

June 11, 1968

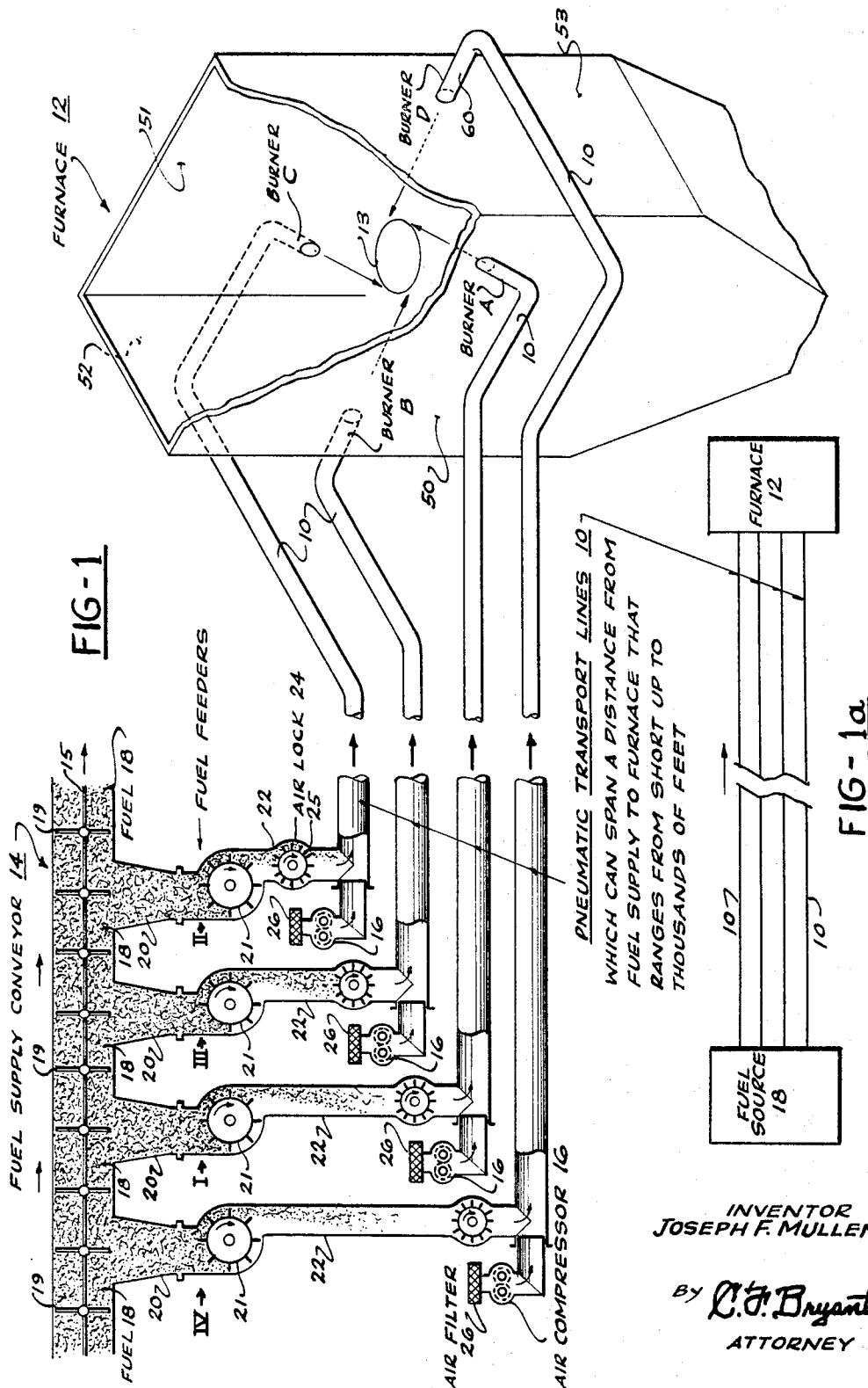
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3,387,574

SYSTEM FOR PNEUMATICALLY TRANSPORTING HIGH-MOISTURE FUELS
SUCH AS BAGASSE AND BARK AND AN INCLUDED FURNACE
FOR DRYING AND BURNING THOSE FUELS IN SUSPENSION
UNDER HIGH TURBULENCE

Filed Nov. 14, 1966

6 Sheets-Sheet 1



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6 Sheets-Sheet 2

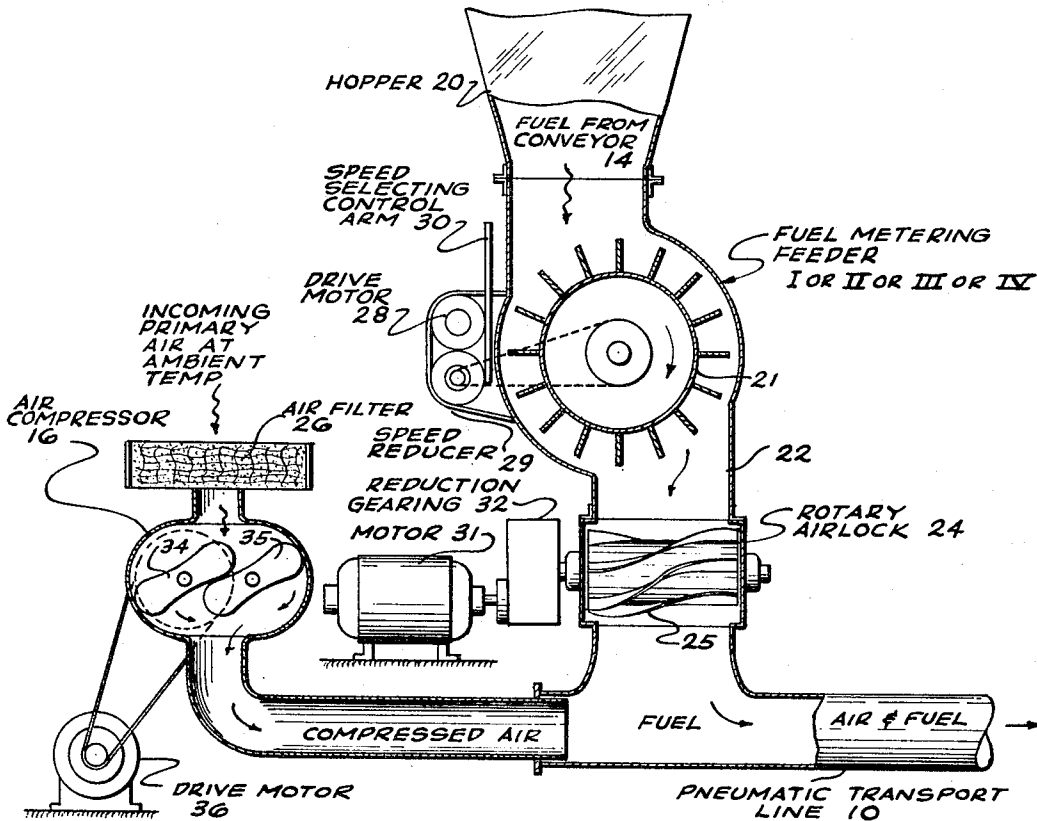


FIG-2

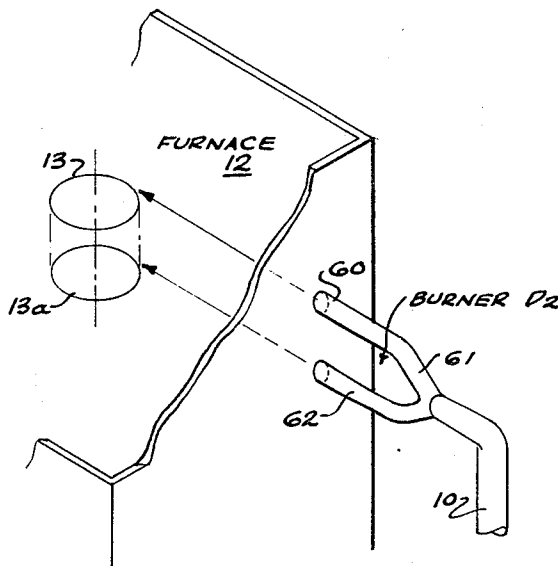


FIG-3

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6 Sheets-Sheet 3

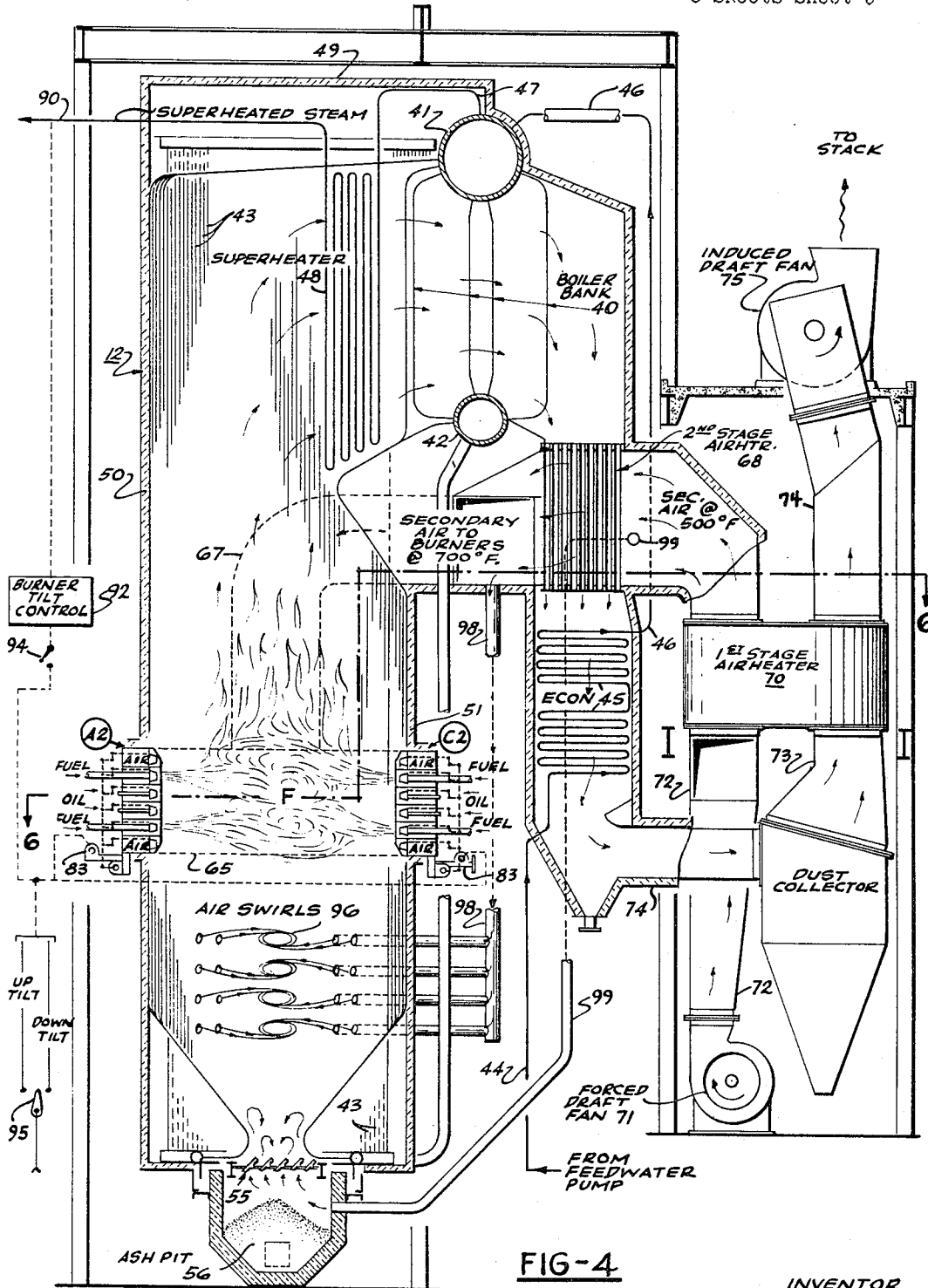


FIG-4

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6 Sheets-Sheet 4

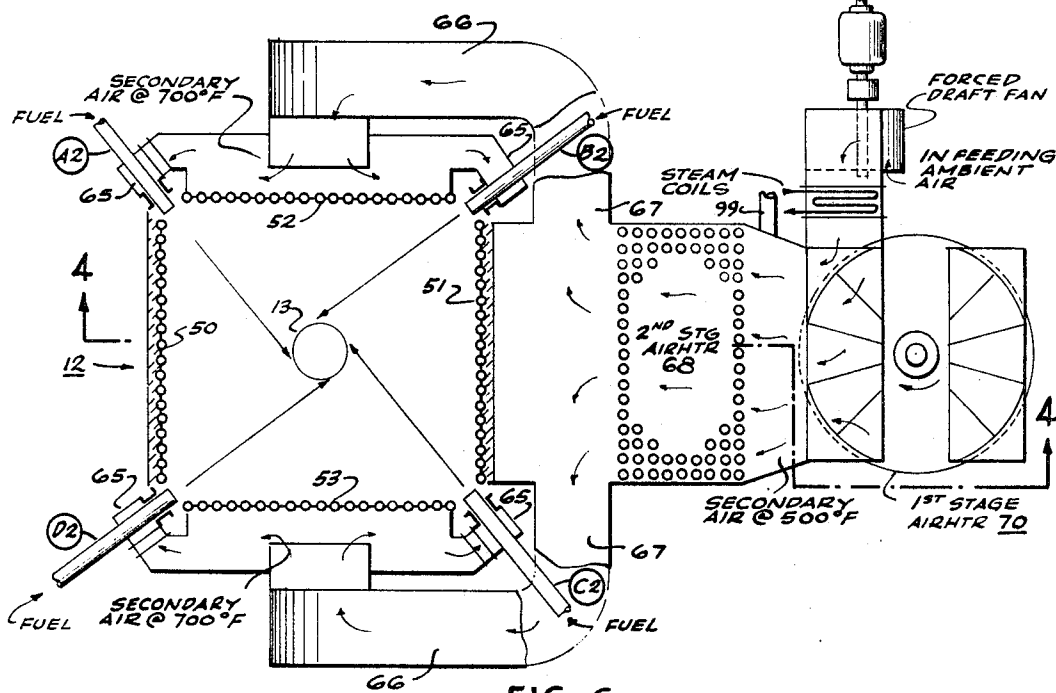


FIG-6

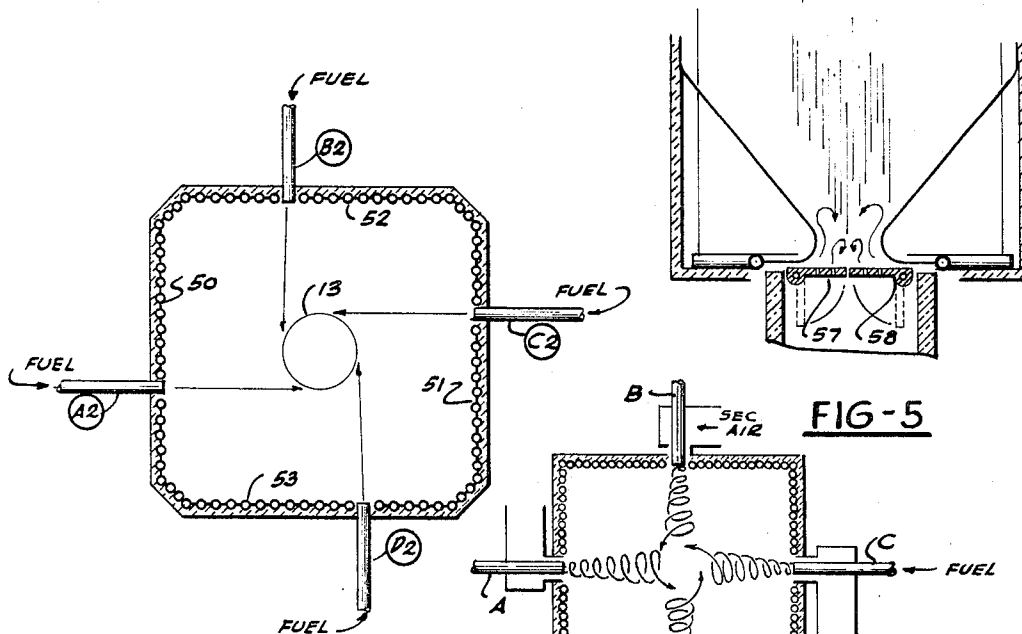


FIG-7

FIG-7a

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6 Sheets-Sheet 5

TILTING TANGENTIAL BURNER A2 OR B2 OR C2 OR D2

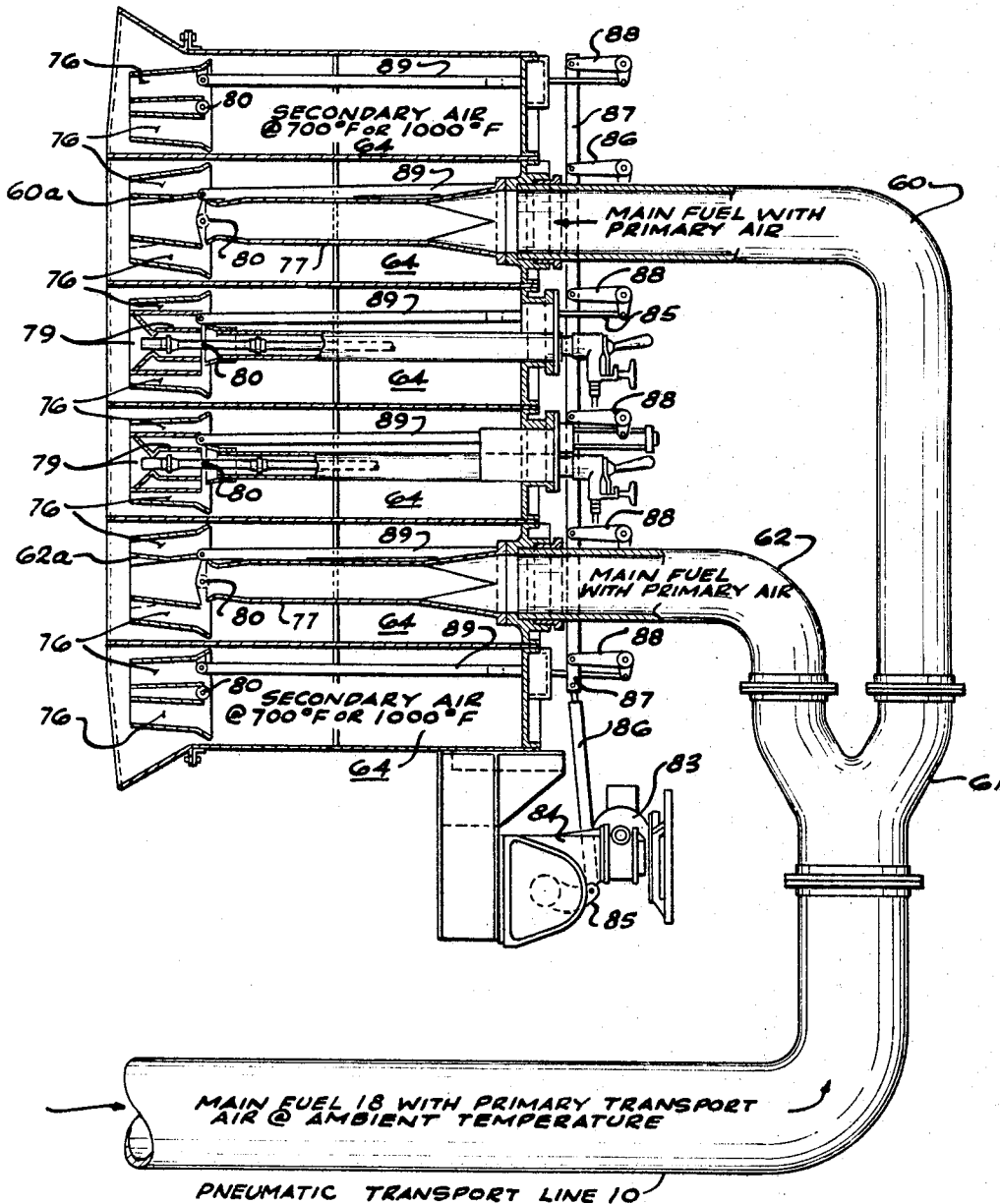


FIG-8

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6 Sheets-Sheet 6

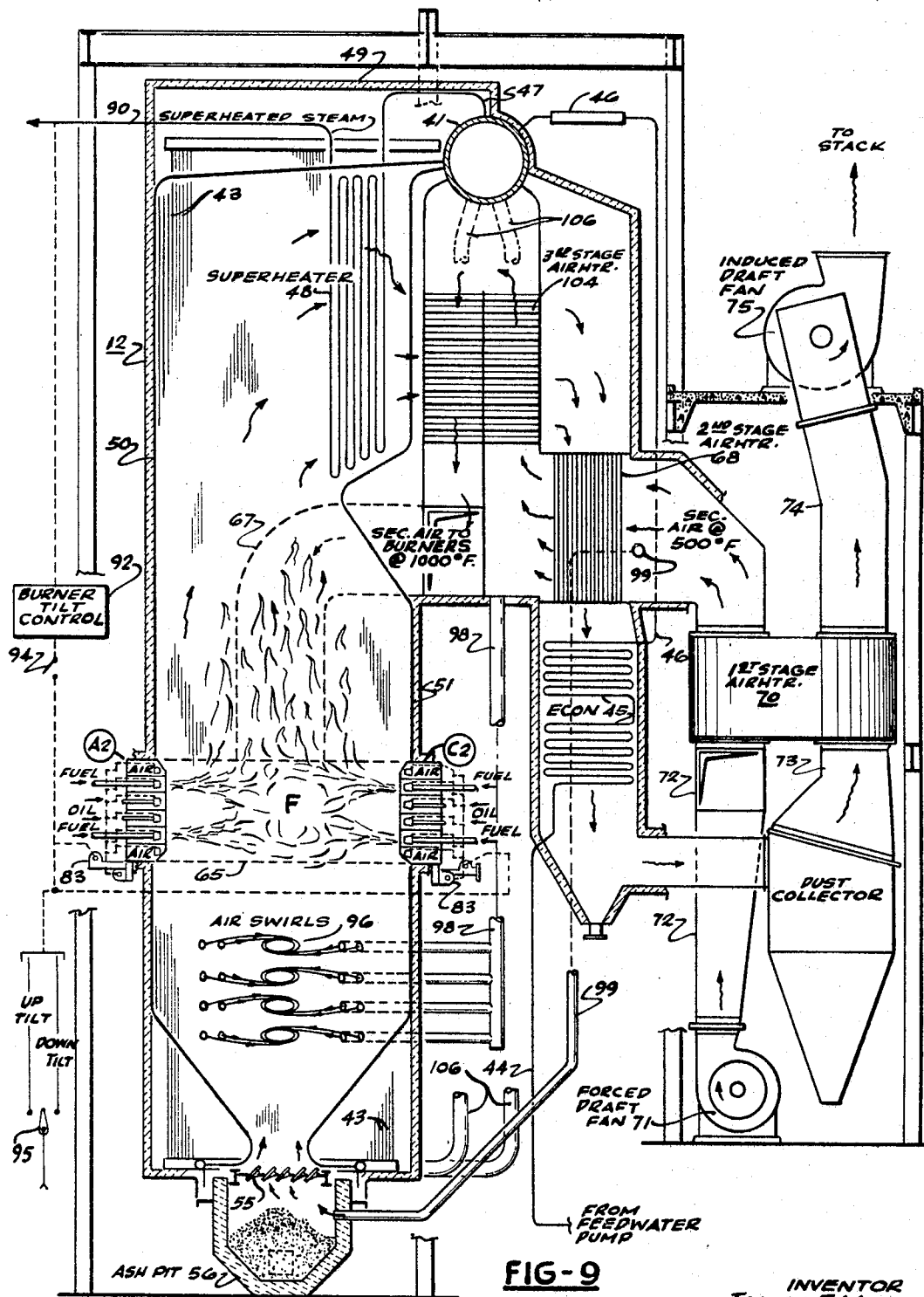


FIG-9

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SYSTEM FOR PNEUMATICALLY TRANSPORTING HIGH-MOISTURE FUELS SUCH AS BAGASSE AND BARK AND AN INCLUDED FURNACE FOR DRYING AND BURNING THOSE FUELS IN SUSPENSION UNDER HIGH TURBULENCE

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14 Claims. (Cl. 110-7)

ABSTRACT OF THE DISCLOSURE

A system, and method of operation thereof, for pneumatically transporting high-moisture fuels such as bagasse and bark and an included furnace for drying and burning those fuels in suspension under high turbulence. A transport pipeline supplied with primary air as by an air compressor has the high-moisture fuel metered thereinto at a rate of at least 3.5 times that of the transport air by weight, and such fuel-air mixture is delivered by the pipeline directly into the combustion furnace. Highly heated secondary air further is brought into the furnace at a rate of about twelve times that of the incoming primary air by weight, and is there turbulently mixed with the fuel and primary transporting air entering from the pipeline. The particular ratios of the fuel to the primary transport air and of the highly heated secondary air to the primary air enable the incoming fuel to be completely dried and burned in suspension on a self-sustaining basis.

This invention relates to the transporting and burning of high-moisture fuels typified by bagasse and wood bark plus other fibrous-type materials and also by lignite plus certain related fossil-type materials not including conventional liquid and gaseous fuels, and it has particular reference to accomplishing such transport by means of pneumatic pipelines or conduits through which primary air at ambient temperature and relatively high pressure but of low volume moves the high-moisture fuel at high velocity. The invention also has reference to injecting this pneumatically transported fuel directly into a furnace without predrying or appreciable particle-size change during the transport operation and with the quantity of ambient-temperature transport air being small as compared with the quantity of the fuel pneumatically conveyed and delivered into the furnace. And the invention has further reference to an improved drying and ignition and burning of the so-delivered fuel accomplished within the furnace combustion chamber by uniquely maintaining such fuel in prolonged suspension there under conditions of high turbulence and aided by an intimate intermingling therewith of extremely hot secondary air in such quantities as to permit operation closer to the theoretical total air requirements, thus producing little excess air and thereby resulting in a furnace temperature higher than heretofore employed; with the furnace heat liberated by such burning being utilized for preheating said secondary air as well as for the usual generation of steam and the other customary purposes.

The "high-moisture" fuels to which the improvements of this invention especially apply are partly of the fibrous type and partly of the fossil type, with neither of these categories including conventional liquid-type fuels or gaseous-type fuels. Among the fuels here being dealt with are fibrous-type materials typified by the bagasse that results from cane-sugar production, along with waste wood products like tree bark and wood chips and shavings and

sawdust as well as the above and other burnables hogged into small pieces; also corn cobs and husks and stalks plus the hulls of sunflowers and of cotton seeds and of rice and other grain along with related items such as straw fuel and chaff; also refuse leather and the tan bark from leather processing; also industrial and municipal wastes having included combustibles as well as the "garbage" output from homes and residences; and also turf and peat and lignite along with such other low grades of coal whose moisture content likewise is significant.

The bagasse referred to above has a moisture content normally ranging from 40 to 60 percent by weight as taken from the cane-sugar grinding mill. The mentioned tree bark as received from the log barking drums of a paper pulping mill is at least as wet, with its moisture content even being as high as 80 percent by weight in certain instances. The lignite ranks of coal also referred to normally have moisture contents ranging from 25 percent to 50 percent by weight. And the other fuels above listed by way of example likewise have moisture contents of a significant order.

These inventive improvements further find their greatest usefulness when the furnace wherein the pneumatically transported fuel is burned is equipped with fluid-cooled walls which serve to enclose the extremely high temperatures associated with the combustion taking place therein, with boiler furnaces both for generating steam and for producing high temperature water being two familiar examples.

Broadly stated, the object of this invention is to transport and burn high-moisture fuels such as those mentioned above with greater efficiency and reliability and at lower cost than has been possible heretofore.

A more specific object is to accomplish such transporting and burning without having to reduce the moisture content of the fuel external to the furnace before bringing the fuel into the furnace, as has been necessary in many applications heretofore.

An additional object is to effect such transport of the fuel over relatively long distances pneumatically and through simple pipes or conduits which adapt themselves to being run along the ground level or to being suspended above the ground or to being buried underneath the ground while at the same time being readily routable around physical objects which may lie in the direct path of such conveyance.

A closely related object is to make possible the simplifying of sugar-mill and paper-mill and other related processing installations and the lowering of both their initial and their operating costs by replacing the expensive and cumbersome mechanical conveying means having moving parts, as universally used during the past 100 years or longer, by the highly preferable pneumatic fuel transport lines which this invention now makes available for such economically advantageous use by the processing industries.

Another object is to bring the so-pneumatically transported fuel into the furnace at a plurality of blow-in points so interrelated as to give the fuel particles a swirling motion which keeps them suspended in the turbulent air currents of the combustion chamber long enough to accomplish drying and ignition and burning thereof.

A related object is to carry out the foregoing within a water-cooled furnace, such as is used for the generation of steam and for the heating of high-temperature water or other fluid, through the medium of tangential firing so uniquely coordinated with the other system elements as to accomplish suspension burning of the in-blown fuel more simply and effectively than has been possible in the past.

A further object is to accomplish such pneumatic con-

veyance of the fuel from its source into the furnace by using transport air in a quantity which is extremely small as compared with the total air that is required within the furnace for the combustion of the fuel.

A related object is to keep at a minimum the quantity of the transport air so utilized in conveying the fuel and thereby enable a proportionately greater quantity of highly heated secondary air to be intermixed with the fuel in the furnace incident to achieving optimum drying and combustion with minimum excess air.

Another object specifically related to the one stated immediately above is to make use of a now larger portion of secondary air in quantities greater and at temperatures higher than have heretofore been practical without objectionably increasing the total combustion air above that theoretically required.

Other objects and advantages will become apparent from the following description of an illustrative embodiment of the invention when taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a diagrammatic representation, using a somewhat smaller scale in its right portion than in its left, showing how the system components are organized to accomplish my improved pneumatic fuel transport over distances either short or long, and also showing how the fuel burning furnace is coordinated with the fuel transport lines so as tangentially to swirl the fuel within the combustion chamber in a way which prolongs the time of fuel-particle suspension and thus facilitates drying and burning;

FIG. 1a shows in simplified diagrammatic manner how the pneumatic transport lines of FIG. 1 communicate between the fuel-source and the furnace locations regardless of whether those locations are close together or far apart;

FIG. 2 is an enlarged showing of the pneumatic transport apparatus provided at the location of fuel supply for charging each of the pneumatic transport lines leading to a furnace burner with metered fuel plus compressed air for moving it through the line;

FIG. 3 is a fragmentary portion of one corner of the FIG. 1 furnace showing the fuel burner therein equipped with two injecting nozzles both of which receive fuel from the associated single transport line of FIG. 1;

FIG. 4 is a side elevation taken on line 4—4 of FIG. 6 through a steam generating furnace which is usable with the pneumatic transport facilities of FIG. 1 to coordinate the suspension burning with the transport system characteristics in a uniquely advantageous way;

FIG. 5 shows how the small dump grate at the bottom of the FIG. 4 furnace can be organized in a manner alternate to FIG. 4;

FIG. 6 is a section on line 6—6 through the boiler furnace of FIG. 4 showing the four tangential burner assemblages along with first and second stage air heaters and allied facilities for supplementing the low input of burner primary air with enlarged inputs of secondary air at highly elevated temperatures;

FIG. 7 indicates how the four tangential burner assemblages used in the furnace of each of FIGS. 1 and 4 and 6 and 9 can if desired be mounted in the respective furnace walls instead of at the furnace corners to accomplish the same results;

FIG. 7a shows how the pneumatically transported fuel can if desired be brought into the furnace in a non-tangential manner by means of fuel nozzles oppositely disposed one to another;

FIG. 8 is an enlarged section through one of the fuel-injecting burner assemblages of FIGS. 4 and 6 and 7 and 9 showing one arrangement for vertically tilting the streams of fuel and air which the assemblage directs into the furnace; and

FIG. 9 shows modification of the FIGS. 4-7 boiler furnace by an inclusion therein of a third stage air pre-

heater whose effect is to boost the temperature of the heated secondary air to a range typified by 1000° F.

The improved transporting and burning technique of the invention

The improvements herein disclosed and now to be described make use in part of features earlier known per se and in remaining part of features which I have newly devised and coordinated with those others in an original way, and the resulting unique combination of all into the novelly unified system hereof yields the new and previously unattainable results here made possible for the first time.

In accordance with this invention, fuels of the "high-moisture" type exemplified by those mentioned earlier herein are as indicated by FIG. 1 pneumatically transported over distances from the fuel-supply location at the left to the furnace location at the right which range from comparatively short spans up to exceedingly long spans of thousands of feet or even miles in length. Such novel conveyance of the fuel is accomplished through simple transport lines shown at 10 in FIGS. 1-1a which lend themselves to readily being run at ground level or to being suspended overhead or to being buried under ground and also of being easily routed around physical obstructions which may lie in the direct path from the fuel-supply location to the furnace location. Even though appearing smaller at the right of FIG. 1 than at the left, these transport lines 10 will in most installations be of the same size throughout the entire length of their span from the fuel source 18 to the furnace 12, as FIG. 1a indicates.

The fuel is moved through these pneumatic transport lines 10 at the relatively high speeds typified by from 50 to 100 feet per second, and this movement is produced by compressed air which is unheated and at ambient temperature and the quantity of which has the extremely low order of only about ¼ pound of air for each pound of fuel.

The pressure required on the part of such unheated primary air depends upon the transport distance being spanned, with only about 2 pounds per square inch being adequate for distances from 100 to 200 feet. Pneumatic-sending apparatus of the type shown at the left of FIG. 1 is capable of generating transport pressures of up to 50 pounds per square inch, and in practice these are adequate for movement of the fuel through the transport lines 10 over the distances of the many thousands of feet earlier mentioned.

In arriving at the furnace or receiving end of this FIG. 1 pneumatic system, the fuel moving at the from 50 to 100 feet per second velocity earlier mentioned enters the furnace 12 via the nozzles shown at A-B-C-D in the right portion of FIG. 1, with the rate of such entry also being within the range just stated. In the illustrative organization represented there as well as in each of FIGS. 4 and 6 and 7, these four nozzles are at the same elevation in the combustion chamber and they direct their air-fuel streams tangent to the imaginary firing circle 13 within the furnace. The resulting intense turbulence serves to prolong the time that the fuel particles remain in suspension for drying and ignition and burning within the combustion chamber. Under the aiding influence of intensely hot secondary air likewise introduced into the furnace in relatively large quantity as later described, the thus-introduced fuel of any of the high-moisture varieties earlier mentioned is both dried and burned in suspension with an effectiveness and simplicity far superior to what has been possible heretofore.

The illustrative fuel metering and pneumatic facilities at the input end of the FIG. 1 transport system

The sending or left end of each of the FIG. 1 transport lines 10 receives both metered fuel from a supply conveyor 14 and compressed air from an associated compres-

sor 16. In the illustrative form represented, this conveyor 14 utilizes a chain 15 which is continuously moving from left to right carries pockets of fuel 18 between its slats 19 horizontally spaced as shown along the chain length. The fuel in these moving pockets 18 drops by gravity into the hoppers 20 of the fuel metering feeders I and II and III and IV and serves to keep all of those hoppers fully filled at all times. Within each feeder casing is a rotating drum 21 which is equipped with serrated-edge blades spaced around its circumference. Fuel from hopper 20 thus filling by gravity into the pockets between the blades of each feeder drum 21 is fed by these moving blades at a predetermined rate downwardly into the feeder outlet chute 22 through which it drops by gravity into an air lock 24 at the lower end of the chute.

As illustratively shown by FIGS. 1-2, the rotating drum 25 of each of these air locks likewise has blades spaced around its circumference, and the fuel falling into the pockets therebetween is carried by such drum further downwardly into the associated transport line 10 downstream of the left or inlet end. The associated air compressor 16 also communicating with the same end of the transport line 10 introduces behind or upstream of the fuel dropping thereinto the compressed air which is needed to push the air-fuel mixture through the entire length of the line and into the associated nozzle A or B or C or D of the furnace 12. All such transport air is filtered at 26 before being so brought into the system, and the internal pressure so built up in each transport line 10 is prevented by the associated air lock 24 from leaking upwardly into the discharge chute 22 of the associated fuel feeder.

The fuel metering and pneumatic elements which have been generally described as being provided at the left or sending ends of the four pneumatic transport lines 10 may satisfactorily be of the illustrative forms which FIG. 2 shows in greater detail and somewhat more clearly. As to the fuel metering feeders I-II-III-IV, the general design of each forms the subject of U.S. Patent 2,796,198 on "Apparatus for Feeding Bagasse" which is assigned to the same assignee as this invention and which issued on June 18, 1957, in the names of A. C. Weigel and H. G. Meissner. Rotation of the drum 21 in each feeder is imparted by a motor 28 through a reduction gearing 29, and the drum speed can via lever 30 be adjusted to give the particular rate of fuel feed needed.

With regard to the rotary air locks which FIGS. 1 and 2 designate as 24, the drum 25 of each is shown by FIG. 2 as being rotated by a motor 31 through reduction gearing 32. As already mentioned, each of these locks 24 serves to prevent the pneumatic pressures within the transport line 10 from leaking upwardly into the feeder outlet chute 22 thereabove; and in furtherance of this the tolerances between the blades of drum 25 and the sides of the surrounding casing are kept precise and close, with this being particularly important since the pressure within each of the transport lines 10 to be sealed may in certain applications be as high as the 50 pounds per square inch earlier mentioned.

Coming next to the air compressors illustratively shown at 16, each of these is of the positive displacement type and may satisfactorily include internal rotating elements 34 and 35 which are by drive motor 31 rotated at the relatively high and constant speed appropriate for delivering the needed compressed air into the left or sending end of the associated transport line 10. Such constant-speed driving causes the intermeshed and rotating elements 34-35 to pull down through the air filter 26 incoming air of the ambient temperature earlier mentioned and at a rate which remains substantially constant regardless of how fast or how slow the fuel from conveyor 14 is being metered by the associated feeder I or II or III or IV through air lock 24 into the left or input end of the associated transport line 10. The fuel-air mixer being pushed through each such line by this constant output from the associated air compressor 16 thus can be made

richer by stepping up the speed of feeder drum 21 or can be made leaner by correspondingly cutting down such feeder speed.

One representative air-to-fuel ratio which works well in practice is the above $\frac{1}{4}$ pound of air for each pound of the fuel earlier mentioned as being carried thereby. The particular ratio value found to be most satisfactory for a given installation may differ somewhat from said one part of air by weight for each four parts of fuel by weight, but for transport distances of from the 100 to 200 feet in length here dealt with the departure will ordinarily not be great. For transport distances of greater length, the pressure requirements will be correspondingly greater, as earlier observed.

As to the pneumatic transport lines 10 themselves, in the illustrative installation here being described each of these has a diameter of 6 inches. Transport lines 10 of this 6-inch diameter are found adequate for conveying up to about 20,000 pounds of fuel per hour. Greater transport capacities will of course make correspondingly larger diameters necessary, while lower fuel transport capacities can be served by lines whose diameters are correspondingly smaller.

The illustrative boiler furnace here shown as being fuelled by the pneumatic transport lines 10

Referring to FIGS. 1 and 4 and 6 of the drawings, the steam generating boiler furnace here specially correlated as just stated is illustratively shown as utilizing a bank of boiler tubes 40, upper and lower drums 41 and 42 interconnected by those tubes, and furnace waterwall tubes 43 also connected into the boiler circulation system in well-known manner. Feedwater suitably introduced into that pressure-part system by conduit 44 and economizer 45 plus a second conduit 46 is converted by the fuel-combustion heat produced as later described into steam which leaves the upper drum 41 by way of outlet 47. Such steam passes through a superheater 48, here shown as being of the convection type, to a point of use via the conduit 90 extending out of the furnace setting. Such setting may satisfactorily include a front wall 50, roof 49, rear wall 51 and spaced side walls 52 and 53 which complete the boiler-furnace enclosure.

Serving to fire this furnace 12 are the fuel-introducing nozzles indicated at A-B-C-D by FIG. 1 and redesignated A2-B2-C2-D2 in the more detailed furnace representations of FIGS. 4 and 6 and 7. The tangential firing organization indicated by FIG. 1 as involving the imaginary circle 13 likewise is repeated in the above more detailed furnace representations; and the furnace burner assemblages A2-B2-C2-D2 thereof accordingly project their incoming streams of fuel and air into the combustion chamber in directions tangential to the surface of an imaginary cylinder, such as FIG. 3 shows at 13-13a as being located vertically within the furnace at or near the center.

As the description proceeds it will become apparent that burner arrangements other than the tangential one here illustratively represented can alternately be used to fire the furnace 12 which receives the in-blown fuel from the pneumatic transport lines 10 and which accomplishes the drying and suspension burning thereof on a self-sustaining basis; also that the tangential effect of importance here can if desired be gotten from a mounting of the four assemblages A2-B2-C2-D2 in the furnace walls as shown by FIG. 7 rather than at the furnace corners as FIG. 6 shows.

Coming back to FIG. 3, it shows how each of the four single nozzles of FIG. 1 may be supplemented with a second nozzle 62 which is positioned below the first nozzle 60, with both of the nozzles then receiving fuel from the associated single transport line 10 through the medium of a suitable flow splitter 61. Similar flow division at the outlet of transport line 10 can if desired be extended to fuel nozzles numbering more than the two of this FIG. 3 showing, such as to three or four or even more.

*The tangential burner assemblages A2-B2-C2-D2
with their vertical tilt provision*

The boiler furnace of FIGS. 4 and 6 and 7 is arranged to make use of two such fuel input pipes 60 and 62 in each of its burner assemblages A2-B2-C2-D2, as FIG. 8 shows. The illustrative arrangement of that during view includes six air chambers or ducts 64 arranged one above the other in the common vertical row and connected at their sides to an air conduit, shown at 65 in each of FIGS. 4 and 6, through which heated secondary air is brought to these assemblages from left and right supply conduits 66. The latter are represented in FIG. 6 and are described more fully later.

Each of these burner assemblages A2-B2-C2-D2 admits secondary air through all six of its FIG. 8 ducts 64 and delivers it into the combustion chamber by way of the six air nozzle tips 76. Pneumatically transported fuel from the branch lines 60 and 62 of FIG. 8 is conveyed into the furnace by way of fuel nozzles 77 and their associated fuel tips 60a and 62a. The fuel emanating from the latter tips is completely surrounded by secondary air emanating from the associated air ports 76. This arrangement assures an intimate mixing of the incoming fuel with the incoming secondary air. Auxiliary fuel in the form of oil or gas can if desired also be introduced through the remaining fuel nozzles 79.

The illustrative showing of the furnace 12 hereof as being equipped with four such burners of this FIG. 8 design does not rule out a possible substitution of any other burner arrangements and designs which may be preferred. Thus as the capacity requirements increase, other sets of fuel and air nozzles similar to those of FIG. 8 can be provided as needed at elevation above and/or below the illustrative one here shown, with each added set of such nozzles being equipped with the same wind box facilities as are the burner nozzles here represented and also being provided with whatever additional transport lines 10 plus input-end units 21-16 the particular installation may need.

A still further fuel-delivery arrangement also possible appears in FIG. 7a. Each of the four fuel nozzles A-B-C-D thereof may be installed singly in the furnace walls or have the total four-unit organization wherein A is directly opposite to C and B is directly opposite to D. Each such unit may include spin-imparting vanes (not shown) for whirling the fuel as it enters therethrough with the transport air and intermingles with the secondary furnace air. Provision for vertical tilting also may be incorporated as described.

The vertically tilting features of this FIG. 8 burner assemblage are more fully shown and described by U.S. Patent 2,575,885 issued Nov. 20, 1951, for "Steam Superheat Control by Automatic and Extended-Range Means" and assigned to the same assignee as the present application. In connection with the suspension-burning system of this present invention, it is to be observed that all six of the assemblage tips represented at the left of FIG. 8 are mounted on side support pins 80 around which they can vertically tilt. With these six tips in their horizontal-axis position represented, the main or pneumatically transported fuel passing through the burner tips 60a and 62a enters the furnace in a substantially horizontal direction, so do also the accompanying streams of secondary air. Either upward or downward vertical tilt now can when desired be imparted to all six of these tips by a motor 83. Upon control activation, that motor 83 produces the appropriate tilting motion and communicates it to all six tips of the FIG. 8 burner; with this being done through reduction gearing 84 plus an arm 85 rotated thereby, and from that arm through the six linkages shown at 86-87 and the six bell cranks shown at 88 and the six push-pull rods shown at 89.

Tilt-adjusting motors like the one shown at 83 in FIG. 8 are incorporated into all four of the furnace burner assemblages A2-B2-C2-D-2, and all four of these motors

83 are controlled parallelly through use of facilities such as are shown and described by the U.S. Patent 2,575,885 already mentioned. In FIG. 4 and in FIG. 9 such tilt-motor control is accomplished either manually through a first switch 95 or automatically upon the closing of a second switch 94.

In effecting such "manual" control, that second switch 94 is kept open. A closing of the first switch 95 to the left now causes the four motors 83 to tilt their associated burner tips upwardly, and a closing of said switch 95 to the right causes those motors to tilt their associated burner tips downwardly.

One purpose for which such control of the burner tilt can be used, if so desired and if the characteristics of the fired fuel so permit, is to keep the generated steam leaving the convection superheater's outlet 90 at a constant temperature during fluctuations in the steam loading on the FIG. 4 boiler and on the FIG. 9 boiler. Upon this superheat temperature rising too high, the corrective action called for is a downward tilting of the furnace burners with resultant shifting of the flame mass F to a lower location in the water walled combustion chamber. And upon the superheat temperature dropping too low, the corrective action called for is an upward tilting of the furnace burners with resultant shifting of the flame mass F to a higher location in the water walled chamber.

The above corrective adjustments in burner tilt are in the boiler furnaces of FIGS. 4 and 9 made in the "automatic" manner earlier mentioned through the medium of a control unit shown at 92. Switch 94 now being closed, deviation in the superheat temperature at 90 from a desired value is translated by this unit 92 into a running of the four associated burner motors 83 in whichever tilt-adjusting direction is needed to bring said superheat temperature back to its desired value.

*Burner tilting here utilized to adjust the time of
fuel-particle suspension*

In the pneumatic transport and suspension firing system of this invention the tilting provision described above is further utilized for the more significant purpose of adjusting the fuel-particle suspension time into optimum accord with the burning characteristics of the particular fuel being fired. In the case of fuels whose incoming particles are small and only moderately laden with moisture, the particles of such fuel need be retained in the furnace atmosphere for only a relatively modest time in order for both suspension drying and suspension burning to be accomplished effectively; and here the tips of the four furnace burners can if desired be tilted downwardly somewhat below the horizontal position thereof here represented.

But when dealing with fuels whose incoming particles are larger and heavier and hence subject to rapid dropping by gravity or whose incoming particles though of modest size have a high content of moisture, the particles of such fuel require a much longer time of retention in the furnace atmosphere in order for suspension drying and suspension burning both to be accomplished. Here such longer required exposure to the combustion gases is simply but effectively made available by upwardly tilting the tips of the entire four furnace burners. The accompanying shifting of the particle trajectories to a higher location in the combustion chamber now serves to lengthen the retention time for these larger and for these wetter particles of incoming fuel.

This retention time lengthening results from the upwardly inclined paths now taken by the fuel and air streams as they are blown into the combustion chamber from all four of the furnace burners. As such upward inclination is made steeper by further increasing the upward tilt of the burner tips, the longer will the fuel particles be kept suspended in the turbulently swirling gases within and around the FIG. 4 flame mass F and the FIG. 9 flame mass F. Even relatively large and even relatively

wet particles of a fuel so fired now become properly dryable and properly burnable in suspension when the retention time thereof is so prolonged in this unique and highly effective way. The upward component of initial fuel introduction brings the particles to higher points in the furnace before they begin their downward descents. In this way the particles are kept in intimate contact with the upflowing hot gases for longer periods of time.

Particle suspension time can be lengthened still further through use of supplemental air swirls 96

If upwardly tilting the fuel-introducing burners as just described does not fully meet the suspension time needs in special-fuel situations which are particularly challenging, use further can be made of air swirls such as the tangential ones which FIGS. 4 and 9 each indicate at 96. Conduit 98 then serves to supply these jets with secondary air from the outlet of the second stage air heater 68; and this air has the same 700° F. temperature as does the main secondary air being brought into the FIG. 4 furnace through its burners A2-B2-C2-D2, by way of the air ducts 67-66-65 soon to be described.

Some of the advantages made available by such tangential air swirls 96 are indicated by U.S. Patent No. 2,483,728 issued Oct. 4, 1949, in the name of A. L. Glaeser and under title of "Method and Apparatus for Burning High-Moisture Content Fuel." Especial benefits are realized in the case of cellulose-type fuels of high-moisture content such as tree bark. In practicing the present invention these supplemental swirls 96 will be required in varying degrees depending upon the physical and chemical characteristics of the fuel that is being fired.

Only small bottom grates are needed by the furnaces of this invention

Since essentially all of the pneumatically transported fuel entering the FIG. 4 and FIG. 9 furnaces hereof through the burner assemblages A2-B2-C2-D2 is dried and burned while still in suspension, there is very little of such fuel which falls to the furnace bottom in an unburned condition. This permits the furnace to have only the very small bottom grate shown at 55 in the lower portion of FIGS. 4 and 9. Such grate is at the top of an ash pit 56 and spans only the narrow opening between the nose portions of the inwardly sloping tubes at the furnace bottom. In the design of FIGS. 4 and 9, this small grate 55 can be periodically dumped by moving the sections of bars thereof towards their vertical position that opens spaces therebetween through which accumulated ash can drop by gravity into the pit 56 therebeneath. In the alternate grate construction of FIG. 5, similar results are achieved through the use of the perforated sections 57 and 58. The represented hinge mounting of these sections along their outer edges permits the center portions thereof to be swung down at proper times into the dotted positions with an accompanying release of accumulated ashes into a pit 56 therebeneath.

Secondary air for use in conjunction with this small furnace grate 55 of FIGS. 4 and 9 and 57-58 of FIG. 5 is introduced into the ash pit 56 therebelow from the first stage air heater 70 by way of conduit 99 and at the intermediate temperature marked 500° F. in the drawings. Temperatures either higher or lower can be substituted if desired. Such under-grade air in passing upwardly into the furnace through the openings in grate 55 and in grates 57-58 makes available to those few oversize fuel particles which may drop from the combustion chamber upon the grate surface the oxygen required for their burning. Incident to so burning on and above the grate such oversized fuel particles as were not earlier completely consumed in the main suspension burning process, such air from conduit 99 in passing upwardly through the grate openings physically lifts those dropped out fuel particles above the grate surface and burns them

in the suspension manner indicated by the arrow markings in each of FIGS. 4 and 5 and 9. In situations where desirable, the velocity of air flowing up through the grate can be increased sufficiently to fluidize the bed thereon, thus lifting such unburned particles upwardly into the air swirls 96 where their combustion is completed in suspension manner.

Supply of highly heated secondary air to burners

Earlier portions of this specification have already referred to the supply and intense heating of the secondary air which is introduced into the combustion chamber of the furnace 12 hereof. This intensely heated secondary air is admitted into that chamber in intimate contact with the pneumatically transported fuel which is admitted into the same combustion chamber through the nozzles 60a-62a of each furnace burner. The conduits shown at 66 by FIGS. 4 and 6 as conveying such highly heated secondary air to the four furnace burners are in communication with the main secondary duct 67 that receives the high temperature air from the second stage air heater represented at 68.

This illustrated air heater 68 is of the well-known tubular type, and ahead of it in the path of secondary air flow is the first stage air heater 70 here represented as being of the well-known rotary regenerative type. The secondary air required for combustion is brought into the system by the usual forced draft fan 71 and passed via duct 72 (FIGS. 4 and 9) through the left or output side of the regenerative air heater 70; and preliminary warming of such inflowing secondary air can if desired be accomplished through the use of steam coils installed as shown at 101 in FIG. 6.

By the named passage of the incoming air from the forced draft fan 71 through the left or output side of the first stage heater 70 the temperature of that incoming air is raised to some intermediate value such as 500° F. The heat so imparted to this incoming air is taken by the right or input side of rotary heater 70 from the combustion gases which leave furnace 12 by way of conduits 73 and 74 under the action of the usual induced draft fan shown at 75 in FIG. 4.

Such incoming secondary air thus heated to about 500° F. by the first stage heater 70 in passing through the second stage heater 68 has its temperature further raised to the higher order of about 700° F., and it is this extremely hot secondary air which the burners A2-B2-C2-D2 of the FIGS. 4-6 boiler furnace receive via the earlier-mentioned ducts 67 and 66 and 65 thereof.

For the purpose of making still hotter secondary air available in situations where benefit can be derived therefrom, there is shown in FIG. 9 a modified form of the FIGS. 4-6 boiler furnace wherein a third stage air heater is further provided, as shown at 104. Extension of the second stage air heater 68 can instead be used to obtain the same results. Taking the 700° F. air from the output of the second stage heater 68, this added third stage heater 104 further raises its temperature to some still higher value such as the 1000° F. marked in FIG. 9. In the FIG. 9 furnace this 1000° F. secondary air is delivered into the four burners A2-B2-C2-D2 via conduits corresponding to those shown at 67-66-65 in FIG. 4.

In the burner representation of FIG. 8, the delivery just mentioned is indicated by the 1000° F. markings which appear along with the related 700° F. markings that are identified with the furnace of FIGS. 4-6. Stated in another way, fuel burning operations corresponding to those carried out in the FIGS. 4 and 6 steam generator using 700° F. secondary air can similarly be performed in the FIG. 9 boiler furnace using the still hotter 1000° F. secondary air made available thereto. As already indicated, such 1000° F. air here shown as coming from the third stage heater 104 can instead be derived from an extension of the second stage air heater 68.

Invention opens the way for furnace operation at pressures above atmospheric

The pneumatic transport and suspension firing organization here disclosed lends itself to operating the furnace 12 under a pressure which is higher than atmospheric and which is sufficient to permit an elimination of the induced draft fan 75. In the event of such pressurized operation, the internal pressure within furnace 12 is made just sufficient to overcome the resistance to gas flow offered by the components or elements through which the gas passes en route to the atmosphere. Such above-atmospheric pressure within the furnace originates in the forced draft fan 71 which now is operated to supply and maintain it; and such furnace pressure also is contributed to by the air compressors 16 at the FIG. 1 input ends of the pneumatic fuel transport lines 10. As earlier noted, the about two-pound-per-square-inch level of such compressor pressure is significantly higher than the smaller above-atmospheric pressure now present in the furnace 12.

Operation of the complete pneumatic transport and suspension drying plus burning system hereof

How the complete system of this invention operates will have become more or less apparent from the foregoing descriptions of the system's individual components and of their unique combination into the system and of their novel interrelationship therewithin.

The moisture-laden fuel designated 18 in FIG. 1 is fitted into the feeder hoppers 20 either by the illustrated supply conveyor 15 or in other suitable manner effective to keep these hoppers continuously filled. This fuel thus can if desired also be taken directly from a storage pile or bin or building and then similarly introduced at a controlled rate into the pneumatic transport system hereof.

Such fuel 18 from the FIG. 1 hoppers 20 is fed by the bladed feeder drums 21 at a metered rate into the air locks 24 and then on into the pneumatic transport lines 10. The compressor 16 provided for each line delivers thereinto, upstream of the entering fuel, compressed carrying air in the earlier-mentioned quantity of approximately one quarter pound of air for each pound of the fuel 18 delivered into the same line by its metering feeder. This incoming transport air being at ambient temperature may vary from as low as minus 50° F. in cold climates to as high as plus 100° F. or more in warm climates or when drawn from a heated room or building. At 80° F. the above-stated one quarter pound of air is normally sufficient to transport each pound of the fuel. However as the air temperature decreases and the air density correspondingly goes up, it becomes possible to convey each pound of fuel with as little as one sixth of a pound of the transport air. Stated in another way, in cold climates as much as six pounds of fuel can be conveyed by each pound of such transport air.

The pressure of this transport air as delivered by each compressor 16 into its fuel transport line 10 is maintained at a level sufficient to overcome the resistance to flow through the line and at the same time to provide other forces also required. Such other forces are those needed for imparting initial acceleration to the incoming fuel and for keeping the fuel particles moving along with the transport stream and for injecting that stream of mixed fuel and air into the furnace 12 at a velocity sufficient to contribute to the furnace turbulence.

In a representative installation involving a transport distance of approximately 150 feet, an air-discharge pressure at the compressors 16 of less than two pounds per square inch is found adequate for providing all of the forces outlined above. Such pressure acts to move the downstream entering fuel through each line 10 at a velocity within the range of from 50 to 100 feet per second, with the value depending first upon fuel characteristics and second upon the size and the configuration of

the furnace. The fuel so transported enters furnace 12 at a velocity also within the above range.

The secondary air surrounding this incoming fuel enters the furnace through all four of the burner assemblages A2-B2-C2-D2 thereof and it does this by way of the FIG. 8 nozzles 76 in each. The furnace-entering velocity of this secondary air is significantly higher than the furnace-entering velocity of the incoming fuel, and normally lies within the range of from 125 to 180 feet per second. The high mass flow of this secondary air combined with its elevated temperature of 700° F. in FIG. 4 and of 1000° F. in FIG. 9 and in association with its above high furnace-entering velocity contributes with unexpected effectiveness to a turbulence which promotes extremely rapid evaporation of the water from the surface of the incoming fuel.

Such extremely quick drying enables the fuel particles to reach ignition temperature in a far shorter time than heretofore, and the fuel particles dried so extremely quickly in suspension now attain their ignition temperature almost instantly. At this point the oxygen content of the secondary air intimately surrounding each fuel particle immediately combines with the particle in the amount "theoretically" required for combustion of the particle. This combining is uniquely done with lower percentages of excess air and with higher resultant furnace temperatures than have heretofore been attainable.

The practical significance of the above improvement becomes more apparent upon considering the illustrative figures set forth below. In burning a given fuel in a furnace of given configuration and with zero percent excess air, such fuel may have a theoretical flame temperature of over 3500° F. However the same fuel burned in the same furnace with 20% excess air may have a theoretical flame temperature which now is lowered to about 3000° F. And upon further increasing the excess air to 100% this same fuel burned in the same furnace may have a theoretical flame temperature which is further lowered to only about 2200° F. Excess air in such 100% quantity means that the oxygen made available to the fuel is twice that theoretically required for combustion of the fuel.

The foregoing illustrative data reveals how significantly the temperature within a furnace is lowered merely through the use of excess air in relatively large quantity, and it emphasizes the extreme desirability of closely limiting such excess air to the very minimum quantity with which the furnace can satisfactorily operate. This latter approach is utilized in the system of my invention with beneficial results of an unexpectedly high order. The furnaces of FIGS. 4 and 9 are accordingly uniquely arranged to utilize secondary air in volumes and at temperatures which promote rapid and complete combustion with a resulting furnace temperature which is far above what normally is encountered with high-moisture fuels. And it recognizes that the rate at which liquid water in an entering fuel is converted to a vapor by means of air is a function first of the temperature difference between the air and the particle and second of the air quantity utilized.

In the FIG. 4 furnace and in the FIG. 9 furnace hereof, the quantity of the secondary air needed to provide the oxygen required for fuel combustion is more than that needed to retain in a superheated state the moisture which is evaporated from the incoming fuel during its drying. This means that the predominant factor in rapidly evaporating the moisture from the incoming fuel is the elevated temperature of the secondary air.

It is for the above reason that in the FIG. 4 furnace hereof I arrange to bring in the secondary air at the indicated high temperature of about 700° F., and that in the FIG. 9 furnace I similarly arrange to bring in the secondary air at the still higher temperature of about 1000° F. Such 1000° F. proves useful to the suspension drying and burning of fuels whose particles are large or whose physical structure is such that internal moisture cannot readily be removed at lower temperatures.

Regarding the volume of such secondary air, it first is to be observed that fuels of the high-moisture type here dealt with require approximately 658 pounds of theoretical combustion air for each million B.t.u. of the heat contained in the fuel. Assuming as representative a fuel that has 5000 B.t.u. of heating value per pound, this means that the aforesaid 658 pounds of theoretical combustion air likewise are needed for each 200 pounds of that representative fuel. Such fuel when burned with 20% excess air thus requires total air in a quantity of about 787 pounds for each 200 pounds of the fuel. This is approximately four pounds of total air for each pound of this representative fuel.

With the foregoing in mind, it is appropriate to consider how the ambient primary air used for fuel transport relates to the above total air that is required for combustion of the fuel. With the primary air so needed being one-quarter of a pound or less per pound of the transported fuel, each million B.t.u.'s or each 200 pounds of the fuel is conveyed into the furnace through the use of only 50 pounds of such primary transport air at ambient temperature. The balance of the total air here required for each 200 pounds of fuel, or 737 pounds of air by weight, thus becomes available for being brought into the furnace as secondary air. Dividing said 50 pounds of primary air into said 737 pounds of secondary gives 14.7 as the secondary to primary air ratio.

In the new system hereof such incoming secondary air has the elevated temperature of 700° F. as it enters the FIG. 4 furnace and the further elevated temperature of 1000° F. as it enters the FIG. 9 furnace.

The pneumatic transport and suspension burning system of this invention thus achieves a marked gain over the about 1½ pounds of transport air which previously has been used in delivering each pound of fuel into the furnace. Instead of the only 50 pounds of transport air used by the present invention in bringing each 200 pounds of fuel into the furnace, such past practice has required that 300 pounds of primary transport air at ambient temperature be used for conveying the same one million B.t.u.'s heat content or 200 pounds of fuel into the furnace. Of the aforementioned 787 pounds of total combustion air required by each 200 pounds of the fuel, this left only 487 pounds of such total air as available for being received by the furnace in the form of heated secondary air. That 487 pounds is only 66% of the 737 pounds of heated second air which the furnace of my invention is so advantageously made capable of receiving.

The above larger 737 pounds of heated secondary air per 200 pounds of fuel which the furnace of my invention is enabled so to receive approaches the aforementioned 787 pounds of total furnace air per 200 pounds of fuel far more closely than has heretofore been possible, and my delivery of the secondary air in said enlarged quantity further takes place in a novel manner by which intimate mixing with the incoming fuel is uniquely provided under conditions of high turbulence.

Advantages of the invention and distinctions over the prior art

The elimination of the fuel-drying and air-with-fuel mixing equipment external to the furnace which this invention achieves has the highly practical advantage of reducing the capital costs of new installations and of simplifying their operation. Allied benefits include corresponding reductions in operating expense as well as in maintenance and in outage or down time. Along with these are significant reductions in the man-power requirements. Even though fuels of the high-moisture type here being dealt with can be burned through use of the conventional or past techniques and equipment, the accomplishment of such prior-art burning is far more costly and more complex and less reliable than what the present invention makes possible. The advantages of this new technique are therefore highly practical and impart to

the new system a commercial attractiveness which is of a high order.

More specifically, where ratios of secondary air to primary air are less than 4 to 1, it previously has been essential that predrying and mixing of the primary air and fuel be accomplished outside of the furnace. With fuels of the high-moisture type here being dealt with, it has not been thought possible to utilize secondary air to primary air ratios greater than 4 to 1 and still properly mix, dry and convey the fuel and primary air from a point external to the furnace into the interior of the furnace. With drying of the fuel external to the furnace, the past difficulty has been that there are no fans or blowers capable of handling the primary conveying air at the high temperatures necessary to achieve such drying and still keep the air-to-fuel ratio during transport of a low order such as the 1 to 4 ratio now utilized by the invention hereof. But with the ambient-temperature primary air now used, that obstacle is removed with the attendant benefits which this invention can and does achieve.

Within the furnace when used for drying as here, the incoming low quantity of unheated primary air is relatively unobjectionable because the remaining combustion requirements of nearly four pounds of air per pound of fuel are relatively undiluted when using the highly heated secondary air in accordance with the present invention.

Of outstandingly high practical significance is the bettering in high-moisture fuel combustion which results from use of unheated transport air in the very low relative quantity of ¼ pound for each pound of fuel and the accompanying opening of the way for use in the furnace of hot secondary air in proportionately larger quantities and at relatively higher temperatures, thereby achieving relative complete suspension burning of the fuel without having to utilize excess air in the significantly large quantities heretofore required. In prior furnaces used for burning high-moisture fuels it has been customary to use large and cumbersome furnace grates upon which most of the fuel burning occurs, with the secondary air then coming into the furnace upwardly through such bottom grates and intermingling with the fuel thereon as well as during its descent from the point of introduction higher up in the furnace. Illustrative of this familiar prior-art organization is the grate-type furnace for burning bagasse which the earlier-mentioned U.S. Patent 2,796,198 to Weigel and Meissner shows and describes.

In such a conventional system, the air coming up through the grate and into direct contact with the fuel thereon constitutes the primary air and normally makes up about 40% of the total air required for combustion. Such conventional primary air in its relatively large quantity is limited with regard to permissible temperature by the mechanical aspects of the grate structure which in practice do not permit the temperature of such primary air to be more than about 500° F. This means that in a furnace employing such conventional grate-type burning about 40% of the total air needed for combustion must be brought into the furnace at a temperature not exceeding this 500° F.

And with such conventional grate-type burning, the remaining about 60% of total air needed is brought in as secondary air through the furnace sides as via the tangentially arranged air nozzles in the manner covered by the earlier-mentioned U.S. Patent 2,483,728 to Glaeser. For practical reasons it has been usual to bring secondary air, accounting for about 60% of the total, in at the same about 500° F. maximum temperature as is the primary air accounting for the remaining 40% of the total and coming up through the bottom grate of the furnace. Tangential air nozzles of the general type shown by the Glaeser patent take the form of the air swirls shown at 96 in FIGS. 4 and 9 of the present application.

In contrast to the prior Glaeser patent organization just described, the improved furnace organization of the present application eliminates those former large grate

surfaces for mechanically supporting the fuel while burning by the far smaller grate areas designated at 55 in FIGS. 4 and 9 hereof and at 57-58 in FIG. 5. Such smaller grates are no longer depended upon to perform a major burning function but merely are used to retain that portion of the fuel that is not fully burned in suspension under conditions of operation other than the design conditions, as during startup or the like. The quantity of air passed upwardly through these small grates is perhaps only 5 to 7% of the total air.

With my new furnace organization as disclosed herein, essentially all of the primary air comes in from the pneumatic transport lines 10 with the fuel delivered by these lines into the furnace through burners A2-B2-C2-D2, with such unheated primary air having such a low quantity that it represents only 5 to 7% of the total air utilized by furnace 12 for combustion under design conditions. This means that the remaining about 85 to 90% of the total air needed for fuel combustion can be and is in the form of secondary air whose temperatures no longer being limited by mechanical considerations can be significantly higher than the 500° F. and may satisfactorily go as high as the 700° F. used by FIG. 4 hereof and even the still higher 1000° F. used by FIG. 9. This in turn significantly broadens the performance capability of furnace 12 in the effectiveness with which it can first dry and then suspension burn the in-blown fuel as delivered thereto by the pneumatic transport lines 10. With from 85-90% of the total furnace air so coming in at the 700° F. of FIG. 4 and the 1000° F. of FIG. 9, the furnace atmosphere surrounding those incoming particles of fuel now has a temperature significantly higher than the 500° F. earlier mentioned as being the maximum attainable in prior art furnaces as of the Glaeser patent type. And the resulting extreme hotness for all of the air coming into the new furnace 12 is herein attained without having to resort to the greatly enlarged quantity of excess secondary air which otherwise would be required in order to achieve the extremely high temperature level within the furnaces of this invention.

The accompanying maintenance of such high furnace temperature without the need for excess air in objectionably large quantities constitutes an operating gain which is of high practical significance and by which broad commercial attractiveness is given. Not only does the suspension burning of the incoming fuel go forward with greater efficiency, but the volume of furnace 12 can be kept correspondingly smaller with a similar lowering in the capital investment for which a new installation calls. And the accompanying simplicity of the system design assures lower maintenance and relatively fewer outages, as already indicated earlier herein.

While I have shown and described the preferred embodiment of my invention, it is to be understood that the inventive improvements herein disclosed are not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

What I claim is:

1. In a system for transporting high-moisture fuel such as bagasse and bark and the like from a source thereof directly into a furnace and for both drying and suspension burning said fuel within the furnace, the combination of a transport pipeline directly communicating with the furnace interior; a feeder for metering said fuel from said source at a predetermined rate and for introducing it into said transport line downstream of the line's input end; means for preventing pressure leakage from said transport line back into said feeder; an air compressor operable to deliver into said input end of the transport line upstream of the fuel coming thereinto compressed primary air which is at ambient temperature and which carries said incoming metered fuel through the transport line and delivers it directly into the combustion chamber of said furnace; the pneumatic transport elements thereof being coordinated so that the fuel entering the transport

line from the supply source does so at a rate which by weight is at least 3.5 times the rate of primary air delivery into the transport line by the compressor; and means associated with said furnace chamber for bringing heated secondary air thereinto in a quantity by weight which is at least 12 times that of the ambient primary air coming into the furnace from the pneumatic transport line along with said fuel, said last mentioned means serving also to turbulently mix said heated secondary air with said in-blown fuel and primary air whereby to effect first the drying and then the ignition plus suspension burning of said fuel on a self-sustaining basis.

2. The pneumatic fuel transport and suspension drying-plus-burning organization of claim 1 wherein said heated secondary air has a furnace-entering temperature of at least 650° F.

3. The pneumatic fuel transport and suspension drying and burning organization of claim 1 wherein said heated secondary air has a furnace-entering temperature of at least 950° F.

4. The pneumatic fuel transport and compression drying-plus-burning system of claim 1 wherein a common burner assemblage serves to project both said heated secondary air and the said fuel with its carrying primary air into the furnace as a common unitary stream by and within which these named stream components are intimately intermingled and intermixed.

5. The pneumatic fuel transport and compression drying-plus-burning system of claim 1 wherein a common burner assemblage serves to project both said heated secondary air and the said fuel with its carrying primary air into the furnace as a common unitary stream, and further wherein vertical tilt-adjusting means are included in said assemblage for enabling said common stream to be projected into the furnace at the particular inclination with respect to the horizontal which best achieves optimum operating conditions within the furnace.

6. The pneumatic fuel transport and suspension drying-plus-burning system of claim 1 wherein a plurality of burner assemblages arranged to discharge tangentially to an imaginary cylinder within the furnace are utilized for bringing both the said heated secondary air and the said fuel with its primary carrying air into the furnace and further for intimately intermingling and intermixing these stream components within the furnace interior.

7. The pneumatic fuel transport and suspension drying-plus-burning system of claim 1 wherein at least 2 burner assemblages in generally opposed relationship with respect to the furnace center are arranged to discharge both the said heated secondary air and the said fuel with its primary carrying air into the furnace where a meeting of those generally oppositely directed streams produces intimate intermingling and intermixing of the stream components within the furnace interior.

8. The pneumatic fuel transport and suspension drying-plus-burning system of claim 1 wherein at least 2 burner assemblages in generally opposed relationship with respect to the furnace center are arranged to discharge both the said heated secondary air and the said fuel with its primary carrying air into the furnace where a meeting of those generally oppositely directed streams produces intimate intermingling and intermixing of the stream components within the furnace interior, and further wherein vertical tilt-adjusting means provided in each of those burner assemblages enable said generally opposed incoming streams to enter the furnace at the particular inclination with respect to the horizontal which best achieves optimum operating conditions within the furnace.

9. The pneumatic fuel transport and suspending drying-plus-burning organization defined by claim 1 wherein said furnace is provided with at least 2 burner assemblages arranged for generally opposed firing thereinto and with each serving to bring its pro rata portion of said secondary air and of said fuel with carrying primary air into the furnace in the form of a unitary fuel-and-air stream

so issuing from the assemblage as to meet and intermingle with the corresponding fuel-and-air stream coming into the furnace from the companion burner assemblage referred to above, and further wherein vertical-tilt adjusting means are included in each assemblage for enabling said fuel-and-air streams from the assemblages to be projected into the furnace in directions upwardly inclined with respect to the horizontal when fuels with large particles which require long suspension times are being fired and to be projected into the furnace in directions essentially horizontal or inclined downwardly therebelow when fuels with small particles dryable and burnable during shorter suspension times are being fired.

10. In a method for conveying a high-moisture fuel such as bagasse and bark and the like from a source thereof directly into a boiler furnace and for both suspension drying and suspension burning said fuel within the furnace chamber, the steps which comprise establishing a primary flow of transport air less than 8 percent by weight of the total air that is supplied to the furnace in order to effect such drying and combustion therein; introducing the fuel to be dried and burned into said primary transport flow at a location external to the furnace chamber such that each pound of transport air in said primary flow serves to convey at least 3.5 pounds of the said fuel and deliver it into the furnace; conveying the fuel with only the primary transport air to the boiler furnace and projecting the primary stream directly into the furnace chamber, with the fuel having essentially the same moisture content as when introduced into said primary stream; burning within said furnace chamber the fuel so projected thereinto and establishing a flow of combustion gases; establishing a second flow of secondary furnace air; passing the combustion gases in heat exchange relation with at least a portion of the secondary air flow whereby to heat that secondary air; and conveying said secondary air flow into the furnace chamber in such a manner that it intermixes with said first primary flow of fuel and transport air and supplies drying heat and combustion supporting air for the fuel.

11. The method of pneumatically transporting fuel for suspension drying-plus-burning in a furnace as defined by claim 10 wherein there is received by said secondary air flow from said combustion gas flow a heating that is effective to raise the secondary air temperature to at least 650° F.

12. The method of pneumatically transporting fuel for suspension drying-plus-burning in a furnace as defined by claim 10 wherein there is received by said secondary air flow from said combustion gas flow a heating that is effective to raise the secondary air temperature to at least 950° F.

13. In a system for transporting high-moisture fuel such as bagasse and bark and the like from a source thereof directly into a furnace and for both suspension drying and suspension burning said fuel within the furnace, the combination of a transport pipeline directly communicating with the furnace interior; means for flowing primary

air through said transport line in an amount not greater than about 10 percent by weight of the total air that is supplied into the furnace for so drying and burning the high-moisture fuel therewithin; means for metering the said fuel from said source at a rate not less than about 3.5 pounds of fuel for each pound of the said primary air passing through said transport line; means for introducing such metered fuel into the transport line in a way enabling the said flow of primary air to carry the fuel through the line and project it directly into the furnace chamber along with the primary air; and means for further introducing hot secondary air into the furnace chamber at a temperature of at least 650° F. and in an amount not less than about 90 percent by weight of the aforementioned total furnace air, with this introduction being such as intimately to intermix the hot secondary air with the said incoming fuel and primary carrying air and as to supply drying heat and combustion-supporting air to the incoming fuel particles.

14. In a method for conveying a high-moisture fuel such as bagasse and bark and the like from a source thereof directly into a furnace and for both suspension drying and suspension burning said fuel within the furnace, the steps which comprise establishing a primary flow of transport air less than about 10 percent by weight of the total air that is supplied into the furnace for so drying and burning the high-moisture fuel therewithin; metering the said fuel from said source and introducing it into said primary transport flow at a location external to the furnace chamber; conveying such metered fuel to the furnace in this primary transport air and projecting the transport stream of fuel and air directly into the furnace chamber, with at least 3.5 pounds of the fuel being so brought into the furnace along with each pound of the primary transport air; establishing a flow of secondary furnace air; heating the air in such secondary flow to a temperature of at least 650° F.; and conveying this flow of heated secondary air into the furnace chamber in such a manner so as to effect intermixing with said primary flow of entering fuel and transport air and as to supply drying heat and combustion-supporting air to the incoming fuel particles, with this heated secondary air being brought into the furnace in a quantity which is not less than about 90 percent by weight of the aforementioned total furnace air.

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