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Try et al.

[11] **3,882,612**

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[54] **METHOD AND APPARATUS FOR LIMITING THE CONCENTRATION OF COMBUSTIBLE VOLATILES IN DRYER EMISSIONS**

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[52] **U.S. Cl.** **34/27**; 34/46; 34/54; 34/72; 34/212; 34/216; 432/72

[51] **Int. Cl.** **F26b 3/02**

[58] **Field of Search** 34/23, 27, 29, 30, 32, 34/34, 46, 48, 54, 72, 79, 102, 212, 216, 219, 224, 47, 231, 232; 110/8; 432/48, 72

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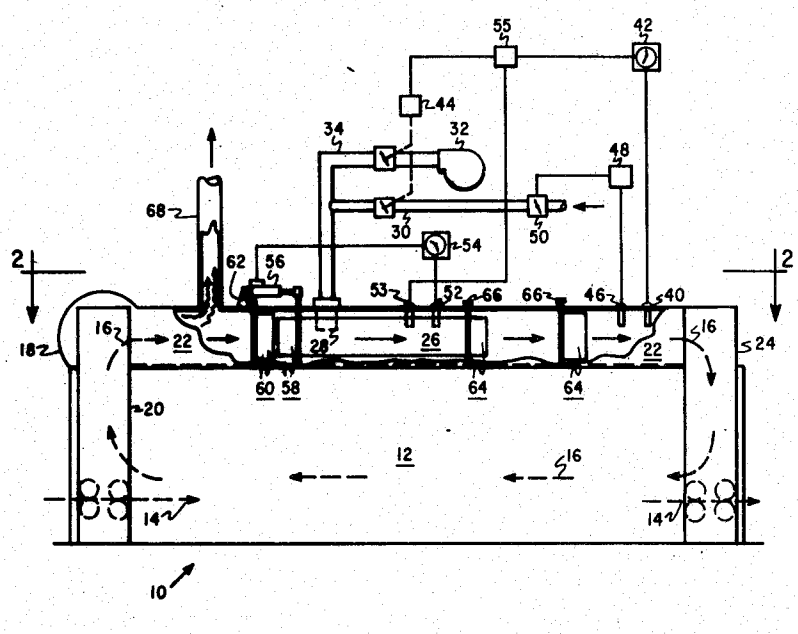
[57] **ABSTRACT**

Method and apparatus for limiting the concentration of combustible volatiles in the stack gases of a recirculating dryer adapted for treating materials containing such volatiles. A portion of the recirculating drying gases is directed through a heater duct interposed between the drying gas inlet and outlet ports of the drying chamber, such heater duct including a high temperature heat source for heating such gas portion to the combustion temperature of the entrained volatiles to incinerate them. Another portion of the recirculating drying gases bypasses the heater duct and is mixed with the heated gases at the discharge end of the heater duct, thereby forming a gas mixture suitable for introduction into the drying chamber having a temperature substantially lower than that imposed upon the gases in the heater duct. The length of the heater duct in a direction downstream from the high temperature heat source is sufficient to maintain the gases in the duct at or above the combustion temperature of the volatiles for a dwell period sufficient to permit the complete combustion of the volatiles prior to the mixing of the two gas streams. A temperature sensor monitors the temperature of the gases in the heater duct, and power-actuated adjustable dampers located at the entrance to the duct automatically decrease the flow rate of the drying gases through the duct if the temperature drops below that necessary to support combustion of the volatiles. Another temperature sensor monitors the temperature of the gas mixture introduced into the drying chamber, and a controller automatically responsive to the latter temperature modulates the energy output from the heat source so as to maintain the temperature of the gas mixture within a predetermined operating range. The concentration of volatiles in the stack gases is dependent upon the volumetric flow rate of that portion of the recirculating gases passing through the heater duct and its relation to the volumetric flow rate of the stack gases.

17 Claims, 2 Drawing Figures



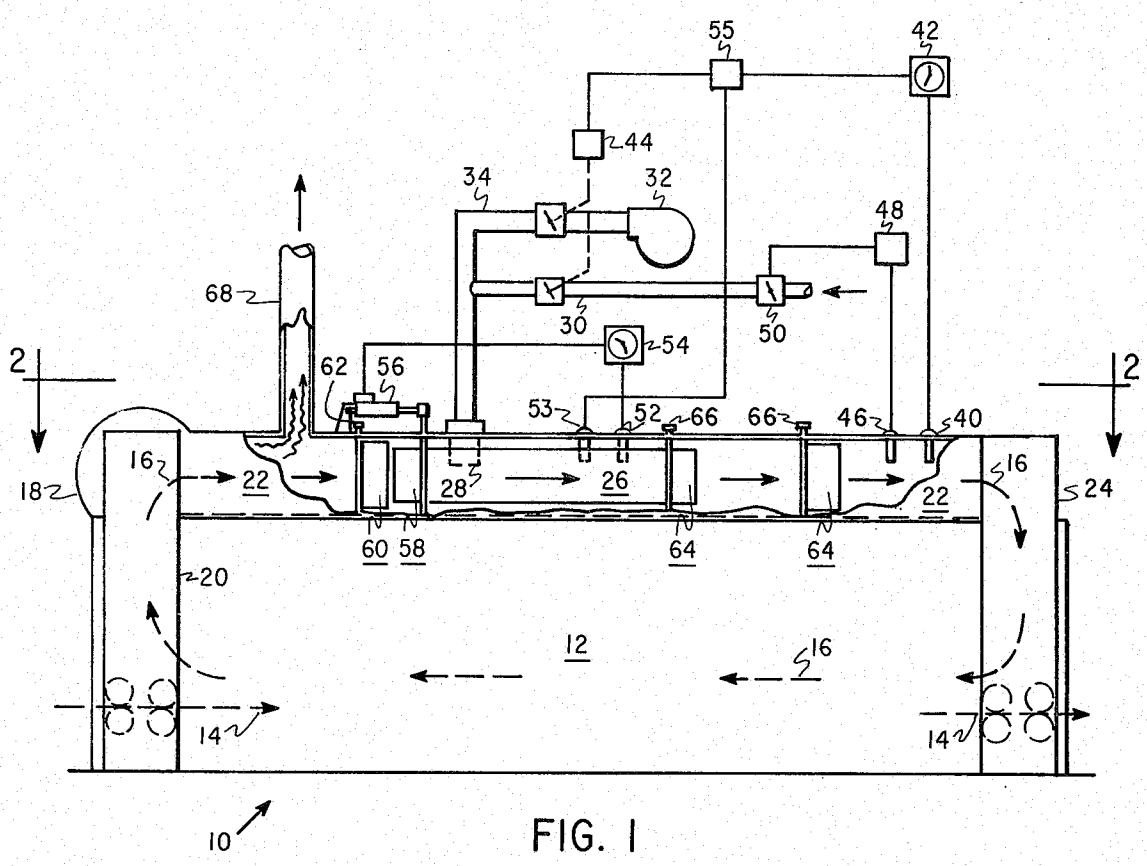

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FIG. 1

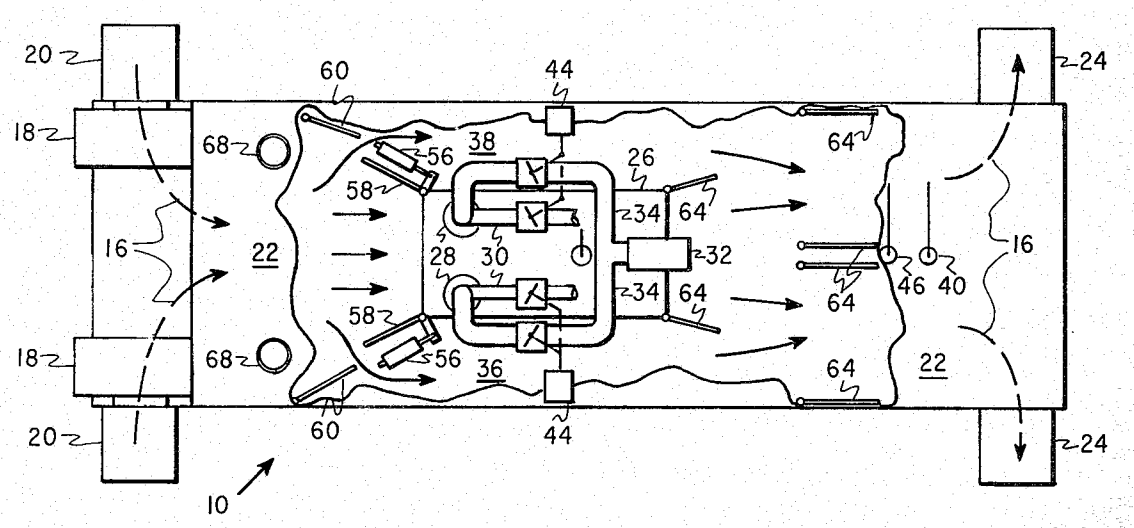
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FIG. 2

METHOD AND APPARATUS FOR LIMITING THE CONCENTRATION OF COMBUSTIBLE VOLATILES IN DRYER EMISSIONS

BACKGROUND OF THE INVENTION

This invention relates to improvements in method and apparatus for drying materials containing combustible volatiles. More particularly, the system is applicable to direct-fired recirculating dryers and provides means for heating a portion of the recirculating drying gases to the combustion temperature of the entrained volatiles and thereby incinerating the volatiles to decrease their concentration in the dryer stack gases.

In direct-fired recirculating dryers of the type known to the art and shown for example in Jones U.S. Pat. No. 3,675,600 and Erickson U.S. Pat. No. 3,131,035, all of the recirculating drying gases are heated to the combustion temperature of the volatiles to remove such volatiles by incineration prior to emission of the drying gases into the atmosphere. Such systems present problems, however, when applied to dryers wherein the incineration temperatures, to be effective, must be much higher than the desired operating temperature of the drying gases. For example in commercial dryers such as those used for drying wood veneer, the desired operating temperature of the drying gases is in the range of 200°F. – **500**°F. while the temperature necessary to effect combustion of the hydrocarbon volatiles drawn from such veneer is in the range of 1,000°F. – **1500**°F. Accordingly it is difficult to obtain compatability between the two temperatures in such systems without the costly and inefficient step of cooling the gases from one temperature to the other, or alternatively limiting the incineration temperatures.

In contrast to the foregoing systems, the Blesch et al U.S. Pat. No. 3,001,298 features a recirculating dryer wherein only a portion of the recirculating gases are heated to the combustion temperature of the volatiles, the remaining gases bypassing the incinerator and being mixed with the hot gases emitted from the incinerator to form a resultant gas mixture of much lower temperature suitable for introduction to the drying chamber. However the Blesch system requires a number of significant improvements to adapt it to the purpose of pollution control, for which use it was not specifically intended, and improve its practicability under the conditions normally encountered in commercial dryers for wood and other materials. One such condition is that the total heat requirement of the recirculating drying gases varies dependent upon material species, thickness and moisture content. Since, in the Blesch-type system, the heat energy emitted from the incinerator burner is also used to supply such heat requirement and must also therefore vary accordingly, there is a corresponding need for variation of the volumetric flow rate of that portion of the gases passing through the incinerator. Otherwise the incinerator temperature will rise or fall with changes in the heat output from the burner and the temperature may not always be high enough to effect combustion of the volatiles. Consequently a flow modulating system is needed at the entry to the incinerator automatically responsive to the incinerator temperature. Moreover there is a need for providing a "dwell time" for the gases in the incinerator whereby, after they have been heated to the combustion temperature of the volatiles, they will be maintained at that temperature for a time period long enough to insure completion of combustion. Finally, in order successfully to employ a process whereby only a portion of the recirculating drying gases are incinerated to achieve the desired low concentration of combustible volatiles in the stack gases, certain critical relationships must be established between the volumetric flow rate of the incinerated gases and the volumetric flow rate of the stack gases.

SUMMARY OF THE PRESENT INVENTION

The present invention is directed to a drying method and apparatus of the general type described wherein a portion, less than all, of the recirculating drying gases is passed through a heater duct having a high temperature heat source therein for incinerating the entrained combustible volatiles carried by such gases so as to limit their concentration in the dryer stack gases. That portion of the recirculating drying gases which is not directed through the heater duct is mixed with the gases emerging from the heater duct to form a resultant mixture having a temperature much lower than the combustion temperature of the volatiles and suitable for introduction to the drying chamber. A temperature sensor monitors the temperature of the gases in the heater duct, and power actuated dampers located at the entrance to the heater duct automatically decrease the volumetric flow rate of the gases through the duct whenever such temperature falls below the predetermined temperature required to effect the desired combustion of the volatiles. Another sensor monitors the temperature of the aforementioned resultant drying gas mixture, and a controller responsive to such temperature varies the heat output of the high temperature heat source so as to maintain the temperature of the gas mixture at a predetermined setting or within a predetermined operating range suitable for use in the drying chamber.

The heater duct is of elongate shape and has sufficient length in a direction downstream from the heat source to insure that the gases will be maintained in the duct at their high combustion temperature for a sufficient dwell period, prior to mixing with the other portion of the recirculating gases, to insure that the necessary combustion of the volatiles will be completed. The dwell time provided by the elongate heater duct generally minimizes the required high temperature which must be maintained in the duct to achieve the desired degree of combustion, which in turn maximizes the volume of recirculating gases which can be recirculated through the duct and obviates any requirement for exceptionally heat-resistant duct materials. To provide efficient mixing of the incinerated and non-incinerated gas streams, adjustable dampers are located at the outlet of the heater duct to induce turbulence into the respective converging streams and thus aid in the mixing process.

The magnitude of the volumetric flow rate of drying gases through the heater duct, determined by the area of the duct and modulated by the aforementioned power actuated dampers at the duct entrance, is critical to the degree to which the concentration of volatiles in the stack gases can be limited. Specifically, if a given dryer would have a certain normal concentration of volatiles in its stack gases without any incineration of the recirculating drying gases, then to reduce such concentration to some predetermined concentration which is a fraction X of the normal concentration requires

that the volumetric flow rate of gases through the heater duct be at least $(1-X)/X$ times the volumetric flow rate of stack gases emitted from the dryer. The application of the foregoing minimum flow rate parameter enables the employment of the present invention both in original equipment dryers and in retrofit kits adaptable for modifying existing dryers, and is especially valuable for use in meeting maximum pollutant concentration limits imposed by governmental regulatory bodies.

Accordingly it is a primary objective of the present invention to provide a method and apparatus for drying wood veneer, and other materials of the type containing combustible volatiles, which insures a predetermined maximum concentration of such volatiles in the stack gases by virtue of the incineration of the volatiles entrained in a portion, less than all, of the recirculating drying gases.

It is a further primary objective of the present invention to utilize the same heat energy both for effecting the incineration of the volatiles and for heating the recirculating drying gases.

It is a still further objective of the present invention to limit pollutant concentration in new and existing dryers by the installation of a heater duct for effecting such incineration having sufficient volumetric capacity to establish a concentration of stack gas volatiles no greater than such predetermined maximum concentration.

Another objective of the present invention is to provide such heater duct with means automatically responsive to the temperature in such duct for decreasing the volumetric flow rate of gases through the duct whenever the temperature therein falls below the combustion temperature of such volatiles.

It is a further objective of the present invention to make such duct of elongate shape adaptable to provide a dwell period for such gases in the duct sufficient to insure adequate combustion of the volatiles while minimizing the required duct temperature.

The foregoing and other objectives, features and advantages of the present invention will be more readily understood upon consideration of the following detailed description of the invention, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partially schematic side view of a representative recirculating dryer equipped with a heater duct for limiting the concentration of pollutants in the stack gases, with portions of the dryer broken away to show interior elements.

FIG. **2** is a top view of the dryer taken along lines **2—2** of FIG. **1**, with portions broken away for clarity.

DETAILED DESCRIPTION OF THE INVENTION

The exemplary dryer designated generally as **10** in FIGS. **1** and **2** constitutes a single zone, recirculating type longitudinal veneer dryer having a drying chamber **12** through which wood veneer sheets are passed in the direction shown schematically by arrows **14.** Drying gases, flowing in the direction indicated by arrows **16,** are recirculated through the drying chamber **12** by fans **18** which draw the gases from exhaust ports **20** of the chamber **12** and direct them through a recirculating duct assembly **22** back into the drying chamber **12** through inlet ports **24.** Although the invention is depicted as applied to a single zone, recirculating longitudinal dryer, the invention is equally applicable to virtually any type of recirculating dryer, or one which can be modified to recirculate, including multiple zone dryers, cross-circulation dryers and jet dryers. Moreover, the material being dried need not necessarily be veneer, but may be any other type of material from which combustible volatiles are drawn during the drying process.

The duct assembly **22** joining the exhaust ports **20** with the inlet ports **24** is divided into at least two separate parallel branches. One of the branches comprises a heater duct **26** adapted for accepting a portion, less than all, of the recirculating drying gases **16.** The heater duct **26** is equipped with high temperature heating means **28** which is capable of operating at a predetermined temperature sufficient to effect combustion of at least the major components of the combustible volatiles, which predetermined temperature is hereafter referred to for convenience as the "combustion temperature" of the volatiles. The heating means **26** may be of any convenient type such as a gun or nozzle type burner using natural gas or propane fuel, a wood waste fired burner, etc. In FIGS. **1** and **2** a pair of burners **28** are provided, each being of the nozzle type fueled with natural gas through conduits **30** and receiving combustion air from fan **32** through conduits **34.**

The primary purpose of the heater duct **26** is to heat that portion of the recirculating drying gases which passes through the heater duct **26** at least to the combustion temperature of the combustible volatiles drawn from the wood veneer or other materials being treated. In the case of wood veneer, the temperature in the duct should preferably be in the range of 1,000°F. – 1,500°F. to effect sufficient combustion. That portion of the recirculating drying gases which does not pass through the heater duct **26** bypasses the heater duct through branch ducts **36** and **38** respectively and is then mixed with the incinerated portion of the drying gases emerging from the heater duct **26.** This results in a mixture of the two gas streams which, due to the cooling effect of the non-incinerated bypass stream, has a substantially lower temperature than that imposed in the heater duct **26.** Such result is desirable since drying criteria call for optimum operating temperatures of the drying gases **16** in a much lower range than the combustion temperature of the volatiles, for example 250°F. – 500°F. for veneer drying. Accordingly the heater duct **26** performs not only the function of heating a portion of the recirculating drying gases to the combustion temperature of the volatiles to cause their incineration, but also performs the further function of providing the total heat input to the recirculating drying gases, although some additional heat could be introduced from another source if required.

The operation of a dryer in accordance with the foregoing principles requires the control of two temperatures. First, the temperature of the gas mixture introduced into the drying chamber **12** must be maintained within some predetermined operating temperature range suitable for drying the particular materials being treated, such temperature range being variable depending upon the type of dryer, material species, thickness and moisture content. This operating temperature is monitored by a temperature sensor **40** inserted in the duct assembly **22** at a location downstream from the heater duct **26** so as to enable the sensor **40** to measure

the temperature of the drying gases as they are introduced into the drying chamber **12.** A temperature controller **42** receives the temperature measurement and transmits a corresponding signal to a pair of control valves **44** which automatically regulate the flow of air and fuel to the burners **28** in response to the signals, thereby controlling heat output. (The temperature sensor, controller and control valves are conventional items well known to the industry.) Whenever the operating temperature of the drying gas mixture, as measured by temperature sensor **40,** falls below a predetermined temperature, controller **42** causes valves **44** automatically to increase the air and fuel supply to the burners **28,** thereby increasing the heat output. Conversely, if the operating temperature of the drying gas mixture rises above a predetermined temperature, valves **44** automatically reduce the air and fuel supply, thereby decreasing the heat output of the burners **28.** A back-up temperature sensor **46** acting through a switch **48** is adapted automatically to interrupt the fuel supply to the burners by actuating valve **50** as a safety precaution against excessive temperatures caused by any malfunction of the operating temperature control system.

A second temperature in the system which must be controlled, particularly in view of the varying heat output from burners **28,** is that of the gases within heater duct **26** so as to insure that the gases will continually be heated at least to the combustion temperature of the volatiles to support the required incineration. The control system for maintaining such temperature comprises another sensor **52,** for monitoring the temperature within the heater duct **26,** which acts through a controller **54** to actuate a pair of pneumatic cylinders **56** which determine the respective positions of a pair of pivoted dampers **58** located on either side of the entrance to the heater duct **26.** The dampers **58** act to proportion the volumetric flow rate of recirculating drying gases between the heater duct **26** and the branch ducts **36, 38** and operate automatically in response to the controller **54** to permit a predetermined volumetric flow rate through the heater duct **26** so long as the temperature within the duct remains at or above the predetermined minimum temperature required to effect combustion of the volatiles. However should the temperature sensor **52** monitor a temperature in the duct **26** below such minimum temperature, the pneumatic cylinders **56** react pursuant to signals received from the controller **54** to rotate the dampers **58** toward one another and thereby decrease the volumetric flow rate into the heater duct sufficiently to raise the temperature in the duct to the predetermined minimum. The latter situation might arise, for example, in the case of lowered dryer heat demand causing reduced heat output from the burners **28,** or due to an adjustment of controller **42** to lower the desired operating temperature of the dryer. A back-up temperature sensor **53** which also monitors the temperature within heater duct **26** acts through controller **55** to override controller **42** and automatically reduce the fuel and air supply to burners **28** if the temperature within heater duct **26** exceeds a predetermined maximum value.

In the embodiment of FIGS. **1** and **2,** the heater duct **26** comprises an open-ended housing of rectangular cross-section mounted within, and colinear with, the larger recirculating duct assembly **22** and located substantially equidistant from the sidewalls of the larger duct so as to form the parallel branch ducts **36** and **38.** With this type of configuration it is desirable to have a second pair of dampers **60** pivotally mounted upstream of the power actuated dampers **58** on either side of the larger duct assembly **22** for balancing the gas flow and insuring that the power actuated dampers receive sufficient air for good control. The respective positions of the pivotal dampers **60** are manually adjustable by virtue of handles **62** mounted atop the dryer.

It should be noted that heater duct **26** need not necessarily be located within a duct having a larger cross-section as in FIGS. **1** and **2,** but might instead be mounted exterior of, and in parallel relation with, another recirculating duct, each adaptable to conduct a portion of the recirculating drying gases. Furthermore, there may be a plurality of heater ducts and/or a plurality of bypass ducts if the type of dryer most conveniently lends itself to such duct configuration.

Regardless of the duct configuration, it is important that the incinerated and non-incinerated portions of the recirculating drying gases be joined together in such a manner as to facilitate and enhance their mixture and produce a resultant gas mixture having a uniform predetermined temperature suitable for introducing into the drying chamber **12.** It has been found that such mixture can best be enhanced by providing a series of movable, adjustable baffles such as pivotal baffles **64** at the location where the respective gas streams join one another, to induce turbulence into the joined streams. The baffles **64** may be manually adjusted to any desired position by means of handles such as **66.**

It is important to the proper operation of the system that the heater duct be of elongate shape having sufficient length in a direction downstream from the location of the heat source, (e.g., the location of burners **28**) so as to provide a dwell period during which the gases in the duct will be maintained at the combustion temperature of the volatiles before such gases are emitted from the duct and mixed with the non-incinerated portion of the recirculating gases. The dwell period referred to permits completion of combustion of the volatiles after the volatiles have been heated to the combustion temperature, and reflects the fact that completion of combustion of the volatiles, primarily hydrocarbons, is a function both of time and temperature. For example if an extremely high temperature is imposed upon the volatiles, the time necessary for completion of combustion will be substantially less than that necessary if merely the minimum temperature necessary to induce combustion is initially imposed. In a system of this type, wherein only a portion of the recirculating drying gases is incinerated, the objective is to minimize the required predetermined combustion temperature in the heater duct necessary to complete combustion so as to maximize the volumetric flow rate of gases through the duct and thereby maximize the quantity of volatiles incinerated. Such objective provides the most effective pollution reduction while at the same time obviating the need for special temperature-resistant metals or refractory lining in the heater duct. To minimize the required combustion temperature in the duct requires as large a dwell time as possible, and accordingly the primary purpose of the heater duct **26** is not only to concentrate the heat from the burners **28** to attain the required combustion temperature, but also to provide sufficient length, dependent upon the predetermined linear velocity of the drying gases through the duct, to achieve

a dwell period which will minimize the required combustion temperature. The minimum required combustion temperature in the duct will of course be at least as great as the temperature necessary initially to induce combustion, and may be greater depending upon physical factors limiting the length of the heater duct and the linear velocity of the gases for any given installation. The excess air necessary to support combustion of the volatiles may be introduced into the heater duct **26** in any suitable manner; however one convenient way is simply to introduce the excess air with the combustion air for the burners by means of fan **32** and conduit **34.**

In practice, the apparatus described above is utilized to limit the concentration of combustible volatiles in the stack gases of dryers either by providing such apparatus as original equipment on new dryers or by retrofitting existing dryers by modifying them to include the equipment. In most cases there is a governmental regulatory body which has already set standards for maximum pollutant concentrations in dryer emissions to protect the quality of the air. Such governmental regulations act as a guide in preselecting a maximum allowable concentration of combustible volatiles in the dryer stack gases.

The volumetric flow rate capacity of the heater duct or ducts is the critical factor in achieving the desired limited concentration of volatiles in the stack gases. To determine such volumetric flow rate capacity, which will in turn dictate the cross-sectional area of the duct, two other factors should also be known. One of these is the normal concentration of volatiles in the stack gases of a particular dryer. (As used in the specification and claims, the term "normal concentration" means the concentration of volatiles in the stack gases when the dryer is operated without the partial incineration of the recirculating drying gases herein described.) For new and existing dryers the normal concentration can be determined by measuring actual concentrations in the stack gases by methods well known to the industry. The other factor to be determined is the volumetric flow rate of the stack gases, which is also readily determinable by known measuring methods. Since the heater duct is installed in the dryer with its outlet end located downstream from the position of the dryer exhaust stacks **68** to prevent undue heat loss, the concentration of combustible volatiles will be the same in both the stack gases and in that portion of the recirculating gases which passes into the heater duct **26.** Accordingly:

$$Q = \frac{Ce}{Ve} = \frac{Ci}{Vi}$$

Where:

Q = concentration of combustibles in stack gases, grains per cu. ft.

Ce = combustibles exhausted, grains per minute

Ci = combustibles incinerated, grains per minute

Ve = stack gases emitted, cu. ft. per minute

Vi = recirculating gases incinerated, cu. ft. per minute

The rate of generation of combustible volatiles Cg must equal the rate incinerated plus the rate exhausted for steady state operation. Thus:

$$Cg = Ce + Ci$$

If no incineration is provided, then Ci and Vi equal zero and the normal concentration Q_1 of combustibles in the stack gases, is:

$$Q_1 = \frac{Cg}{Ve}$$

With a heater duct employed to incinerate a portion of the recirculating drying gases, the new concentration Q_2 of combustibles in the stack gases is:

$$Q_2 = \frac{Ce}{Ve} = \frac{Ci}{Vi} \qquad \text{from which}$$

$$Q_2Ve = Ce \qquad \text{and}$$

$$Q_2Vi = Ci$$

Since $Ce + Ci = Cg$ it follows that $Q_2Ve + Q_2Vi = Cg$ and that therefore

$$Q_2 = \frac{Cg}{Ve + Vi}$$

To reduce the normal concentration Q_1 of a dryer to a predetermined lesser maximum allowable concentration Q_2, which is a fraction X of the normal concentration, requires a minimum volumetric flow rate Vi through the heater duct calculated as follows (assuming complete combustion of the volatiles passing through the duct):

$$X = \frac{Q_2}{Q_1} = \frac{\frac{Cg}{Vi + Ve}}{\frac{Cg}{Ve}} = \frac{Ve}{Vi + Ve}$$

$$+ Ve = \frac{Ve}{X}$$

$$Vi = \frac{Ve}{X} - Ve = \frac{Ve - XVe}{X}$$

$$Vi = \frac{Ve\,(1 - X)}{X}$$

Accordingly, assuming that a dryer would normally emit stack gases having a concentration of combustible volatiles of 0.3 grains per cubic foot, and it is desired that the maximum allowable concentration be limited to 0.1 grains per cubic foot, a heater duct or ducts would be interposed between the inlet and outlet of the drying chamber **12** adapted for accepting a portion of the recirculating drying gases equal to at least $(1 - \frac{1}{3})/\frac{1}{3}$ or twice the volumetric flow rate of the stack gases of the dryer. Alternatively, if it were necessary to reduce the concentration only to 0.2 grains per cubic foot, the heater duct or ducts would be adapted to accept a total volumetric flow rate equal to at least $(1 - \frac{2}{3})/\frac{2}{3}$ or ½ of the volumetric flow rate of the stack gases.

Inasmuch as automatic modulating means, i.e., the power actuated dampers **58,** are provided for changing the volumetric flow rate of gases through the heater duct, the duct and its associated burners should be designed to accept the aforementioned flow rate at the lowest expected heat output of the burners without causing the temperature of the gases in the duct to fall below the combustion temperature of the volatiles, so that variations in heat output occasioned by varying

heat demands of the dryer will not cause any combustible concentrations above the predetermined maximum allowable limit.

The terms and expressions which have been employed in the foregoing abstract and specification are used therein as terms of description and not of limitation, and there is no intenton, in the use of such terms and expressions, of excluding equivalents of the features shown and described or portions thereof, it being recognized that the scope of the invention is defined and limited only by the claims which follow:

What is claimed is:

1. A dryer for drying materials containing combustible volatiles by the recirculation of heated drying gases through a chamber containing said materials, said dryer having a system for both heating said drying gases to a predetermined operating temperature range suitable for drying said materials and simultaneously incinerating a portion of said combustible volatiles drawn from said materials during drying so as to limit the concentration of said volatiles in the stack gases emitted from said dryer, said dryer comprising:

a. heater duct means for accepting a portion, less than all, of said drying gases from said drying chamber after said gases have been passed over said materials, said heater duct including means for heating said portion of said gases at least to a predetermined minimum required combustion temperature of said volatiles, said combustion temperature being substantially greater than said predetermined operating temperature range, and further including means for supplying at least the majority of the heat requirement of all of said drying gases;

b. bypass duct means for accepting a separate portion of said drying gases from said drying chamber;

c. means for intermixing said respective portions of said drying gases emitted from said respective duct means and for conducting the resultant mixture of said drying gases through said drying chamber for passage over said materials;

d. means automatically responsive to the temperature of said resultant mixture of drying gases for modulating the heat output from said heating means so as to maintain the temperature of said resultant mixture within said predetermined operating temperature range; and

e. variable gas flow modulating means automatically responsive to the temperature of said gases within said heater duct means for decreasing the volumetric flow rate of said portion of said gases passing through said heater duct means whenever the temperature of said gases within said heater duct means falls below said predetermined minimum required combustion temperature of said volatiles.

2. The dryer of claim **1** wherein said intermixing means (c) includes baffle means located in advance of said drying chamber for inducing turbulence into said respetive joined gas portions and thereby promoting the mixing of said portions with one another.

3. The dryer of claim **2** including adjustable means for movably mounting said baffle means so as to permit variable adjustment of the position of said baffle means.

4. The dryer of claim **1** wherein said respective heater and bypass duct means comprise an open-ended heater duct mounted within and colinear with a bypass duct having a substantially larger cross-section than said heater duct, said heater duct being mounted substantially equidistant from the side walls of said bypass duct so as to define passageways along either side of said heater duct, said variable gas flow modulating means comprising a pair of power actuated movable dampers mounted on either side of the entrance of said heater duct for regulating the respective flow proportions of the drying gases through said heater duct and around the sides of said heater duct respectively.

5. The dryer of claim **4** including a second pair of movable dampers mounted upstream of said pair of power actuated dampers on either side of said bypass duct for balancing the volumetric flow of gases approaching said pair of power actuated dampers.

6. The dryer of claim **1** including back-up temperature sensor means for measuring the temperature of said gases within said heater duct means, and means automatically responsive to said back-up temperature sensing means for automatically decreasing the heat output from said heating means whenever the temperature of said gases in said heater duct means rises above a predetermined maximum temperature.

7. A dryer for drying materials containing combustible volatiles by the recirculation of heated drying gases through a chamber containing said materials, said dryer having a system for both heating said drying gases to a predetermined operating temperature range suitable for drying said materials and simultaneously incinerating a portion of said combustible volatiles drawn from said materials during drying so as to limit the concentration of said volatiles in the stack gases emitted from said dryer, said dryer comprising:

a. heater duct means for accepting a portion, less than all, of said drying gases from said drying chamber after said gases have been passed over said materials, said heater duct including means for heating said portion of said gases at least to a predetermined minimum combustion temperature of said volatiles, said combustion temperature being substantially greater than said predetermined operating temperature range, and further including means for supplying at least the majority of the heat requirement of all of said drying gases;

b. bypass duct means for accepting a separate portion of said drying gases from said drying chamber;

c. means for intermixing said respective portions of said drying gases emitted from said respective duct means and for conducting the resultant mixture of said drying gases through said drying chamber for passage over said materials; and

d. regulating means automatically responsive both to the temperature of said resultant mixture of drying gases and to the temperature of said gases within said heater duct means for variably modulating the heat supplied from said heater duct means to said resultant mixture so as to maintain said resultant mixture within said predetermined operating temperature range while simultaneously maintaining said gases within said heater duct means at least at said predetermined minimum combustion temperature regardless of said modulation of said heat supply.

8. The dryer of claim **7** wherein said regulating means (d) comprises temperature sensor means for measuring the operating temperature of said resultant mixture of drying gases, means automatically responsive to said temperature sensor means for increasing the heat out-

put from said heater duct means whenever said operating temperature falls below a predetermined temperature and decreasing said heat output whenever said operating temperature rises above a predetermined temperature, second temperature sensor means for measuring the temperature of said gases within said heater duct means, and variable gas flow modulating means automatically responsive to said second temperature sensor means for decreasing the volumetric flow rate of said portion of said drying gases passing through said heater duct means in response to a decrease in the temperature of said gases in said heater duct means below said predetermined minimum combustion temperature.

9. The dryer of claim **8** wherein said intermixing means (c) includes baffle means located in advance of said drying chamber for inducing turbulence into the respective joined gas portions and thereby promoting the mixture of said portions with one another.

10. The dryer of claim **9** including adjustable means for movably mounting said baffle means so as to permit variable adjustment of the position of said baffle means.

11. The dryer of claim **8** wherein said respective heater and bypass duct means comprise an open-ended heater duct mounted within and colinear with a bypass duct having a substantially larger cross-section than said heater duct, said heater duct being mounted substantially equidistant from the side walls of said bypass duct so as to define passageways along either side of said heater duct, said variable gas flow modulating means comprising a pair of power actuated movable dampers mounted on either side of the entrance of said heater duct for regulating the respective flow proportions of the drying gases through said heater duct and around the sides of said heater duct respectively.

12. The dryer of claim **11** including a second pair of movable dampers mounted upstream of said pair of power actuated dampers on either side of said larger duct for balancing the volumetric flow of gases approaching said pair of power actuated dampers.

13. The dryer of claim **8** including back-up temperature sensing means for measuring the tempertaure of said gases within said heater duct means, and means automatically responsive to said back-up temperature sensing means for automatically decreasing the heat output from said heater duct means whenever the temperature of said gases in said heater duct means rises above a predetermined temperature.

14. A method of drying materials containing combustible volatiles which comprises:

a. recirculating heated drying gases over said materials at a predetermined operating temperature range suitable for drying said materials;

b. during siad recirculation of said drying gases heating a portion, less than all, of said recirculating drying gases to a predetermined minimum combustion temperature of said volatiles and burning at least a portion of said volatiles, thereby also supplying at least the majority of the heat requirement of all said drying gases;

c. mixing a separate portion of said recirculating drying gases with said portion of gases heated pursuant to step (b) to form a gas mixture having a temperature lower than that of said heated gases alone; and

d variably modulating the heat supplied to said gas mixture in step (b) so as to maintain said resultant mixture within said predetermined operating temperature range while simultaneously maintaining said gases heated in step (b) at least at said predetermined minimum combustion temperature regardless of said modulation of said heat supply.

15. The method of claim **14** wherein said modulating step (d) comprises automatically increasing the rate at which heat is supplied in step (b) in response to the temperature of said gas mixture falling below a predetermined temperature and decreasing said rate of heat supply automatically in response to said temperature of said gas mixture rising above a predetermined temperature, and automatically decreasing the volumetric flow rate of said portion of gases heated in step (b) in response to any decrease in the temperature of said gases heated in step (b) below said combustion temperature of said volatiles.

16. The method of claim **14** wherein said step (b) includes maintaining the temperature of said portion of said recirculated drying gases heated in step (b) at least at said minimum combustion temperature for a sufficient period of time before mixing said heated gas portion with said other gas portion to insure completion of combustion of said volatiles.

17. The method of claim **14** including the further step of emitting a portion of said gas mixture into the atmosphere as stack gases after said gases have been recirculated over said materials, selecting a fraction X of the normal concentration of said volatiles in said stack gases to which said concentration of volatiles is to be reduced, and causing the volumetric flow rate of said portion of gases heated in step (b) to be substantially at least $(1-X)/X$ times the volumetric flow rate of said stack gases emitted to the atmosphere.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,882,612

DATED : May 13, 1975

INVENTOR(S) : Robert W. Try and David W. Campbell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 8, Lines 35-43	The second line of the four-line equation should read "$Vi + Ve = \frac{Ve}{X}$".
Col. 9, Line 58	Change "respetive" to --respective--.
Col. 11, Line 42	Change "tempertaure" to --temperature--.
Col. 12, Line 14	After the letter "d" insert a period (.).

Signed and Sealed this

second Day of *September 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks