is a detail view, partly in vertical section and partly in elevation, of the fly-ash separator and cooler showing the inter-connections therebetween;

Fig. 3 is a vertical section taken on line 3—3 of Fig. 2, showing the fly-ash discharge means from the bottom of the fly-ash separator, and

Fig. 4 is a horizontal section taken on lines 4—4 of Fig. 2, showing the inlet into the fly-ash cooler and separator.

In the gas turbine-generating electric power

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unit shown in Fig. 1, and more particularly claimed in my application Serial No. 746,818, filed May 8, 1947, now Patent No. 2,583,921, issued January 29, 1952, the power plant comprises a bed or base 10 of spaced parallel everted channels 11, secured by interposed cross-bracing members, designated generally by the numeral 12. When used in a locomotive, the bed may be integral with the locomotive frame. The power unit comprises a gas turbine 20, an air compressor 60, and a generator 80 coupled to the turbine shaft through gear box 70. Gas turbine 20 has an exhaust stack 21 in which is mounted a combustor 30 and two banks of regenerator tubes 40 on either side of the combustor unit. A pair of inlet ducts 22, 23 connect the turbine to a fly-ash separator 100. Separator 100 is secured between the frame members 11 in any suitable manner. An air compressor 60 is mounted on the turbine shaft and discharges moderate pressure air of the order of 60 to 100 p. s. i. through ducts 61 into the combustor and regenerator tubes, as will be described more in detail hereinafter. Gear box 70 serves to couple the turbo-compressor shaft to generator unit 80, mounting auxiliary generators 81, 82 thereon. The auxiliary generator 81 serves to power auxiliary equipment, including a field generator or exciter 83 for the main generator 80. Auxiliary generator 82 is D. C. wound and the same shaft powers the high pressure booster compressor 84. This booster compressor, or auxiliary air pump, is connected through line 85 to the pressure or discharge side of compressor 60, as shown in Fig. 1. Booster compressor 84 discharges through line 86 and a T connection to an auxiliary high pressure air tank 87, and a separate high pressure air line 88. The pressure tank 87 can also serve as a reservoir for air-brake air, and for other equipment, such as bell ringers, sanders, control equipment, and the like.

The coal utilized for combustion is fed from supply means, not shown, by high pressure air line 88, the streaming entrainment of fluidized solid particles being delivered through line 89 and coal atomizer 90 to feed line 91 of combustor 30. A by-pass for the air-borne coal from feed line 89 back to the storage hopper, not shown, is provided by line 92, which is connected to the atomizer 90 through two-way valve 93. This arrangement permits the discontinuance of the coal feed and, conversely, the initiation of the coal feed, as when the turbine is first being started, after being initially supplied with gaseous or liquid fuel.

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An aspirator 95 having a relatively large open chamber 96 is connected to the tip or discharge end 97 of dump line 92, the discharge end being preferably reduced, aligned with, and discharging into line 98 through the aspirator 95, the other end of the line 98 discharging into the crushed coal hopper, not shown. When, as in the case of an emergency stop, or when shutting down the engine at the end of a run, or for any other reason (as indicated above), the fluidized solid fuel supply in high pressure line 89 is diverted through the atomizer into line 92 by operating valve lever 94, any excess temperature possessed by the coal contained therein is reduced by contact with an excess of ambient air of low temperature inducted through the chamber 95, aspirated through constriction 97 into line 98. This operation effectually cools the heated pressurized, fluidized pulverulent fuel mass which has been previously heated by contact with the high pressure atomizing air. This discharged pressure air, now reduced in pressure and effectively cooled to a temperature below the danger point of spontaneous combustion, with its pulverulent coal, which forms a very fine powder, is discharged into the hopper (not shown) and prevented from discharging directly into the atmosphere.

Because of this novel safety feature, fire or explosion hazards in the operation of the novel pressurized combustion system herein, are reduced below any danger point, even under conditions of shock such as can obtain in train wrecks and the like.

The combustor 30 in its combination with the compressor 60, turbine 20, exhaust stack 21, regenerator tube banks 40, and the fly-ash separator 100, is more particularly shown and claimed in my said Patent No. 2,583,921 and will be described herein only in sufficient detail to point out the novel elements of the system forming the present invention. The combustor 30 discharges directly into the plenum chamber of the fly-ash separator 100. At the fuel inlet end the combustor is provided with a cap or cover 36. The closure or cap member 36 will receive the fuel supply pipe 91, which introduces pulverized fuel into the flame tube in a pressurized, air-borne stream. The cap 36 is provided further with a fluid fuel inlet tube 37 for introducing liquid or gaseous fuel for starting the turbine, and a second fuel pipe 38 is provided for the introduction of a liquid or gaseous fuel to serve as a pilot light or igniter for the system. A sight tube 39 is also provided adjacent to the flame carrier, so as to permit inspection thereof. For remote inspection and control, the sight tube may be provided with a suitable alarm system. A photoelectric cell, or other flame-and-heat-responsive device may be connected thereto, suitable connections to the instrument board of the system being provided.

The fuel delivered through coal atomizer 90 and feed pipe 91 to the combustor 30, will be combusted therein and the products of combustion will be diluted in the upper mixing chamber of fly-ash separator 100 by the extra, relatively cool air delivered through ducts of the combustor casing and the air delivered through the tube sheets of the regenerator banks 40. The details of the novel fly-ash separator will be described.

As shown in Fig. 2, the fly-ash separator comprises a generally cylindrical, laminated pressure vessel 100, having an outer steel wall, an inner stainless steel heat-resistant lining, and an intermediate or internal insulation filler between the

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two wall sections. The upper end of the cylinder is necked in, as indicated at 104, to form a man hole 106. The neck 104 is provided with an everted flange 105 whose function will be described more in detail hereinafter. A top cover 110 is fitted into the top opening or man hole 106, and secured in place on the flanges 105 by means of bolts and nuts, not shown. The top cover is of the same material as the bottom cover and the wall of the container. The cover 110 is centrally apertured to receive shaft 114 of piston 115, which, as shown, is mounted for reciprocation in cylinder 116 having a closed bottom with a central boss centrally apertured to receive the shaft 114 in sliding bearing engagement. The outer portion of the central boss is received in a conformed aperture in the cover 110, and the cylinder is secured to the cover by machine screws, not shown, passing through the flanged base and into the top cover section. The upper end of the piston cylinder is closed by a removable plate 120, secured in place by the usual bolts and nuts, not shown. The piston 115 divides the piston cylinder into an upper chamber and a lower chamber, which are severally connected to suitable sources of fluid supply by pipes 125, 126, respectively. A closure disc 127, having a beveled seat is fixedly mounted on shaft 114. The disc 127 is adapted to be lifted up by the shaft 114 when piston 115 is urged upwardly by fluid pressure in the chamber 124. The function of the closure disc 127 will be described more in detail hereinafter in connection with the particular description of the separator tube assembly.

An inlet chamber 130 connects the upper portion of the cylinder 100 with the combustor discharge and the regenerator discharge outlets. The inlet duct or passageway 130 is provided with parallel top and bottom walls 131, 132 and outwardly flaring side walls, formed as a unit with the fly-ash separator, and secured to the exhaust stack of the turbine in pressure-tight relation. A pair of parallel outlet ducts 135, 136 are formed in the wall of the container immediately below the duct 130 and are disposed somewhat below the middle of the vessel. These ducts are severally connected to the inlets 22, 23 of the gas turbine by flexible coupling members 137, 138. Internally, the chamber or vessel 100 is divided into three sections: an upper plenum chamber 140, a bottom fly-ash receiving chamber 141, and an intermediate cleaned gas-receiving chamber 142, which discharges into the outlets 135, 136.

The plenum chamber and intermediate cleaned gas receiving chamber, together with the fly-ash flue chamber and the cyclone separators 150, are all described and claimed in my Patent No. 2,583,921, of January 29, 1952, above identified, and will not be described further hereinafter.

In the fly-ash separator, the special construction and arrangement is such that the effects of any explosion are minimized due to the excess venting area of the system, as set forth and claimed in my above said Patent No. 2,583,921.

In the instantaneous burning of coal dust, a maximum rise of 3000° F. can occur. Since the normal operating temperature of the air in the inner chamber 141 will be about 1300° F., or 1760° abs., a rise in temperature of 3000° F. would produce a total absolute temperature of 4760° F. This is a three to one increase in absolute temperature, and, in a closed vessel, would result in a pressure rise of three to one. Because of the unusually large venting area provided by the cyclone separators and the adjacent chambers the

inner chamber 141 is instantaneously enlarged to include the upper chamber 140, the annular V trough immediately below it, as well as the throat 133 leading from the combustor unit to the fly-ash separator, and the annular chamber 142, ducts 135, 136, and gas turbine 20. In other words, the quantity of intensely heated air developed in the cylinder and resulting from the explosion, can be allowed to flow into a relatively large volume and certainly at least three times greater than that of the chamber, so that the force of the explosion can be dissipated without resulting in harm to the equipment.

In a series of exhaustive studies on dust explosions the Bureau of Mines has found that a venting area of 5 sq. ft. per hundred cubic feet of explosion volume affords an ample safety factor in closed chambers where explosion hazards exist. Because of the lack of venting space, such conditions indicate positive explosion hazards. As the vent area increases up to $2\frac{1}{2}$ sq. ft. per hundred cubic feet of explosion volume, it will be seen that the pressure developed, expressed in pounds per square foot, decreases, arriving asymptotically at a minimum value between 5 and 10 sq. ft. of venting area per 100 cubic feet of explosion volume.

Considering these controlling factors with respect to the invention herein, the inherent safety factor will be apparent. The fly-ash chamber 141 is in open communication with the upper plenum chamber 140 and the ducts 22, 23 leading to the turbine as well as with the chambers formed by the separator units 150 and their supporting structures. The separator units 150 provide free, substantially unimpeded paths between all chambers so that the fly-ash chamber 141 has a vent area equal to substantially 70% of its surface which affords a positive assurance of safety from explosions due to delayed combustion of solid combustible materials in the fly-ash chamber under high pressure conditions.

In the pressurized combustion system herein this type of safety factor is of maximum importance, as well as from the operating efficiency as from the primary and controlling factor of safe-guarding human life. Because of the relatively enormous vent area provided, the pressures utilized can be greatly increased without increasing explosion dangers in a comparable manner. With any explosion in the fly-ash chamber, the gases are vented immediately, in opposed directions, through the turbine on one side, and back through the plenum chamber and combustor on the other side, so that the volume of discharge space available in the turbine and its inlet ducts and outlet exhaust stack, as well as in the plenum and mixing chamber of the combustor, and the combustor itself together with the regenerator tubes, is extremely large as compared with the restricted volume of the fly-ash chamber.

The special fly-ash disposal system for pressurized combustion systems of the type shown in my said Patent No. 2,583,921, issued January 29, 1952, for Multiple Element Vortical Whirl Ash Separator, and as shown generally in Figs. 1 and 2, comprises a second, combination fly-ash separator and storage tank 200, feed line 210, cleaned air discharge system 220, and high pressure ejector feed line 230. To integrate the fly-ash separator of my above said application with the present system, the fly-ash receiving chamber 141 is provided with a V-trough 241, discharging through elbow 242 of ash dump line 243 into feed

line 210. A worm 244 is mounted for constant rotation in the V-trough 241 and is driven by motor 245, as shown in Fig. 2.

The second, combination fly-ash separator and storage tank 200 comprises a generally cylindrical tank having a body portion 201 with a truncated conical bottom 202 closed by a large dump valve, designated generally by the numeral 203. In place of the dump valve, the tank may discharge through a depressurizer, permitting the ash to be stored at atmospheric pressure. The top of the tank is closed by annular plate 204 having an axial discharge opening 205, and mounting a depending cylinder 206. A tangential inlet 207 is formed in the upper cylinder wall immediately below the cover plate 204.

The air feed line 210 is tapped into the discharge duct 61 of the main compressor 60, and is brought to tank 200 after picking up fly-ash discharged through dump line 243. Immediately upstream of the dump line 243 the line 210 is fitted with a reducing nozzle 211 which serves to increase the velocity of the pickup and coolant air flowing past the discharge opening of dump line 243, and to equalize the pressure in the discharge line. A valve 212 is mounted in the line 210 upstream of the nozzle to control the flow of air therethrough. Normally, the flow through line 210 will be less than 1% of the total air flow. Downstream of dump line 243 the air line 210 is directed upwardly, to form an ash delivery line 213, then horizontally to form tangential delivery line 214, whose outlet is secured to, and is coextensive with inlet 207, in the tank 200. A valve 215 is fitted in line 213 upstream of the outlet.

The cleaned air discharge system 220 comprises a vertical line 221 secured to discharge opening 205 of tank 201. The line 221 is directed horizontally, as indicated at 222 to the inlet 223 of air-operated ejector 224. The ejector 224 discharges downwardly into line 225 fitted with valve 226, the line being directed horizontally, below the valve as indicated at 227, into the plenum or mixing chamber 140 of the fly-ash separator 100.

The high pressure ejector feed line 230, is supplied with air from auxiliary compressor 64, and is connected at 231 to the inlet 223 of ejector nozzle 224. A valve 232 is fitted in line 230 and desirably adjacent the discharge 231. A two-way valve 228 and discharge pipe 229 are provided in line 220 to vent the clean air from the tank 200 to the atmosphere or to auxiliary heating services, when it is not desired to recycle it to the fly-ash chamber.

The operation of the combination ash cooling and auxiliary motive gas generating system, described immediately above, will be considered with respect to the improvement in overall operation and efficiency of coal-burning gas-turbine power plants, and particularly of such power plants as incorporated in locomotives, and marine installations.

Motive gases are delivered from fly-ash separator 100 to gas turbine 20 at maximum operating temperatures of 1300° F., to 1350° F. At these temperatures, the separated fly-ash, which is discharged and collected in fly-ash receiving chamber 141, retains significant quantities of heat. The ash, having a low heat conductivity, is essentially a good insulating material. Because of the poor heat transfer characteristics of the ash, the problem of cooling superheated (1300° F.) masses of the same, in restricted spaces, as in locomotives and marine installations, where space is always at a premium, assumes major engineer-

ing importance. This problem is complicated further by the fact that the system must be maintained pressurized, and, in the instant system, desirably at an operating pressure of 4-5 atmospheres at the turbine inlets. The novel ash-cooling system herein solves this problem by cooling the hot (1300° F.) ash in an ejector stream of coolant gaseous fluid (air, steam, etc.), and discharging it into a cyclone separator where it undergoes further cooling and separation from the gaseous entraining stream.

What is claimed is:

1. In a plant for the pressurized combustion of pulverized fuel, a combustion chamber, a discharge line for the products of combustion, means in said discharge line effective to remove the fly-ash from the products of combustion comprising a first ash separator, a second ash separator, pneumatic conduit means connecting the ash discharge of the first said separator to the inlet of the second said separator, means for discharging ash from the first separator into the said pneumatic conduit, and means for delivering pneumatic coolant through said conduit to the second said separator, whereby entrained ash from the first separator is cooled and delivered to the second separator and the cooled ash is separated from the entraining fluid.

2. System according to claim 1 in which the second said separator incorporates a storage chamber.

3. In a power plant for the pressurized combustion of pulverized fuel, in combination, a combustion chamber, a discharge line for the products of combustion, a first ash separator in said discharge line to remove the ash from the products of combustion, means for cooling said separated ash to remove the heat energy therefrom, means to return to the system the heat energy derived

from the separated ash, said means including a second separator incorporating ash storage means and a cleaned air return line to the system.

4. System according to claim 3 in which the clean gas discharge line from the second separator is connected to the input side of the first said ash separator.

5. In an apparatus for the pressurized burning of pulverized fuel having a combustion chamber, a discharge line for the products of combustion, a fly-ash separator, and a fly-ash receiving chamber in the separator, the improvements comprising fly-ash discharge means in the said chamber, and efferent pneumatic conduit means connected to the said chamber discharge means, whereby the discharged hot ash from the separator is entrained and cooled in said pneumatic conduit.

JOHN I. YELLOTT.

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