# United States Patent

**Phillips**

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[54] **INCINERATOR WITH EXTENDED HEAT EXCHANGE SURFACE**


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[52] **U.S. Cl.** ....................**110/8 A,** 23/277 C

[51] **Int. Cl.** ....................**F23g 7/00**

[58] **Field of Search** ....................110/8, 8 A; 23/277 C



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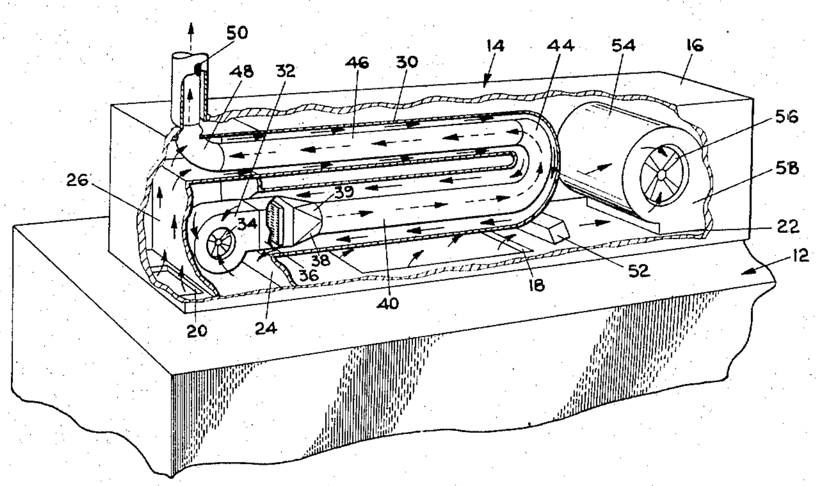
[57] **ABSTRACT**

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 turbulance within the conduit and to increase heat exchange of hot gases with the exterior of the conduit. The incinerator conduit is formed of a plurality of elongated arcuate sections which are secured together at the edges. Heat conducting fins extend through the conduit between the interior and the exterior thereof at the edges of the arcuate sections to facilitate heat transfer between the interior and exterior of the incinerator conduit. The fume-laden gases to be incinerated are channelled along the exterior surface of the incinerator conduit in contact with the heat exchange fins by a larger preheat conduit surrounding the incinerator conduit. 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.


**17 Claims, 4 Drawing Figures**



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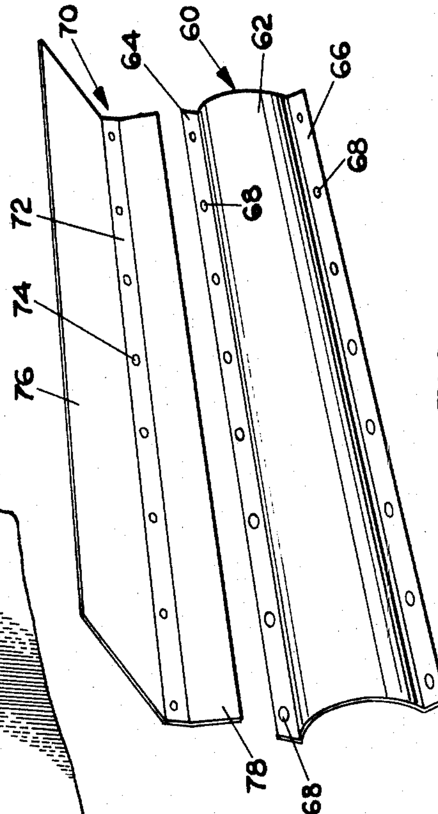


FIG. 4

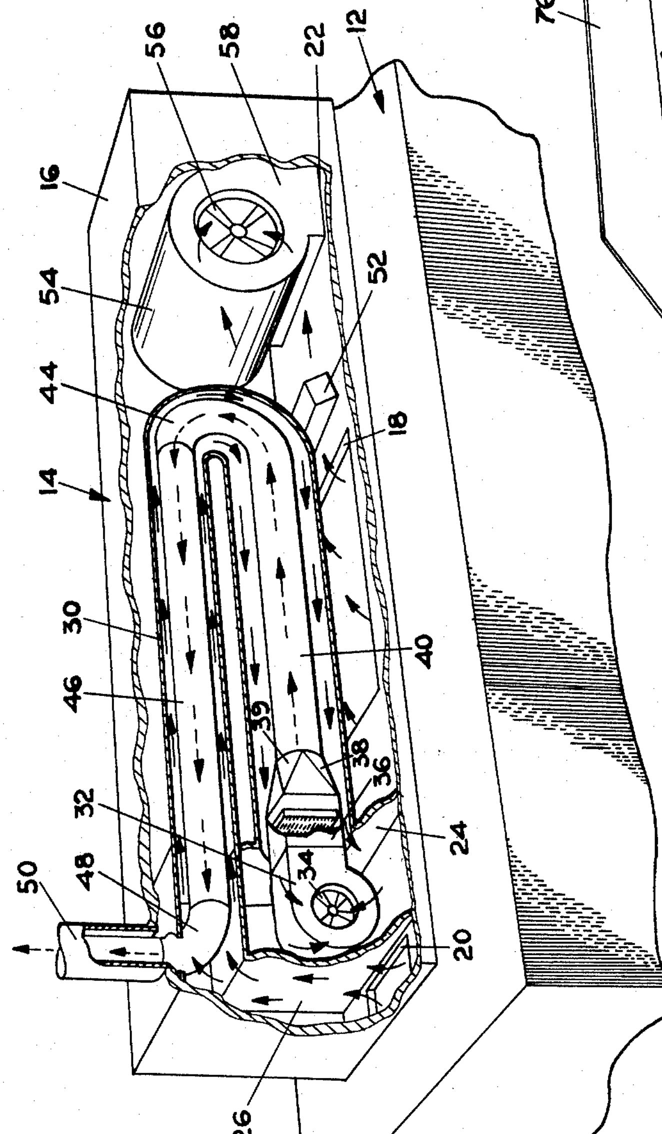


FIG. 1

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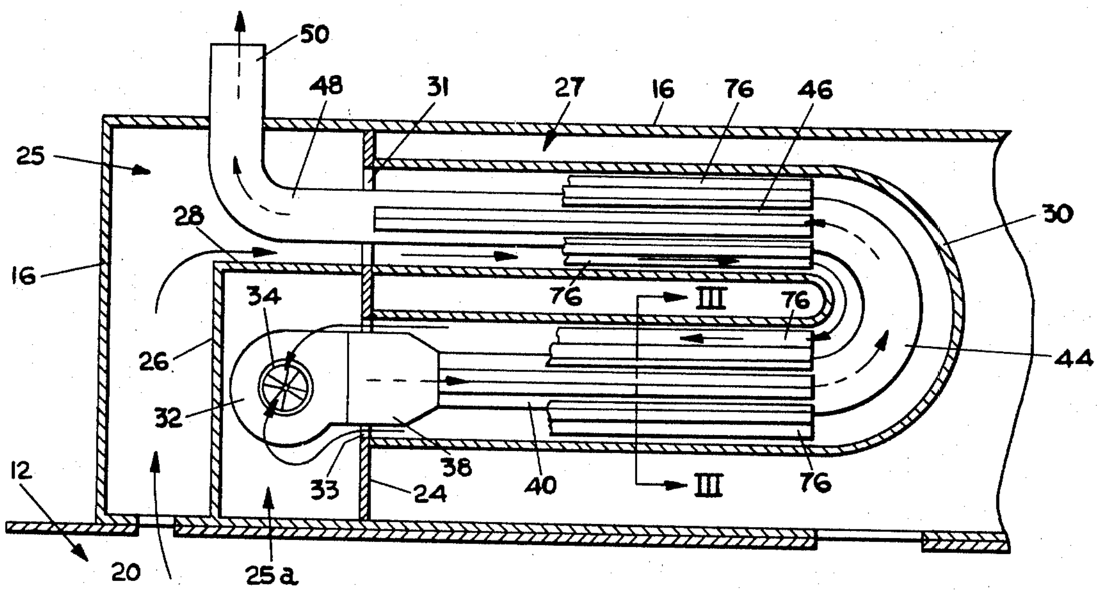


FIG. 2

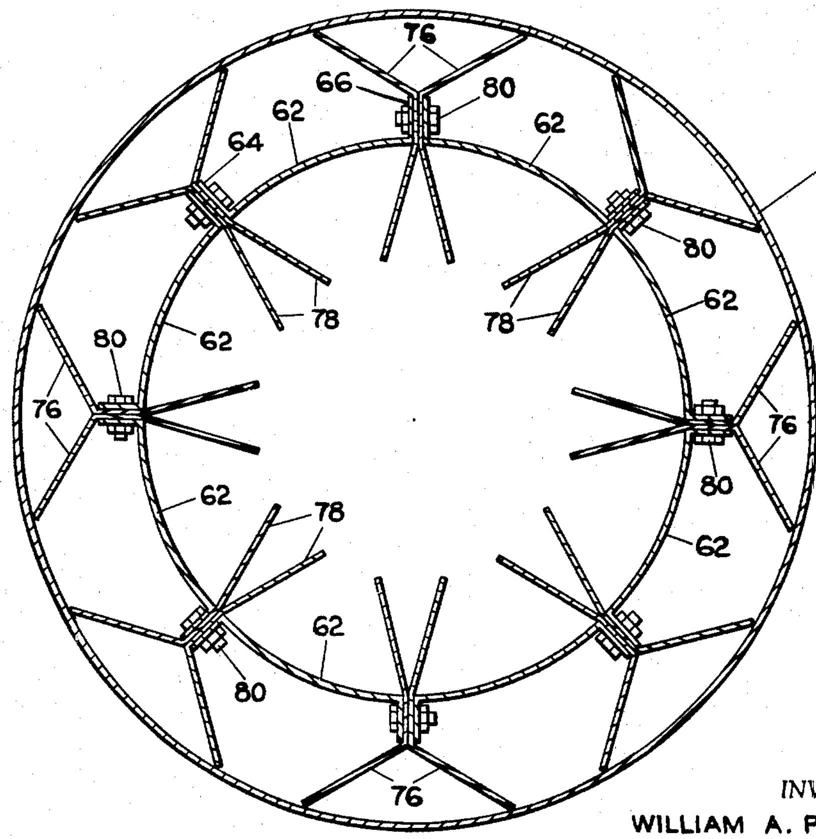


FIG. 3

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## INCINERATOR WITH EXTENDED HEAT EXCHANGE SURFACE

### 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 preheat of the fume-containing gases prior to incineration.

2. State of the Prior Art

In copending, U.S. patent application, Ser. No. 59,142, filed July 29, 1970, assigned to the same assignee of this patent application, there is disclosed and claimed a solvent drying oven with an integrated incinerator formed of an elongated metal burner tube, said tube having at least one U-bend. Solvent-laden gases are removed from the oven, heat exchanged with the burner tube, drawn through a fan and then forced into the interior of the burner tube wherein the solvent and other combustible material in the gases is incinerated. In one embodiment, the solvent-containing gases are drawn through the annulus of a second larger tube which encircles the burner tube.

In the incineration of such gases, it is necessary to raise the temperature of the solvent and air mixture from the oven temperature to the incineration temperature. For drying ovens for lithographed sheets, for example, the temperature of the oven gases must be raised from about 400° F to about 1,300° F. Such a temperature rise requires a considerable amount of fuel which adds substantially to the expense of the drying operation. Not only is the fuel expensive but it is currently in short supply. However, the oxidation of the solvent is an exothermic reaction which yields a significant amount of heat which can be recovered to converse energy requirements of the incineration process. For recovery of such heat, the incinerator tube should have a maximum surface area which can contact the hot gases.

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.

On the other hand, metal incinerators have a very fast recovery time. Heretofore, 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, some metal incinerators have been of a large diameter with a minimum of surface area with which heat exchange can be accomplished. In addition, the heavy gauge metal used 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 over 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 and small, 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.

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 heat exchanger with an extended surface for maximum heat transfer between the interior and exterior of the incinerator tube.

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 for solvent-laden gases has a narrow elongated burner tube surrounded by a heat exchange housing for preheating the gases. Heat exchange fins extend from the heat exchanger area outside the burner tube through the walls of the burner tube and into the interior of the burner tube to greatly enhance heat transfer between the burner tube and the gases. A fan draws the solvent-laden gases over the outer surface of the burner tube and in contact with the heat exchange fins, and then forces the heat exchanged gases through the burner tube at a higher pressure wherein they are further heated and incinerated. The fan creates a higher pressure within the burner tube than outside the tube so that any leaks from the burner tube escape into the preheating gases and are recycled through the incinerator.

The burner is advantageously made from elongated panels which are mechanically fastened together with heat exchange fins extending therebetween. For such purposes, the panels can be provided with outwardly extending flanges through which the mechanical fasteners extend. Preferably, the burner tube has at least one U or reverse bend to minimize the space requirements and to turbulate the gases within the tubes, thereby increasing mixing and incineration of the solvents and increasing the heat exchange properties of the gas. The burner tube construction need not be of air tight welded construction. Preferably, the construction of the burner tube is such that a small fraction of the hot gases escape from the burner tube into the preheat area. Escapement of hot gases through the walls of the burner tube provide direct heat exchange between the oxidized gases and the solvent-air mixture, and thereby enhances the heat exchange quality of the incinerator.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a perspective view, partially broken away, illustrating an incinerator unit according to the invention;

FIG. 2 is a partial side elevational view, in section, of the incinerator unit illustrated in FIG. 1;

FIG. 3 is a partial sectional view taken along lines III—III of FIG. 2; and

FIG. 4 is a perspective view of component parts of the incinerator tube.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, there is illustrated an incinerator unit generally designated by the numeral **14** mounted on top of solvent drying oven generally designated by the numeral **12**. The incinerator **14** is formed from an outer housing **16** of insulating material and has openings **18**, **20** and **22** in the bottom thereof communicating with the upper portion of the drying oven **12**. A dividing wall **24** extends between the bottom, top and side walls of the housing **16**, thereby dividing the incinerator into an intake section or zone **25** and an incinerator and heat exchange section or zone **27**. A vertical wall **26** within the intake section or zone **25** extends upwardly from a floor of the housing **16** and joins a horizontal wall **28** to define a fan intake section or zone **25*a*** within the intake section or zone **25**. The vertical wall **26** and horizontal wall **28** extend between the sides of the housing **16** thereby completely closing off and sealing the intake section **25** from the fan intake section **25*a***. A U-shaped outer tube **30** is mounted within the incineration and heat exchange section. This tube **30** has an upper open end communicating with a hole **31** in the dividing wall **24**. The lower open end of the U-shaped outer tube **30** communicates with a hole **33** in a bottom portion of the wall **24**. Thus, the U-shaped outer tube **30** communicates at one end with the intake section or zone **25** and at the other end with the fan intake section **25*a***.

Mounted within the U-shaped outer tube **30** is a U-shaped incinerator tube formed of a first burner tube section **40**, a U-bend section **44**, and a straight upper section **46**. The annular area within the U-shaped outer tube **30** approximates the area within the burner tube formed by sections **40**, **44**, and **46**. Gases from this incinerator tube are exhausted from section **46** through an elbow section **48** and an exhaust conduit **50**. The incinerator tube section communicates with a cylindrical burner housing **38** which contains a suitable fuel burner **39**. Means (not shown) are provided for supplying fuel to the burner **39**. 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 **32** having an inlet **34** and an outlet **36** is mounted within the fan intake section **25*a***. The fan inlet **34** communicates with the lower portion of the outer tube **30** through the fan intake section **25*a*** and hole **33**. The blower or fan outlet **36** communicates with the cylindrical burner housing **28** and the burner **39**.

The lower incinerator tube section **40** and the upper straight section **46** are formed from elongated metal burner tube panels **60**, best illustrated in FIGS. **3** and **4**. Each elongated panel **60** is formed from an elongated arcuate portion **62** with backwardly bent flanges **64** and **66**. Holes **68** are provided in spaced relationship along flanges **64** and **66**.

Heat exchange fins **70** extend between the interior of the incinerator tube sections **40** and **46** and the annular preheat area between the incinerator tube and the outer U-shaped tube **30**. Such fins are of high heat conducting metal and comprise a central portion **72** having spaced therealong a plurality of holes **74**, an outer fin **76** and an inner fin **78**. As illustrated in FIG. **3**, bolts **80** extend through the holes **68** in the flanges **64** and **66** and through the holes **74** 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 **76** then act as spacers between the burner tube and the U-shaped outer tube **30**. For purposes of simplicity, these fins **76** have not been shown in FIG. **1**.

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, solvent and air mixture at about 300° F to 400° F is drawn from the drying or baking oven **12** through opening **20** into the intake section or zone **25** of the incinerator. These solvent-laden gases pass through the annular space between the U-shaped outer tube **30** and the incinerator burner tube formed by the straight section **46**, the U-bend section **44** and the incinerator tube section **40**. While passing through the annular space, these gases will contact the hot surface of these tubes and will also contact the outer fins **76** of the heat exchange fins **70**. 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 **32**. The U-bend in the tube **30** 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 **32** and passed at a higher pressure through the fan outlet **36** through burner **39** and into the incinerator tube section **40**. The fan **32** serves to draw the fume-laden gases through the annular preheat area within the U-shaped outer tube **30** and to increase the pressure of the preheated gases which flow into the incinerator tube section **40**. Thus, the gas pressure within the incinerator tube (section **40**, U-bend **44**, and straight section **46**) will be greater than the pressure in the annular preheat area between the U-shaped outer tube **30** and the incinerator tube. The above described construction of the tube sections **40** and **46** show inexpensive constructions which need not be airtight. Since the pressure is higher in the incinerator tube section **40** 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 **40** and **46** into the annular preheat area. These gases will be recycled back into the incinerator tube through the fan **34**. 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 bypass 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.

Gas is supplied from a source (not shown) to the burner **39** to further heat the gases passing therethrough to about 1,200° F 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 **40**, **44**, and **46**) to the preheat area. In addition, the hot gases within the incinerator tube contact the inner fins **78** of the heat exchange fins **70** which transfer the heat by conduction to the outer fins **76**. Because the elongated burner tube panels **60** are not required to be welded together to form an air tight tube, lighter gauge materials can be used for these elongated portions **62**. These lighter materials facilitate still further the rapid heat transfer between the interior and exterior of the burner sections **40** and **46**.

The U or reverse bend formed by U-bend section **44** 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 **44** 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 keystone 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 can also be used for maintaining heat in an oven. The oven gases pass through opening **18** in the bottom of housing **16** and contact the outer surface of the U-shaped outer tube **30**. This contact serves to heat these gases which are then recirculated to the furnace through fan **54**. The heated gases are drawn in through the intake **56** of fan **54** and are forced through the outlet **58** back into the oven **12**. Additional heat can be supplied to these gases by the trim burner **52**.

Whereas the invention has been described 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 small 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 saves valuable plant space and avoids 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 small unit and the turbulation effected in this unit eliminates the need for larger incinerator reactors. Because the unit is small and 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. As illustrated in the drawings, the oven gases can be circulated around the U-shaped outer tube to provide 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 favorably affect the economy of the incineration process, and do not adversely affect the incinerating 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 leak proof structures. The heat exchange quality of this device also cools the U-shaped outer tube **30** 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 **60** illustrated in the drawings have been shown as having an arcuate configuration in cross-section. The panels **60** 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 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.

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 are claimed are defined as follows:

**1.** In an incinerator for oxidizing combustible fumes contained in a mixture of such fumes and air, said incinerator comprising:

- a narrow elongated burner tube having an inlet end and an outlet end;
- means in said elongated tube for heating gases passing therethrough to an elevated temperature suitable for oxidizing said combustible fumes in said mixture;
- means surrounding at least a portion of said elongated burner tube defining a preheat zone for said mixture, said surrounding means including an inlet opening for receiving said mixture and an outlet opening for discharging said mixture;
- means for passing preheated gases from said outlet opening of said surrounding means into said burner tube;

the improvement which comprises:

- heat exchange means extending from within said burner tube, through said burner tube and into said preheat zone, whereby heat is effectively transferred from said burner tube to said preheat zone to preheat said mixture passing therethrough.

2. An incinerator according to claim 1 wherein said burner tube contains at least one turbulating means.

3. An incinerator according to claim 1 wherein said burner tube comprises a plurality of elongated panels joined together at the longitudinal edges thereof, and said heat exchange means are positioned between said longitudinal edges of said elongated panels.

4. An incinerator according to claim 3 wherein backwardly bent flanges are formed on said longitudinal edges of said elongated panels, and further comprising fastening means securing together flanges of adjacent panels with said heat exchange means therebetween.

5. An incinerator according to claim 4 wherein said fastening means extend through said flanges and through said heat exchange means, and said fastening means are spaced along the length of said elongated panels, and said passing means includes a fan to draw said mixture through said preheat zone and to force the same into said burner tube at a higher pressure than that of said preheat zone.

6. An incinerator according to claim 4 wherein said heat exchange means comprise elongated thin metal plates which extend into said burner tube one-third to one-half of the radial distance between the circumference of said burner tube and the center thereof.

7. An incinerator according to claim 4 wherein said heat exchange means comprise elongated thin metal plates, there being a plurality of such elongated metal plates between each of said elongated panels, and the outer and inner longitudinal edges of said plates are bent away from each other.

8. An incinerator according to claim 1 wherein said heat exchange means extend outwardly to said surrounding means and form spacers between said burner tube and said surrounding means.

9. An incinerator according to claim 1 wherein said surrounding means is a tubular member in concentric relationship to said burner tube.

10. An incinerator according to claim 9 wherein said inlet opening of said surrounding means is adjacent to said outlet end of said burner tube, and said outlet opening of said surrounding means is adjacent to said inlet end of said burner tube, whereby the flow of said mixture through said preheat zone is countercurrent to the flow of gases through said burner tube.

11. An incinerator for oxidizing combustible fumes contained in a mixture of such fumes and air, said incinerator comprising:

a narrow elongated burner tube having an inlet end and an outlet end;

means in said elongated tube for heating gases passing therethrough to an elevated temperature suitable for oxidizing said combustible fumes in said mixture;

means surrounding at least a portion of said elongated tube defining a preheat zone for said mixture, said surrounding means including an inlet opening for receiving said mixture, and an outlet opening for discharging said mixture;

means communicating with said burner tube and outlet opening of said surrounding means for drawing said mixture through said preheat zone and for forcing the same into said burner tube at a pressure greater than the pressure within said preheat zone;

the improvement which comprises:

said elongated burner tube comprising a plurality of elongated panels; and

means joining said panels together at the longitudinal edges thereof.

12. An incinerator according to claim 11 and further comprising surface extension means secured to said burner tube between said elongated panels to increase the heat exchange area of said burner tube.

13. An incinerator according to claim 12 wherein said surface extension means comprise metal fins which extend into said preheat zone.

14. An incinerator according to claim 12 wherein said surface extension means comprise metal fins which extend into said burner tube.

15. An incinerator according to claim 11 wherein each of said panels contains fastening means extending outwardly of the longitudinal edges thereof, and said joining means extend through said fastening means to adjacent panels.

16. An incinerator according to claim 11 wherein said joining means permits escapement of gases from within said burner tube to said preheat zone to assist in heat transfer from the interior of said burner tube into said preheat zone.

17. In an incinerator for oxidizing combustible fumes contained in a mixture of such fumes and air, said incinerator comprising:

a narrow elongated burner tube having an inlet end and an outlet end;

means in said elongated tube for heating gases passing therethrough to an elevated temperature suitable for oxidizing said combustible fumes in said mixture;

means for heat exchanging said mixture with hot gases within said elongated burner tube, said heat exchange means including an inlet opening for receiving said mixture and an outlet opening for discharging said mixture; and

means communicating with said burner tube inlet and said outlet opening of said heat exchange means for drawing said mixture through said preheat zone and for forcing the same into said burner tube at a pressure greater than the pressure within the preheat zone;

the improvement which comprises:

said elongated burner tube comprising a plurality of elongated panels;

means joining said panels together at the longitudinal edges thereof; and

surface extension means extending between the interior of said burner tube and said heat exchange means at said longitudinal edges of said panels to facilitate heat transfer between said burner tube and said heat exchange means.

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