

[54] FUME INCINERATOR

[72] Inventor: **Charles B. Gentry**, Grand Rapids,
Mich.

[73] Assignee: **Granco Equipment, Inc., Grand Rapids, Mich.**

[22] Filed: **Sept. 30, 1971**

[21] Appl. No.: 185,046

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 59,142, July 29, 1970, abandoned, and a continuation-in-part of Ser. No. 104,905, Jan. 8, 1971, abandoned.

[52] U.S. Cl. 263/8 R, 23/277 C, 34/79,
110/8 A

[51] Int. Cl. F27b 9/30, F23g 7/06

[58] **Field of Search**....263/8 R; 34/79, 83; 126/91 A;
110/8 R, 8 A; 23/277 R, 277 C

References Cited

UNITED STATES PATENTS

1,603,760	10/1926	Furkert.....	263/8 R
3,472,468	10/1969	Price et al.....	23/277 C
3,484,189	12/1969	Hardison et al.....	23/277 C
3,547,592	12/1970	Gladu et al.....	110/8 A
3,549,333	12/1970	Tubak.....	110/8 A

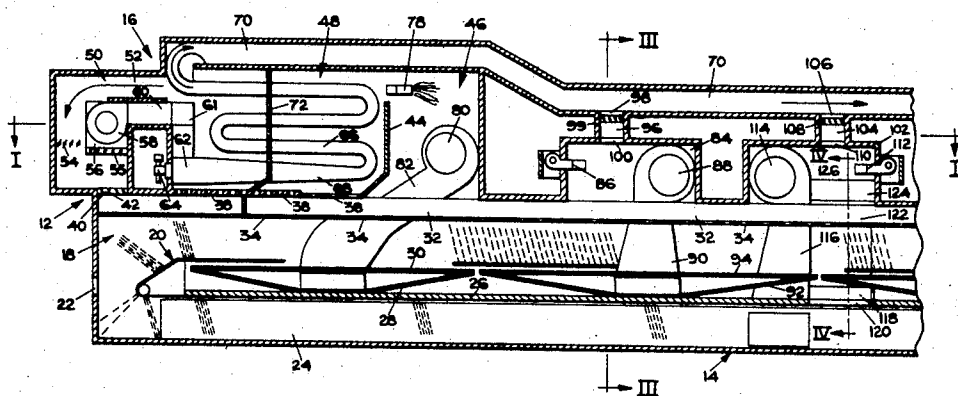
3,311,456 3/1967 Denny et al.23/277

Primary Examiner—John J. Camby
Attorney—John E. McGarry

[57] **ABSTRACT**

An incinerator for a drying oven and the like to remove combustible fumes such as solvent vapors from the exhaust from such ovens. The incinerator is formed from a narrow, elongated, heat-conducting, metal incinerator conduit having at least one U or reverse bend to increase turbulence within the conduit and to increase heat exchange of hot gases with the exterior of the conduit. The fume-laden gases to be incinerated are channelled along the exterior surface of the incinerator conduit for heat exchange with the incinerator. A fan draws the solvent-laden gases through the larger preheat conduit and forces the preheated gases into the incinerator conduit at a higher pressure than that of the preheat conduit. In one embodiment, a portion of the combusted gases from the incinerator conduit is admixed with the solvent and air mixture in the preheat conduit to assist in preheating the mixture. The incinerator can be built into the oven with which it is used, or can be a separate entity mounted on top of the oven or even separated from the oven by ducting.

26 Claims, 9 Drawing Figures



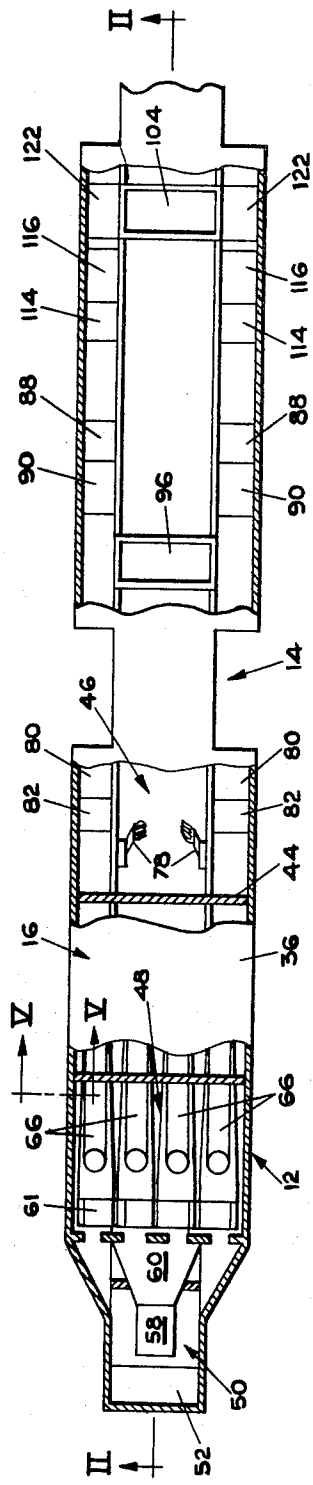


FIG. 1

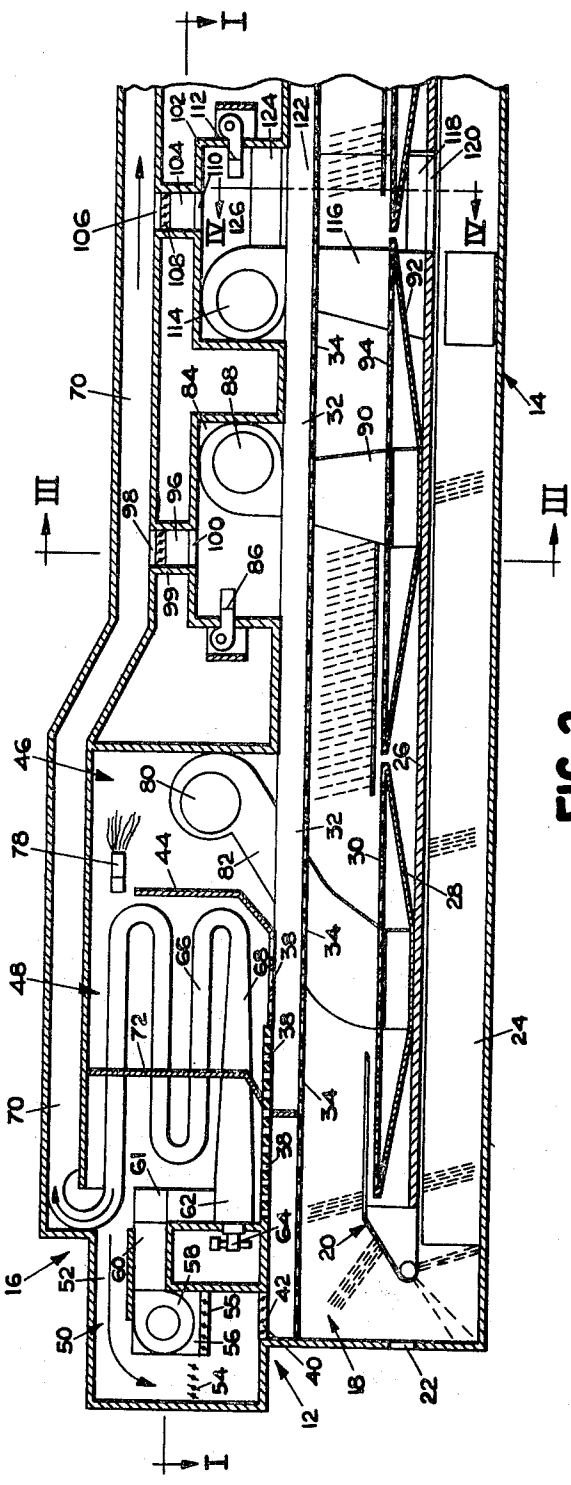
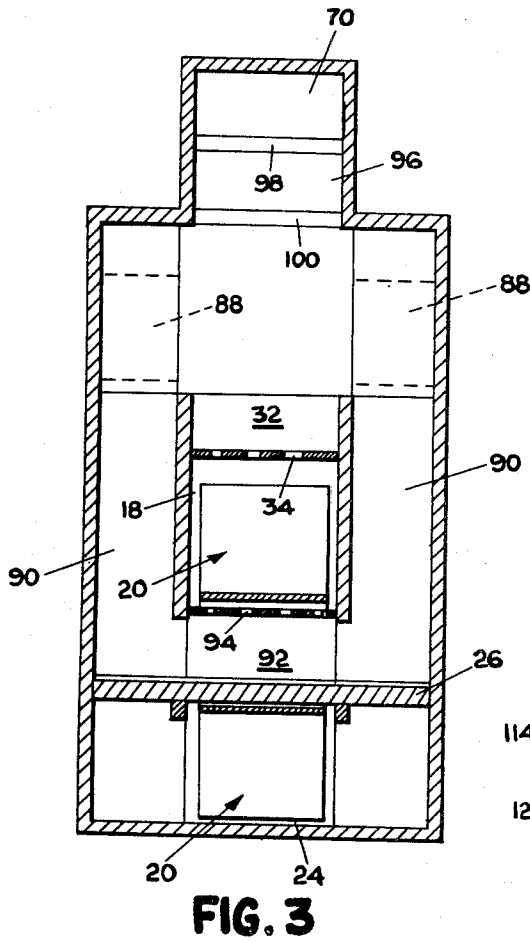
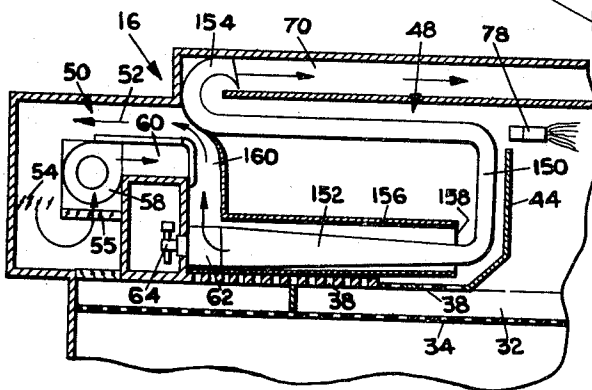
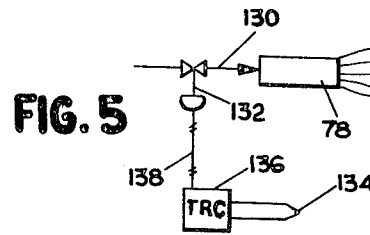
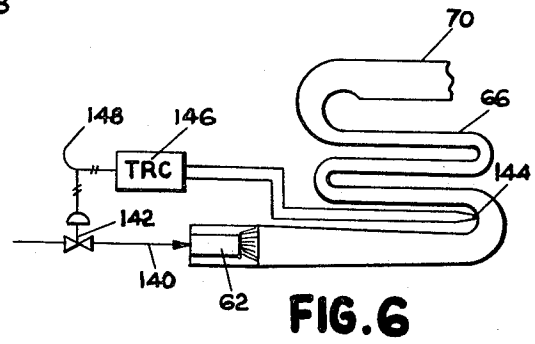
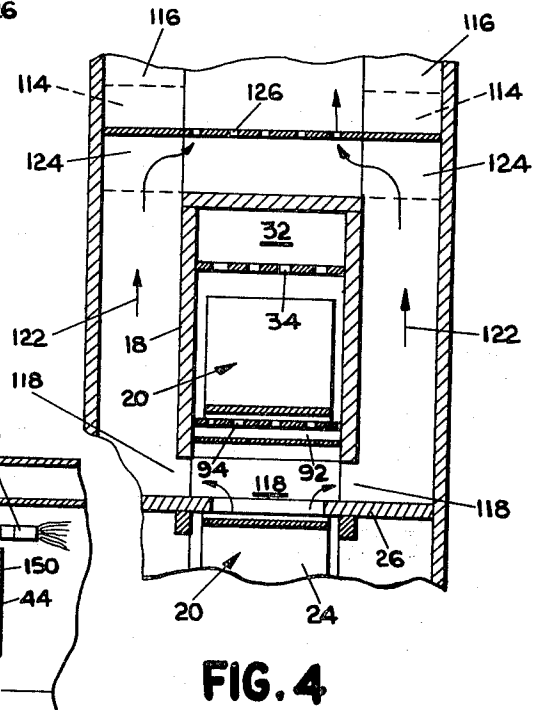


FIG. 2



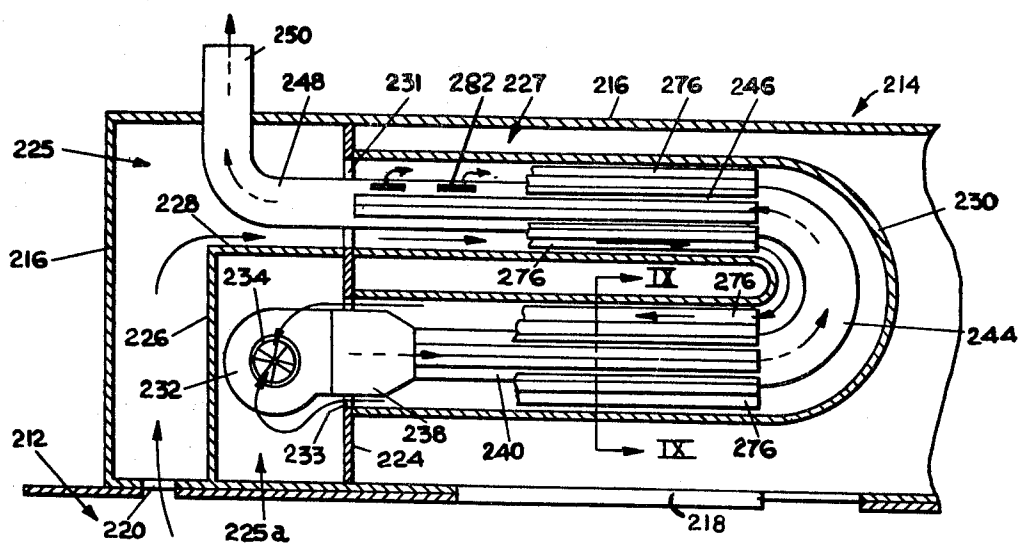


FIG. 8

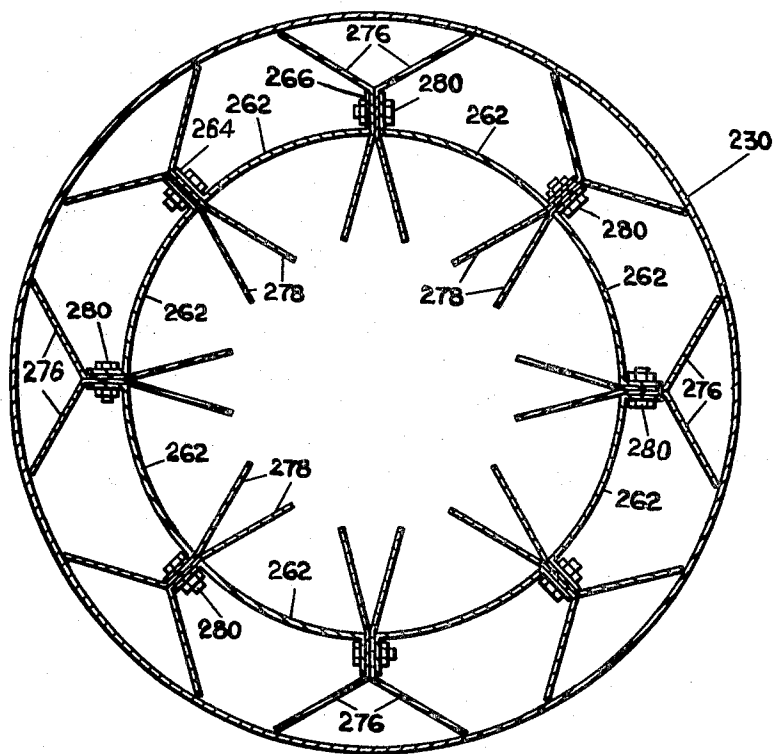


FIG. 9

FUME INCINERATOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of co-pending applications, Ser. No. 59 142, filed July 29, 1970, now abandoned, and Ser. No. 104 905, filed Jan. 8, 1971, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to incineration of combustible fumes. In one of its aspects, the invention relates to a fume incinerator having an improved heat exchanger for recovery of heat of oxidation of the fumes for pre-heat of the fume-containing gases prior to incineration. In another of its aspects, the invention relates to a method of incinerating combustible fumes.

2. State of the Prior Art

In U.S. Pat. No. 2 364 080, there is disclosed a drying and baking oven for lithographed metal sheets. The sheets are carried on spaced vertical wickets throughout an elongated heated chamber which form the drying and baking oven. Heated air contacts each sheet to dry the coatings thereon of solvents and other volatile materials in a first part of the oven and to bake the coatings onto the sheets in a second part of the oven. The coated sheets are used to make cans for food products and the like.

The volume of sheets through such an oven is very large. In larger plants, there may be a number of such ovens operating simultaneously. The amount of solvents removed from such ovens can reach as much as 15,000 gallons per day from, for example, 10 such ovens.

This solvent is in vapor form and combustible. For safety purposes it must be mixed with an excess of air in order to prevent explosion. The oxidation temperature of this mixture is about 1,000° to 1,400° F, and the temperature of the mixture is about 400° F, as it is exhausted from the oven.

Initially, the solvent containing exhausts were merely dumped into the atmosphere. When pollution control standards were adopted in various localities, it was proposed to incinerate the exhausts by feeding them to an outside refractory lined incinerator in which the mixture would be heated to about 1,400° F to oxidize the organic solvents in the mixture. An example of such a refractory lined incinerator is disclosed in Hardison et al, U.S. Pat. No. 3 484 189. The expense of such an incinerator is substantial compared to the cost of the ovens. In addition, the cost of the fuel to heat the mixture substantially increases the cost of drying and baking the coatings on the sheets. As a consequence, plants have been slow to install these pollution control devices and, in many localities, the volatile pollutants are still being dumped into the atmosphere.

Solvent drying ovens are subject to shut down for short periods of time as well as for extended periods of time. Fuel could be conserved if the solvent incinerator could be shut down while the drying oven is shut down or idling. However, conventional refractory lined incinerators depend on the heat of the refractory to maintain the incineration temperatures and therefore have a relatively long lag time which requires such incinerators to be run almost continuously. When the

drying oven is shut down for long periods of time, the refractory incinerators can be shut down, but it takes considerable time and fuel to bring the refractory incinerators up to temperature when the ovens are started again. For these reasons, refractory lined incinerators are expensive to operate.

Further, these refractory lined incinerators are bulky and heavy. They require costly special reinforcement to floors and other plant structures in order to accommodate the required incinerators within existing plant structures. Commonly, such incinerators are placed outside plants with ducting running between the drying ovens and the incinerators. Not only is the ducting expensive to install, but it results in extensive heat loss of the hot gases from the drying oven passing through the ducting so that additional heat must be supplied to the gases to bring them up to incinerating temperature.

It has also been proposed by Ruff, for example, in U.S. Pat. No. 3 216 127, to catalytically oxidize the volatile materials in an integrated oven and incinerator unit. Some of the heat of oxidation is recovered by heat exchange with gases used for drying the coatings in the oven. The cost of the catalyst is high and the catalysts are subject to fouling or poisoning by residues in the volatile exhausts. Other similar catalytic burners are disclosed in U.S. Pat. Nos. 2 795 054 and 2 750 680.

Recovery of process heat of oxidizing the fumes has been proposed by Hardison et al in 3 484 189 and by Davies in U.S. Pat. No. 3 524 632 in metal incinerators which have a very fast recovery time. These metal incinerators have of necessity been of welded air-tight construction to avoid leaks of combustible material into the atmosphere. Such construction requires heavy gauge high temperature metals which are themselves expensive and are expensive to fabricate. The temperature cycling of the incinerator results in fatigue of the welded joints of the metal incinerator. Once the welded joints develop cracks or holes, the costly incinerator becomes ineffective and must be scrapped. Further, the metal incinerator proposed by Hardison et al. is of a large diameter with a minimum of surface area with which heat exchange can be accomplished. In addition, the heavy gauge metal required in these incinerators militates against effective heat transfer. Accordingly, separate heat exchangers have been provided for recovery of heat from the incineration process.

For these reasons, metal incinerators have been heretofore expensive to manufacture, of short life duration if fuel costs are conserved, or expensive to operate in the event that the reactor is maintained at a high temperature. Further, separate heat exchangers have been required to effectively recover heat of oxidation of the incineration process.

OBJECTS

By various aspects of this invention one or more of the following, or other, objects can be obtained.

It is an object of this invention to provide an efficient and effective incinerator for use in oxidizing solvents and the like, the incinerator having a fast response time which can be operated responsive to oven operating conditions so that it can be shut down when the oven is not operating, thereby minimizing the cost of incinerating the solvents, yet of such a construction as to avoid

metal fatigue of welded joints due to temperature cycling.

It is another object of this invention to provide a compact, but highly efficient, incinerator for fume-laden gases and the like, which incinerator can be incorporated into drying ovens, or mounted adjacent existing ovens, for incineration of fumes developed during drying and baking processes within the ovens.

It is another object of this invention to provide a highly efficient and durable incinerator for solvent gases and the like which is inexpensive to manufacture and highly reliable in operation.

It is another object of this invention to provide an incinerator for solvent gases and the like wherein effective heat exchange is carried out directly with the incinerator itself for recovery of substantial amounts of heat energy of the gases of the incinerated products.

It is another object of this invention to provide an incinerator for solvent-laden gases and the like, the incinerator having an inexpensive, yet highly effective, heat exchanger to reduce the cost of incinerating the fumes.

It is yet another object of this invention to provide a high temperature metal incinerator having a surrounding heat exchanger which operates effectively enough to keep the outer surface of the incinerator unit relatively cool to permit mounting of the unit within a building, within an oven or closely adjacent thereto with a minimum of insulation, and to extend the life of the metallic reactor.

It is another object of this invention to provide a high temperature metal incinerator of flexible construction which minimizes the effect of temperature cycling on the incinerator.

It is another object of this invention to provide a metal incinerator of inexpensive construction which eliminates the adverse effects of leaks in the reactor body.

It is another object of this invention to provide a metal tubular incinerator for high velocity incineration of gases containing solvents and other combustible materials.

Another object of this invention is to provide a method of incinerating solvents and the like evolved during a drying operation wherein a substantial portion of the heat of the hot gases resulting from the incineration process is recovered for preheating the solvent for incineration.

Other aspects, objects, and the several advantages of this invention are apparent to one skilled in the art from a study of this disclosure, the drawings, and the appended claims.

BRIEF STATEMENT OF THE INVENTION

According to the invention, an incinerator is provided for use in connection with a drying oven of the type wherein a mixture of an oxidizable solvent and air is evolved during the drying process. The incinerator is formed from an elongated burner tube and has means for heat exchanging the solvent and air mixture with the hot gases within the elongated burner tube. A fan or other suitable means draws the mixture through the heat exchange means, thereby preheating the mixture and forces the mixture under higher pressure into the entrance end of the burner tube at a high velocity so

that the pressure within the burner tube is greater than the pressure within the heat exchange means. Means are provided for heating the preheated mixture within the burner tube to a higher temperature suitable for oxidizing the solvent in the mixture, and means are provided for withdrawing the combusted gases from the exit end of the burner tube. The burner tube has substantial length compared with its cross sectional dimensions and desirably contains one U or reverse bend to turbulate the gases for increased mixing and incineration of the solvents.

Preferably, the construction of the burner tube is such that a small fraction of the hot gases escape from the burner tube and pass into the heat exchange means for admixture with the solvent and air. Escapement of these hot gases through the walls of the burner tube provides direct heat exchange between the oxidized gases and the solvent-air mixture, thereby increasing the rate of heating the solvent-air mixture.

Further, according to the invention, there is provided a method for incinerating combustible fumes in a mixture of such fumes and air. The mixture is drawn through a preheat zone over an external surface of a combustion zone for preheating and then passed to the combustion zone at high velocities wherein the mixture is heated to an elevated temperature suitable for oxidizing the fumes in the mixture, whereby the fumes are oxidized. The heat content of the gases within the combustion zone is transferred to the preheat zone to preheat the solvent and air mixture passing therethrough. The pressure of the preheated mixture in the preheated zone is increased before passing said mixture to the combustion zone so that the pressure of the gases in the combustion zone is greater than in the preheat zone.

Further, according to the invention, a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process in a drying section has an integrated incinerator for oxidizing the solvent before exhausting to the atmosphere. The integrated incinerator communicates with the drying section and has a radiant tube burner formed of an elongated conduit. Hot combustion products and solvents are passed through the conduit at a rate sufficient to heat the elongated conduit to a temperature high enough to oxidize the solvent in the mixture passing through the conduit. Further, the solvent and air mixture withdrawn from the drying section is heat exchanged with the elongated conduit and a portion of the heat exchanged mixture is used to heat the drying section and other sections of the oven. An auxiliary burner is provided to supply any additional heat energy to the heat exchanged mixture to maintain whatever temperature is necessary in the drying section. Control means are provided to adjust the supply of heat to the incinerator and to the oxidized products to maintain the temperature of the drying section at a predetermined value, and to maintain the temperature of the radiant tubes at a predetermined value.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is a partial plan view of a drying oven containing an integrated fume incinerator according to the invention, said view being partially broken away and as generally seen along line I—I of FIG. 2;

FIG. 2 is an elevational view in section taken along line II—II of FIG. 1;

FIG. 3 is a cross-sectional view taken along lines III—III of FIG. 2;

FIG. 4 is a partial cross-sectional view taken along lines IV—IV of FIG. 2;

FIG. 5 is a schematic representation of a control system for the auxiliary burner;

FIG. 6 is a schematic representation of a control system for the radiant tube burner;

FIG. 7 is a partial view similar to FIG. 1 and illustrating a second embodiment of the invention;

FIG. 8 is a partial side elevational view in section of a third embodiment of the invention; and

FIG. 9 is a partial sectional view along lines IX—IX of FIG. 8.

Referring to the drawings and to FIGS. 1 - 4 in particular, there is illustrated a drying oven for lithographed thin sheets and the like. The drying oven has a drying zone 12 for evaporation of solvents and volatile material on the thin sheets and a plurality of baking zones 14, only one of which has been illustrated in the drawings. The oven is desirably provided with a cooling section (not shown) at the end of the baking section. The baking zone 14 serves to bake the coatings which have been deposited onto the thin sheets. An integrated fume incinerator, generally designated as 16, burns a portion of the volatile materials which are driven off in the drying zone and, in so doing, provides a substantial amount of heat for operation of the oven.

The drying zone 12 is formed from an elongated chamber 18 through which passes a continuous wicket conveyor generally indicated by the numeral 20. Coated metal sheets are fed to the wicket conveyor through opening 22 in the front of the drying zone. Air also enters the oven through opening 22 and through a similar opening at the other end of the furnace (not shown). A wicket preheat duct is provided longitudinally within the bottom of the drying zone and extends through the baking zones. A baffle plate 26 separates the upper portion of the drying and baking zones from the lower portion thereof.

A zone heating duct 28 extends longitudinally beneath the wicket conveyor 20 within the drying zone and has a plurality of holes or openings 30 in the top portion thereof to permit flow of heated gases upwardly therethrough and through the wicket conveyor. As illustrated in FIG. 2, the zone supply duct has a relatively fixed central portion and tapers at the forward and rear edges thereof. A recirculating duct 32 extends longitudinally through the drying zones and the baking zones in the upper portion of the elongated chamber 18. A plurality of holes 34 in the bottom of the duct 32 permit withdrawal of the hot gases including any vaporized solvent from the elongated chamber 18 and into the recirculating duct 32.

The fume incinerator 16 comprises a fire box of insulating material which is divided into a heat supply area 46, an incinerator and heat exchange area 48, and a burner air supply area 50. The burner air supply area 50 is formed from an air duct 52 which communicates through damper valves 54 and 55 with an air supply duct 56 and a fan 58. Air duct 52 is open at one end to permit heat exchanged solvent and air to pass therethrough into fan 58. An opening 40 is provided between the duct 50 and the top of the elongated

chamber 18 to permit passage of solvent and air from the front of the drying zone into the return air duct 52. Damper valves 42 control the passage of gases through the opening 40. An outlet duct 60 communicates with the outlet from the fan 58 at one end at the other end with burners 62 through a manifold 61. A fuel supply means 64 supplies fuel to the burners 62. The outlet from the burners 62 communicate with metal radiant tube burners 66 of narrow elongated conduits which form a zig zag or reversing pattern between the bottom and the top of the incinerator area 48. The outlets from the tube burners 66 communicate with an incinerator discharge duct 70 which extends longitudinally along the top of the fume incinerator 16 and along the top of the baking zones 14. The tube burners 66 have a tapered entrance end between the first reverse turn and the entrance end of the tube. This tapered portion assists in maintaining the fast flow of heated gases through the radiant tubes 60.

The incinerator area 48 is divided into two parts by a baffle plate 72 which is slidable along the length of the incinerator area 48 through holes which accommodate the tubes 66.

Openings 38 are provided in the top of the recirculating duct 32 and in the bottom of the incinerator area 48 to permit passage of the solvent and air therethrough into the incinerator area 48.

The heat supply area 46 is separated from the incinerator area 48 by a back wall 44. Auxiliary burners 78 are positioned at the sides of the heat supply area 46. A fan 80 having its inlet communicating with the heat supply area 46 is positioned at each side of the heat supply area 46. The outlet from each fan 80 communicates with a heated air supply duct 82 which passes the heated air from fan 80 into the zone heating duct 28.

The baking zone 14 has a heating box 84 at the top thereof with a burner 86 and a fan 88 on either side thereof. The inlet of each fan communicates with the interior of the heating box 84 and the outlet of each fan 88 communicates with a heat supply duct 90. One heat supply duct 90 extends down each side of the elongated chamber 18 and into a zone heating duct 92 having a shape similar to the heating duct 28. Holes 94 are provided in the top of the zone heating duct 92 to permit passage of heated gases upwardly into the elongated chamber 18 and through the wicket conveyor 20.

The incinerator discharge duct 70 communicates with the heating box 84 through an opening 98, duct 96, and an opening 100 in the top of the heating box 84. Damper valves 99 control the flow of gases between the discharge duct 70 and the heating box 84.

A second heating box 102 is provided on top of the elongated chamber 18 within the baking zone 14. This heating box 102 has a duct 104 which communicates with the incinerator discharge duct 70 through an opening 106 in the bottom of the discharge duct 70 and an opening 110 in the top of the heating box 102. A heater 112 is provided at one end of the heating box 102 and a fan 114 is provided on either side of the other end of the heating box 102. The inlet for each fan 114 communicates with the heating box 102 and the outlet for each fan 114 communicates with a supply duct 116. One supply duct 116 extends down either side of the elongated chamber 18 and communicates with the wicket preheat duct 24.

A collector duct 118 across the top of the baffle plate 26 communicates with the wicket preheat duct 24 through an opening 124. The ends of the collector duct 118 communicate with return ducts 122 which extends upwardly along the sides of the elongated chamber 18. A distributor duct 124 extends across the top of the elongated chamber 118 and has openings 126 in the top portion thereof to permit escape of return air into the heating box 102.

Reference is now made to FIG. 5 which illustrates the auxiliary burner control system. Fuel is fed to burner 78 through a line 130. A control valve 132 controls the flow of fuel through line 130. A thermocouple 134 is positioned within the elongated chamber 18 in the drying zone and transmits this signal to a temperature recorder controller 136. In accordance with a preset input to controller 136, a signal is sent to valve 132 through control line 138 to control the fuel passing to burner 78. In this manner, the heat supplied by the auxiliary burner is controlled to maintain the temperature within the drying section within predetermined limits.

Similar controls can be provided for the heat supply means for the baking sections and for the wicket preheat ducts.

Reference is now made to FIG. 6 which schematically illustrates the radiant tube burner control means. Fuel is supplied to the burner 62 through a supply line 140 which has a control valve 142. A thermocouple 144 senses the temperature of the exterior surface of tube 60 and generates a signal responsive thereto. The signal is sent to temperature recorder controller 146 which controls valve 142 via a control line 148 in accordance with a preset input to the temperature recorder controller 146. The temperature recorder controller 146 maintains the flow of fuel to burner 62 sufficient to produce temperatures within the tube 60 at about 1,400° F.

In operation of the embodiment illustrated in FIGS. 1 through 6, the main burners 62 would initially be operating wide open so that the temperature of the radiant tube burner is in excess of 1,200° F and preferably in excess of 1,400° F. In addition, the auxiliary burners 78 would be operating with sufficient fuel to maintain the drying section temperature at about 400° F. This will be negligible initially.

As the drying operation begins, the solvent and air mixture withdrawn from the drying section of the oven is heat exchanged with the radiant tube burners. A portion of the heat exchanged mixture is passed through return air duct 62 and into the interior of radiant tube burners 66, wherein it is oxidized in an exothermic reaction. This reaction heats the tubes 66 thereby reducing the amount of fuel which needs to be supplied to the burners 62. The evaporation of solvent in the drying section tends to reduce the temperature in the drying section. The decrease in temperature in the drying zone will be sensed by thermocouple 134, and accordingly, the amount of fuel to burner 78 is increased to maintain a temperature of about 400°F therein. Similarly, an increase in the temperature of the radiant tube 66 will be sensed by thermocouple 144. The valve 142 will then be throttled to decrease the amount of fuel supplied to burners 62.

If the oven is idling, such as when inking rolls are changed, the temperature within the drying section

must be maintained at about 400° F. At this time the conveyor 20 is stopped and no new sheets are fed into the oven. The heat of oxidation will be reduced since there are substantially no volatile products being emitted from the drying section. The gases passing through the return air ducts 52 will contain substantially no oxidizable material, necessitating an increase in the temperature of the heated gases supplied to the radiant tube 66. The decrease in the tube temperature is sensed by thermocouple 144 and responsive thereto, the valve 142 is opened to increase the fuel to burners. On the other hand, the heat requirements for the drying section will decrease because of the great decrease in solvent evaporation. The temperature within the drying section will be maintained by decreasing the fuel supplied to the auxiliary burners 78 in accordance with the signal from the thermocouple 144.

The amounts of solvent on the coatings can vary with different operations. The amount of fuel supplied to the main burner 62 and to the auxiliary burners 78 are adjusted to maintain the proper temperatures at the radiant tube burners and within the heat supply ducts. In addition, the baffle plate 72 is slidable along the length of the incinerator section to vary the amounts of solvent and air mixture passing to the burner air supply area 50 and the heat supply area 46. In this manner, a proper balance between these two areas is established so that the proper temperature within the incinerator and the drying oven is maintained.

Reference is now made to FIG. 7 for a description of a modified tube burner according to the invention. Like numerals have been used to describe like parts. In this modified form of the invention, a burner tube 150 is formed in a U-shape having a tapered entrance end 152 and an exit end 154 which communicates with the incinerator discharge duct 70. Alternately, the exit end 154 of the burner tube 150 can be vented directly to the atmosphere.

Instead of the baffle plate 72 illustrated in FIGS. 1 and 2, an annular tube 156 encircles the tapered entrance end 152 of the modified burner tube 150. The annular tube has an open end 158 adjacent the first bend in the U-shaped burner tube 150. The opposite end of the annular tube 156 communicates with a vertical conduit 160. The return air duct 52 communicates directly with the vertical conduit 160.

The operation of the modified form of the invention is substantially the same as that described about with reference to FIGS. 1 through 6. However, in the modified form illustrated in FIG. 7, a portion of the solvent-containing gases enters the open entrance end 158 of the annular tube 156 and passes therethrough in heat exchange relationship with the tapered entrance end 152 of the burner tube 150. In this manner, the solvent-containing gases are heated by the burner tube 150. At the opposite end of the annular tube 156, the heated gases pass into the vertical conduit 160, through conduit 160 and into the return air duct 52. From thence, the heated gases are passed into the interior of the burner tube 150 wherein the solvent is oxidized. Although not illustrated in FIG. 7, the outlet from the fan 58 communicates with vertical ducts adjacent the conduit 160 to supply the heated gases to the burner 62 and into the interior of the burner tube 150.

The heated gases drawn from the drying area and passing through the incinerator area 48 are heat exchanged with the tube burners 150. A portion of these heat exchanged gases are returned to the drying area and a portion of the heat exchanged gases, as described above, are passed to the interior of the tube burner for incineration of the solvent gases.

The arrangement illustrated in FIG. 7 provides for a more efficient heat exchange of the solvent gases which are to be incinerated. In this manner, the portion of the gases to be incinerated is more easily heated to a higher temperature, requiring less fuel for oxidation.

Other modifications are possible within the skill of the art. For example, the outer burner tubes can supply heat to the wicket preheat duct 24 by simply directing the exhaust from the burner tubes downwardly alongside of the drying chamber 18 and into the ducts 24. For these tube burners, the fuel supply means can be at a top portion of the incinerator area 48 and the exit end of the tube burners can be at the bottom of the incinerator area.

Referring now to FIGS. 8 and 9, there is illustrated an incinerator unit generally designated by the numeral 214 mounted on top of solvent drying oven generally designated by the numeral 212. In this embodiment, the incinerator is a separate unit and is not built into the oven. The incinerator 214 is formed from an outer housing 216 of insulating material and has openings 218 and 220 in the bottom thereof communicating with the upper portion of the drying oven 212. A dividing wall 224 extends between the bottom, top and side walls of the housing 216, thereby dividing the incinerator into an intake section or zone 225 and an incinerator and heat exchange section or zone 227. A vertical wall 226 within the intake section or zone 225 extends upwardly from a floor of the housing 216 and joins a horizontal wall 228 to define a fan intake section or zone 225a within the intake section or zone 225. The vertical wall 226 and horizontal wall 228 extend between the sides of the housing 216 thereby completely closing off and sealing the intake section 225 from the fan intake section 225a. A U-shaped outer tube 230 is mounted within the incineration and heat exchange section. This tube 230 has an upper open end communicating with a hole 231 in the dividing wall 224. The lower open end of the U-shaped outer tube 230 communicates with a hole 233 in a bottom portion of the wall 224. Thus, the U-shaped outer tube 230 communicates at one end with the intake section or zone 225 and at the other end with the fan intake section 225a.

Mounted within the U-shaped outer tube 230 is a U-shaped incinerator tube formed of a first burner tube section 240, a U-bend section 244, and a straight upper section 246. The annular area within the U-shaped outer tube 230 approximates the area within the burner tube formed by sections 240, 244 and 246. Gases from this incinerator tube are exhausted from section 246 through an elbow section 248 and an exhaust conduit 250. The incinerator tube section communicates with a cylindrical burner housing 238 which contains a suitable fuel burner (not shown). Means (not shown) are provided for supplying fuel to the burner. A suitable burner is a Zephyr gas burner manufactured by the North American Manufacturing Company, 4455 E. 71st Street, Cleveland, Ohio, 44105. The burner has a

spark plug (not shown) or other suitable means to initiate combustion of the fuel.

A fan 232 having an inlet 234 and an outlet 236 is mounted within the fan intake section 225a. The fan inlet 234 communicates with the lower portion of the outer tube 230 through the fan intake section 252a and hole 233. The blower or fan outlet 236 communicates with the cylindrical burner housing 228 and the burner.

The lower incinerator tube section 240 and the upper straight section 246 are formed from elongated metal burner tube panels, best illustrated in FIG. 9. Each elongated panel is formed from an elongated arcuate portion 262 with backwardly bent flanges 264 and 266. Holes are provided in spaced relationship along flanges 264 and 266.

Heat exchange fins extend between the interior of the incinerator tube sections 240 and 246 and the annular preheat area between the incinerator tube and the outer U-shaped tube 230. For purposes of illustration, the heat exchange fins are shown partly broken away in FIG. 8. Such fins are of high heat conducting metal and comprise a central portion, an outer fin 276 and an inner fin 278. As illustrated in FIG. 9, bolts 80 extend through holes in the flanges 264 and 266 and through the holes of the heat exchange fins to secure the heat exchange fins in place and to secure the burner panels together. Thus, the burner panels are bolted together with the heat exchange fins extending therebetween. The outer heat exchange fins 276 then act as spacers between the burner tube and the U-shaped outer tube 230.

The inner fins 68 extend into the incinerator tube as far as possible to maximize heat transfer to the annular preheat area. Desirably the fins 68 extend one-third to one-half of the radial distance between the burner panels 60 to the center of the incinerator tube.

In operation of the device illustrated in FIGS. 8 and 9, solvent and air mixture at about 300° to 400° F is drawn from the drying or baking oven 212 through opening 220 into the intake section or zone 225 of the incinerator. These solvent-laden gases pass through the annular space between the U-shaped outer tube 230 and the incinerator burner tube formed by the straight section 246, the U-bend section 244 and the incinerator tube section 240. While passing through the annular space, these gases will contact the hot surface of these tubes and will also contact fins 276 of the heat exchange fins. The contact between the gases and these hot surfaces preheat the gases as they pass through the annular space, the temperature reaching about 800°F by the time the gases reach the fan 232. The U-bend in the tube 230 has a turbulating effect on the gases passing through the annular space which further increases the transfer of heat from the hot surfaces to the gases.

The preheated gases are then drawn in through intake 34 of fan 232 and passed at a higher pressure through the fan outlet 236 through the burner and into the incinerator tube section 240. The fan 232 serves to draw the fume-laden gases through the annular preheat area within the U-shaped outer tube 230 and to increase the pressure of the preheated gases which flow into the incinerator tube section 240. Thus, the gas pressure within the incinerator tube (section 240, U-bend 244, and straight section 246) will be greater than

the pressure in the annular preheat area between the U-shaped outer tube 230 and the incinerator tube. The above described construction of the tube sections 240 and 246 show inexpensive constructions which need not be air tight. Since the pressure is higher in the incinerator tube section 240 than in the annular preheat area, a small percentage of the hot gases within the incinerator tube can escape through the walls of the incinerator tube sections 240 and 246 into the annular preheat area. These gases will be recycled back into the incinerator tube through the fan 234. The effect of these hot gases passing from the interior of the incinerator tube into the preheat area is to assist in the preheating of the gases by direct transfer of the heated gases. Because of the higher pressure within the burner tube and outside the outer tube 30, the incombusted solvent gases in the preheat area cannot by-pass the incinerator section and pass into the atmosphere. The stringent governmental requirements of pollution control devices make it necessary that all gases go through the entire incinerator in order to reduce the polluting gases to acceptable standards.

The straight section 246 of the burner tube can also be provided with openings 282 through which the hot gases pass from the burner tube to the annular preheat area. The openings 282 can be in lieu of or in addition to the heat exchange fins 270. These gases will be recycled back through the incinerator tube via fan 254. The solvent and air mixture will be preheated by the admixing therewith of the hot combusted gases from the incinerator tube. Because of the pressure differential between the interior and exterior of burner tube section 246, no incombusted gases will flow from the preheat area into the burner tube through openings 282. Obviously, the openings 282 can be placed anywhere along the length of the burner tube.

Gas is supplied from a source (not shown) to the burner to further heat the gases passing therethrough to about 1,200° to 1,400° F. At this temperature, the solvents and other combustible material will be substantially completely oxidized to carbon dioxide. The heat of these gases is transferred through the walls of the incinerator tube (sections 240, 244 and 246) to the preheat area. In addition, the hot gases within the incinerator tube contact the inner fins 278 of the heat exchange fins which transfer the heat by conduction to the outer fins 276. In actual operation, the fins form waves along the length thereof because of the temperature differential between the fins 276 and fins 278. This wavy configuration aids in turbulating the gases passing through the incinerator, further assisting in the heat transfer between the gases and the fins. Because the elongated burner tube panels 260 are not required to be welded together to form an air tight tube, lighter gauge materials can be used for these elongated portions 262. These lighter materials facilitate still further the rapid heat transfer between the interior and the exterior of the burner sections 240 and 246.

The U or reverse bend formed by U-bend section 244 serves to turbulate the gases flowing through the interior of the burner tube. This turbulation increases the mixing of the gases within the tube to increase the oxidation of the combustible materials within the mixture, thereby substantially completely combusting the oxidizable materials. The turbulation produced by the

U-bend section 244 further enhances the heat transfer properties of the gases so that more heat is transferred between the interior and exterior of the burner tube sections. Other types of turbulators, such as within the tubes, can be employed in the event that a straight tube is desired.

The flow of the gases through the burner tube is quite rapid. For example, it has been found that the gases can pass through the tube at rates as high as 5,000 to 6,000 feet per minute. It has been found that for velocities of about 5,000 feet per minute and an incinerator path length of 25 feet with a U-bend, the residence time of the gases is approximately 0.3 second. Even with this extremely low residence time, it has been found that 812 pounds of carbon in the form of methylethyl ketone solvent passing through the incinerator tube during an 8-hour day can be reduced to 1.3 pounds of carbon in uncombusted form. The remainder of the carbon is substantially converted to carbon dioxide.

The incinerator tube is constructed in a narrow elongated form as illustrated in the drawings. The elongated form maximizes the surface area of the tube for preheating the gases to conserve fuel costs of incineration. The length of the tube depends on the degree of preheating required for the solvent-laden gases. It has been found that a tube length of about 25 feet formed by two tubes 12 to 16 inches in diameter and 10 feet long with a U-bend section therebetween, are suitable for incineration of the solvent to values within the most stringent governmental limits and for preheating the solvent-laden gases.

The incinerator device illustrated in FIGS. 8 and 9 can also be used for maintaining heat in an oven as disclosed hereinbefore with relation to FIGS. 1 through 6. The oven gases pass through opening 218 in the bottom of housing 216 and contact the outer surface of the U-shaped outer tube 230. This contact serves to heat these gases which are then recirculated to the furnace through a fan (not shown).

Whereas the invention has been described in FIGS. 8 and 9 with reference to a single incinerator tube, it is within the scope of the invention to use a plurality of such incinerator tubes in juxtaposed relationship for larger furnaces. The number of tubes will depend on the capacity of the furnace.

The incinerator device described is of metal construction and has a very rapid response time. In other words, the operation of the incinerator tube can be correlated with the oven or ovens with which it works. When the oven is down for short or extended periods of time, the incinerator tube can be shut down. When the oven starts up, the incinerator tube will reach its incinerating temperature in a matter of seconds. In this manner, the amount of fuel required to operate the incinerator is further reduced.

The unit described is a compact unit which can be integrated with an existing oven. It can be mounted on top of the oven or immediately adjacent thereto. The U-bend, in addition to the turbulating function, also makes the unit compact. This kind of unit may save valuable plant space and may avoid the heat loss and expense of ducting from an oven to exterior locations which are often required for other types of incineration units. The high velocity of the gases through the incinerator and the turbulation effected in this incinera-

tor eliminates the need for larger incinerator reactors. Because the unit can be mounted on top or immediately adjacent an existing oven, it permits further heat recovery by using the heat of oxidation for heating of the oven gases.

The incinerator is of inexpensive and flexible construction. Thin gauge material is less expensive and welding is minimized. Leakage of hot gases from the main burner tube may favorably affect the operation of the incineration process due to the rapid heating of the solvent air mixture, and does not adversely affect the incineration qualities of the device. Further, the flexible construction avoids metal fatigue due to the temperature cycling which is required of such an incinerator for optimum economical operation. The novel heat exchanger construction effectively preheats the gases thereby further cutting the fuel costs for operation of the incinerator unit. The heat exchange construction is quite inexpensive as compared with other welded and leakproof structures. The heat exchange quality of this device also cools the U-shaped outer tube 230 (FIGS. 8 and 9) of the housing as well as the inner burner tube to extend the life of these metal parts. In addition, the hotter burner tube is insulated by the preheating gases, thus permitting installation of this incinerator within or immediately adjacent to a drying oven without the necessity of providing expensive and bulky insulating material.

The elongated panels illustrated in the drawings have been shown as having an arcuate configuration in cross-section. The panels can be made in many different cross-sectional shapes. For example, the panels can have a straight cross-section so that the resulting tubular cross-section represents a regular polygon rather than a circle. Further, the panels can be corrugated for still more heat transfer surface area.

The preferred embodiment of the invention illustrated in FIGS. 8 and 9 has an annular preheat area surrounding the elongated burner tube. However, the heat exchange means between the burner tube and the preheat area can take various other forms. For example, the preheat area can be formed entirely within the burner tube so that the burner tube becomes an annular space around a preheat conduit. In addition, a second preheat conduit can be formed around the outside of the burner tube with the result that the annular burner tube will have preheat areas along its outer and inner surfaces.

As discussed above, the incinerator unit illustrated in FIGS. 8 and 9 can be used adjacent to or spaced from a solvent evolving oven. When the unit is used away from the solvent oven, the solvent air mixture is preferably circulated around the outside of the outer U-shaped tube 230 to maintain the temperature within the housing at a lower temperature. To this end, the top of dividing wall 214 is eliminated and the fume-laden gases are introduced into the housing 216 adjacent the U-shaped tube 230, for example at opening 218. Further, a closed conduit is provided to carry the preheated fume-laden gases from the lower open end of the U-shaped tube 230 to the inlet 234 of fan 232.

Reasonable variation and modification are possible within the scope of the foregoing disclosure, the drawings, and appended claims without departing from the spirit of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows.

1. In a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process in a drying section, and in which the mixture is incinerated before exhausting to the atmosphere, the improvement which comprises:

an integrated incinerator section communicating with said drying section;

a radiant tube burner within said incinerator section, said radiant tube formed of an elongated conduit having an entrance end and an exit end;

means communicating said exit end of said elongated conduit directly with the exterior of said incinerator section to exhaust to the atmosphere combustion products passing through said elongated conduit;

means for passing a first portion of said mixture through said incinerator section from said drying section and in heat exchange relationship with the exterior surface of said elongated conduit;

means to pass a second portion of said mixture to said entrance end of and through said elongated conduit; and

means to heat said second portion of said mixture within said elongated conduit to a temperature sufficient to substantially completely oxidize said solvent in said second portion of said mixture.

2. In a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process in a drying section, and in which the mixture is incinerated before exhausting to the atmosphere, the improvement which comprises:

an incinerator section communicating with said drying section;

a radiant tube burner within said incinerator section, said radiant tube burner formed from a narrow elongated conduit having an entrance end and an exit end;

means for passing a first portion of said mixture through said incinerator section from said drying section and in heat exchange relationship with said elongated conduit;

means to pass a second portion of said mixture to said entrance end of and through said elongated conduit, said second portion passing means including means for heat exchanging said second portion of said mixture with said elongated conduit prior to passing through said elongated conduit; and

means to heat said second portion of said mixture within said elongated conduit to a temperature sufficient to oxidize the solvent in said second portion of said mixture passing through said elongated conduit.

3. A drying oven according to claim 2 further comprising means to recycle said first portion of the heat exchanged mixture from said incinerator section to said drying section.

4. A drying oven according to claim 2 and further comprising means for adjusting the relative amounts of said first and second proportions of said mixture passing through said radiant tube and to said drying section.

5. A drying oven according to claim 4 wherein said adjusting means comprises a movable baffle within said incinerator section.

6. A drying oven according to claim 3 and further comprising an auxiliary heating means in said recycle means to maintain the temperature of said first portion of said mixture at a predetermined value.

7. A drying oven according to claim 6 and further comprising temperature sensing means to sense the temperature in said drying section and means to control the heat output from said auxiliary heating means in accordance with a signal from said temperature sensing means to maintain the temperature in said drying section at a predetermined value.

8. In a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process in a drying section, and in which the mixture is incinerated before exhausting to the atmosphere, the improvement which comprises:

an incinerator section communicating with said drying section;

a radiant tube burner within said incinerator section, said radiant tube burner formed of an elongated conduit having an entrance end and an exit end, said elongated conduit forming a reversing coil within said incinerator section;

means for passing a first portion of said mixture through said incinerator section from said drying section and in heat exchange relationship with said elongated conduit;

means to pass a second portion of said mixture to said entrance end of and through said elongated conduit; and

means to heat said second portion of said mixture within said elongated conduit to a temperature sufficient to oxidize the solvent in said second portion of said mixture passing through said elongated conduit.

9. A drying oven for removal of solvents from coated metal sheets, said oven comprising:

an elongated chamber;

means to pass said coated metal sheets through said elongated chamber for drying;

means to supply heated gases to said elongated chamber to remove solvents on said metal sheets within said chamber;

means for removing a mixture of solvents and air from said chamber; and

means to oxidize said solvents thus removed from said chamber; the improvement in said oxidation means which comprises:

a radiant tube burner comprising an elongated tube having at least one reverse or U-bend between an entrance end and an exit end thereof;

means to pass at least a portion of said solvents and air mixture over an outer surface of said elongated tube in heat exchange relationship therewith;

means to pass said heat exchanged solvents and air mixture to said entrance end and through said elongated tube at a high velocity; and

means to heat said solvent and air mixture passing through said elongated tube to an elevated temperature sufficient to oxidize said solvents in said mixture within said elongated tube.

10. A drying oven according to claim 9 wherein said heated gases supply means for said elongated chamber comprises means to pass a second portion of said mixture over an outer surface of said elongated tube in heat exchange relationship therewith, and means to pass said heat exchanged second portion of said mixture to said elongated oven chamber.

11. A drying oven according to claim 10 wherein said oxidizing means comprises a burner for supplying heated gases to said elongated tube; means to sense the temperature within said elongated tube; and control means to adjust the heat output from said burner to maintain said temperature of said elongated tube within predetermined limits responsive to the temperature sensed by said temperature sensing means.

12. A drying oven according to claim 11 and further comprising an auxiliary burner in said heated gas supply means for said elongated chamber; means to sense the temperature within said elongated chamber; and control means to adjust the heat output of said auxiliary burner responsive to the temperature sensed by said elongated chamber temperature sensing means to maintain the temperature within said elongated chamber within given limits.

13. A drying oven according to claim 9 wherein said mixture passing means comprises a tubular conduit encircling at least a portion of said elongated conduit leaving an annular space therebetween, said tubular conduit being open at one end for entrance of said solvent and air mixture, and an opposite end of said tubular conduit being in communication with an entrance end of said elongated conduit.

14. In a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process, and in which the mixture is incinerated before it is exhausted to the atmosphere, the improvement which comprises:

an incinerator comprising a housing with a burner tube extending therethrough, said burner tube having an entrance end and an exit end;

means for introducing at least a portion of said solvent and air mixture from said drying oven into said housing;

means for drawing said mixture through said housing in contact with an exterior surface of said burner tube thereby preheating said mixture, and means for forcing said heat exchanged mixture into said entrance end of said burner tube;

means for heating said preheated mixture within said burner tube to a higher temperature suitable for oxidizing said solvent in said mixture and thereby oxidizing said solvent in said mixture; and

means communicating the exit end of said burner tube with the exterior of said housing to exhaust the oxidized mixture from said burner exteriorly of said housing.

15. The drying oven according to claim 14 wherein said burner tube is of elongated construction and said incinerator further comprises a tubular conduit encircling said burner tube and extending along at least a portion of the length of said burner tube, said tubular conduit being open to the interior of said housing at one end and communicating with the interior of said entrance end of said burner tube at another end through said drawing and forcing means.

16. An incinerator for use in connection with a drying oven of the type wherein an oxidizable mixture of solvent and air is evolved during the drying process, said incinerator comprising:

- a housing with a burner tube extending therethrough, said burner tube having an entrance end and an exit end; means for introducing solvent and air mixture from said drying oven into said housing; means for drawing said mixture through said housing in contact with an exterior surface of said burner tube thereby preheating said mixture, and means for forcing said preheated mixture into said entrance end of said burner tube;
- means for heating said preheated mixture within said burner tube to higher temperature suitable for oxidizing solvent in said mixture, whereby said solvent in said mixture is oxidized; and
- means communicating the exit end of said burner tube with the exterior of said housing to exhaust the oxidized mixture from said burner tube exteriorly of said housing.

17. An incinerator according to claim 16 wherein said burner tube is of elongated construction and further comprising a tubular conduit encircling said burner tube and extending along at least a portion of the length of said burner tube, said tubular conduit being open at one end for reception of said solvent and air mixture and communicating at another end with the interior of said entrance end of said burner tube through said drawing and forcing means.

18. An incinerator according to claim 16 wherein said burner tube has at least one reverse or U-bend.

19. An incinerator for use in connection with a drying oven of the type wherein a mixture of an oxidizable solvent and air is evolved during the drying process, said incinerator comprising:

- an elongated burner tube having an entrance end and an exit end;

means for heat exchanging said solvent and air mixture with hot gases within said elongated burner tube;

fan means for drawing said mixture through said heat exchange means, thereby preheating said mixture, and for forcing said mixture into said entrance end of said burner tube;

means for heating said preheated mixture within said burner tube to a higher temperature suitable for oxidizing said solvent in said mixture; and

means for withdrawing combusted gases from the exit end of said burner tube.

20. An incinerator according to claim 19 wherein said heat exchange means includes means in said elongated burner tube for passing a portion of said combusted gases into a preheat zone for admixture with

said solvent and air mixture for direct heat exchange between said mixture and said hot gases.

21. An incinerator for use in connection with a drying oven of the type wherein a mixture of an oxidizable solvent and air is evolved during the drying process, said incinerator comprising:

- an elongated burner tube having an entrance end and an exit end, said burner tube having a length substantially greater than any cross-sectional dimension of said burner tube;

said burner tube having at least one U or reverse bend between said entrance and exit end;

means for passing said solvent and air mixture over an exterior surface of said burner tube for heat exchange therewith, thereby preheating said mixture;

means for passing said preheated mixture to said entrance end of said burner tube;

means for raising the temperature of said preheated mixture to a higher temperature suitable for oxidizing said solvent in said mixture in said burner tube; and

means for removing products of combustion from said exit end of said burner tube.

22. In a method of incinerating combustible fumes in a mixture of such fumes and air wherein said mixture is heated to an elevated temperature suitable for oxidation of said fumes in a combustion zone, the improvement which comprises:

- drawing said mixture through a preheat zone over an external surface of said combustion zone in heat exchange therewith to preheat said mixture, increasing the pressure on said preheated mixture and passing said mixture to said combustion zone at a pressure higher than said mixture in said preheat zone, and transferring heat from said combustion zone directly to said preheat zone.

23. A method according to claim 22 wherein said heat transfer step comprises passing a portion of the combustion products from said combustion zone to said preheat zone for admixture with said mixture of fumes and air.

24. A method of incinerating combustible fumes according to claim 22 wherein the velocity of said mixture passing through said combustion zone is at least 3,000 feet per minute.

25. A method of incinerating combustible fumes according to claim 22 wherein the velocity of said mixture passing through said combustion zone is in the range of 5,000 to 6,000 feet per minute.

26. A method of incinerating combustible fumes according to claim 22 and further comprising reversing the direction of flow of said mixture in said combustion zone.

* * * * *