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ABSTRACT: According to the exemplary embodiments, a multipurpose furnace for burning refuse, burning away impurities to recover salvageable materials, such as metals, for melting nonferrous metals, and for other various purposes, comprises one or more combustion chambers, each of which has a smoke burning zone, which might be termed a smoke dome, constituted by on the order of 20 percent to 30 percent of the total volume of the chamber and occupying the uppermost portion of the chamber. The smoke dome is closed above and laterally except for an outlet to a smoke afterburner section and is located above the chamber so that there is no opportunity for smoke to escape or for air to enter and cool the smoke burning zone. The smoke afterburner section is constituted by a smoke passage having formations at the inlet to establish a generally helical or spiral flow of smoke through the passage. A burner is located in the passage to add heat to the smoke, and air or another suitable oxygen-containing gas is introduced into the passage to support combustion of combustible components of the smoke. The passage contains baffles arranged to break up flow paths through the passage and establish turbulence and mixing of the gases, but the baffles are constructed so as not to substantially obstruct the flow of smoke through the passage. The furnace is capable of burning all of the combustible components of the smoke so that primarily "clear gases" are discharged from the afterburner section.

[54] **MULTI-PURPOSE FURNACE WITH SMOKE AFTERBURNER**
28 Claims, 14 Drawing Figs.

[52] U.S. CL..... 110/8
[51] Int. Cl..... F23g 5/08
[50] Field of Search..... 110/7, 8,
8A, 18

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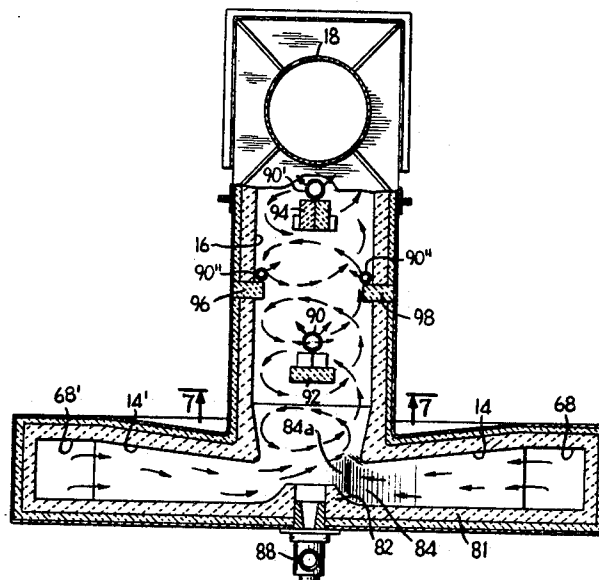
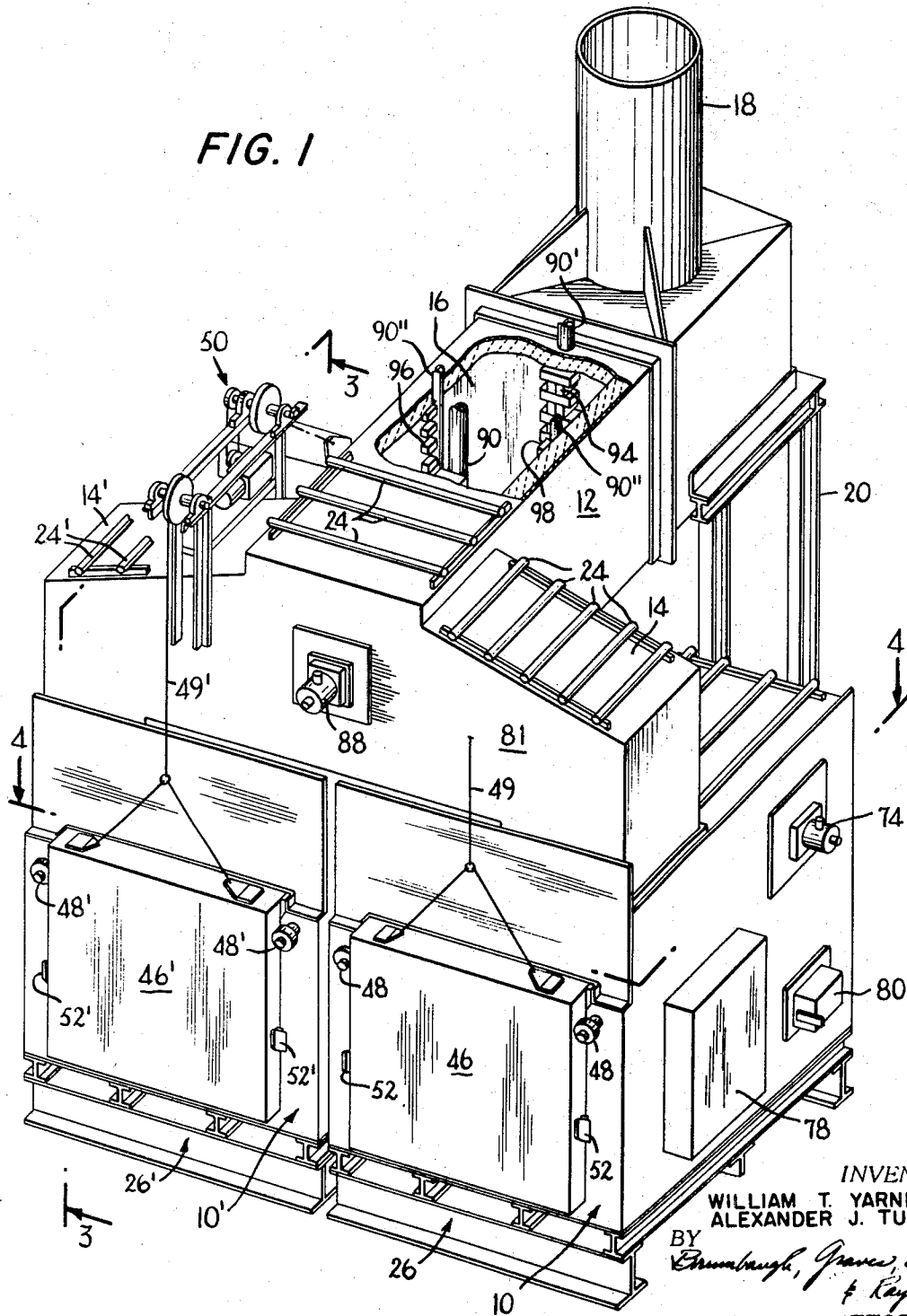


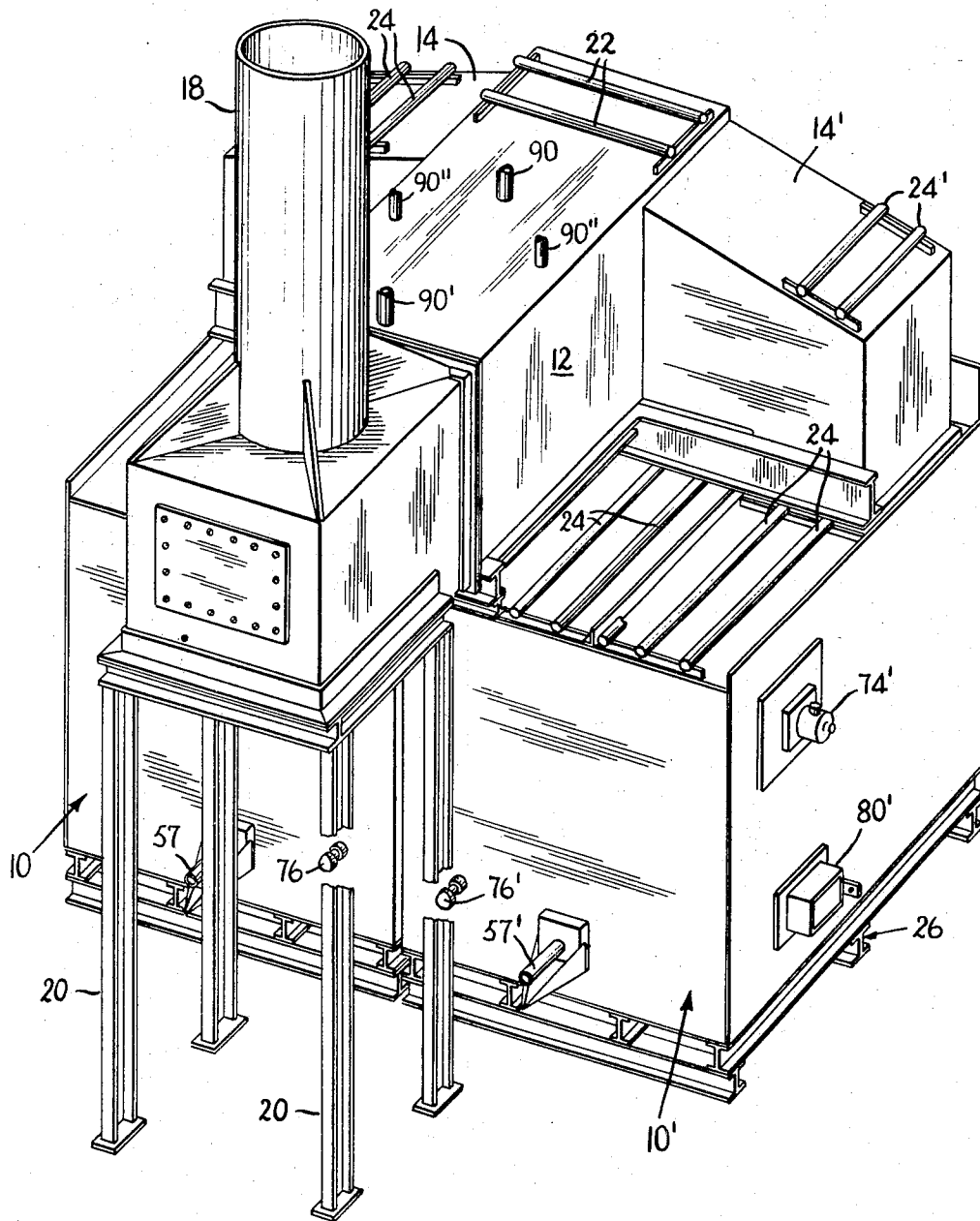
FIG. 1



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FIG. 2



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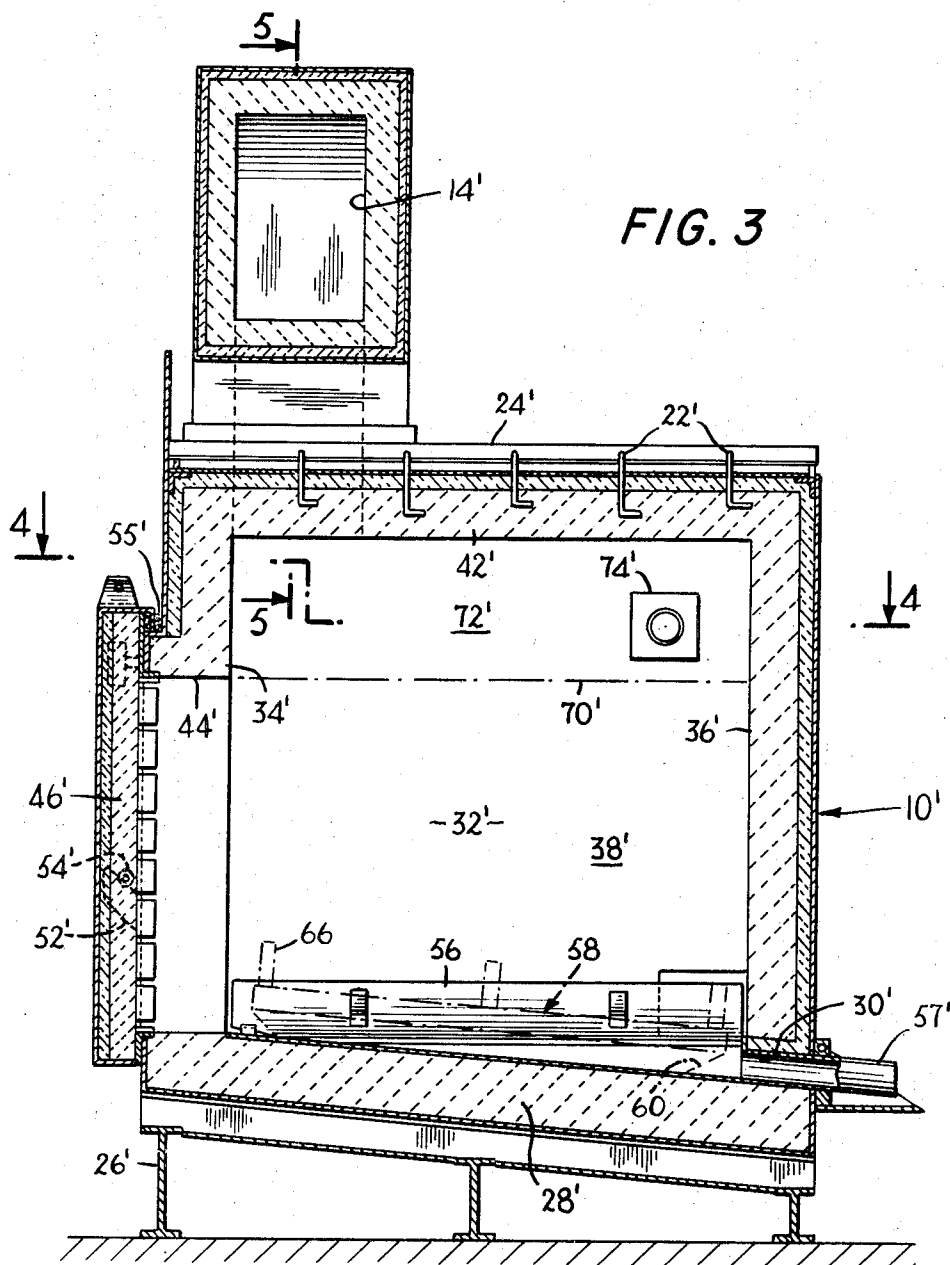


FIG. 3

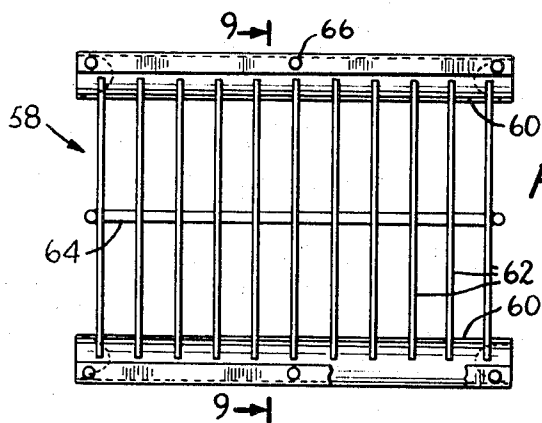


FIG. 8

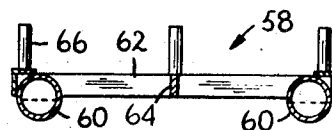


FIG. 9

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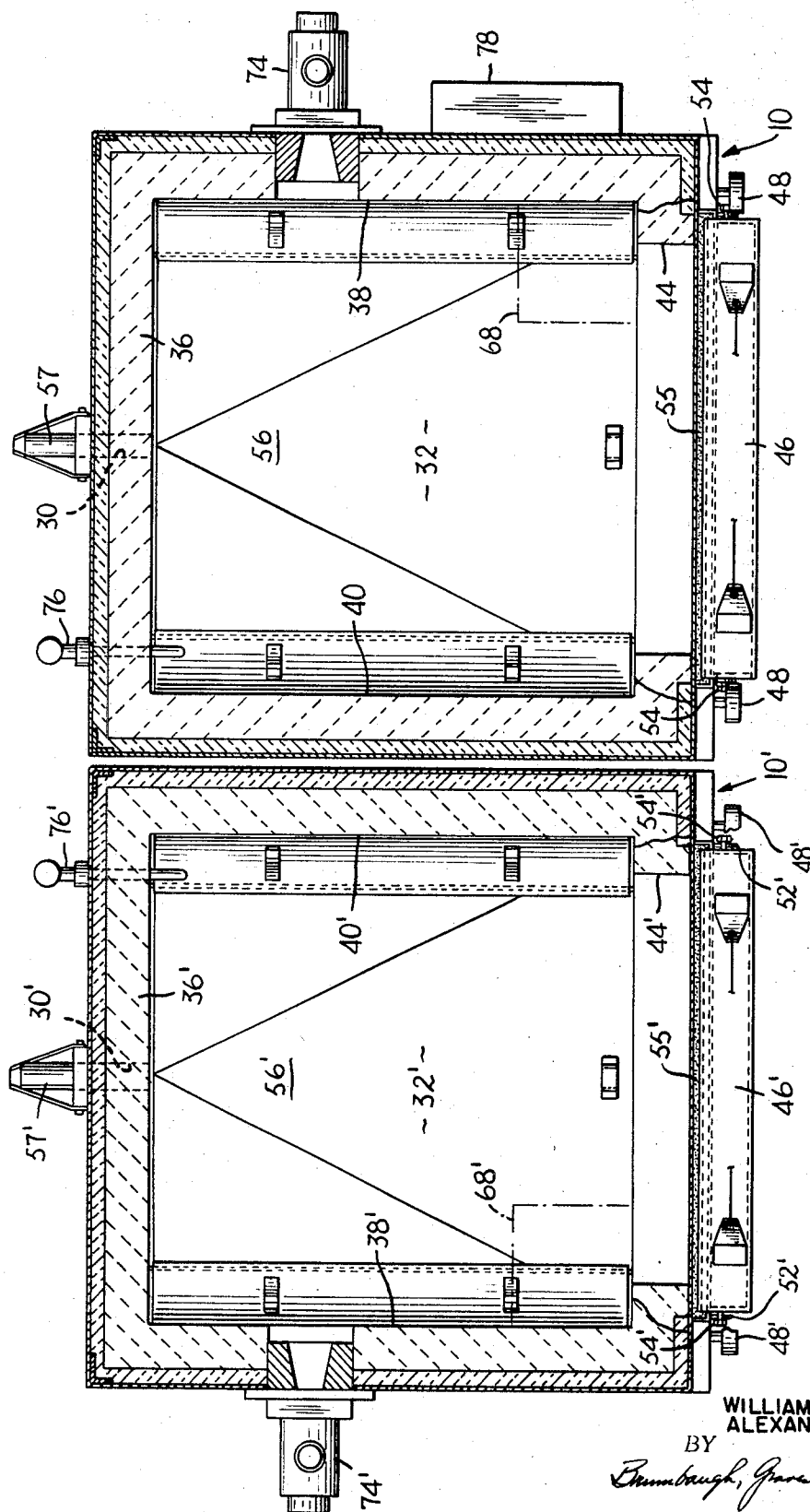


FIG. 4

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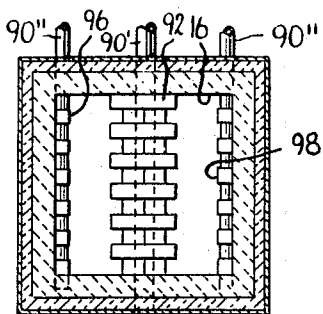


FIG. 7

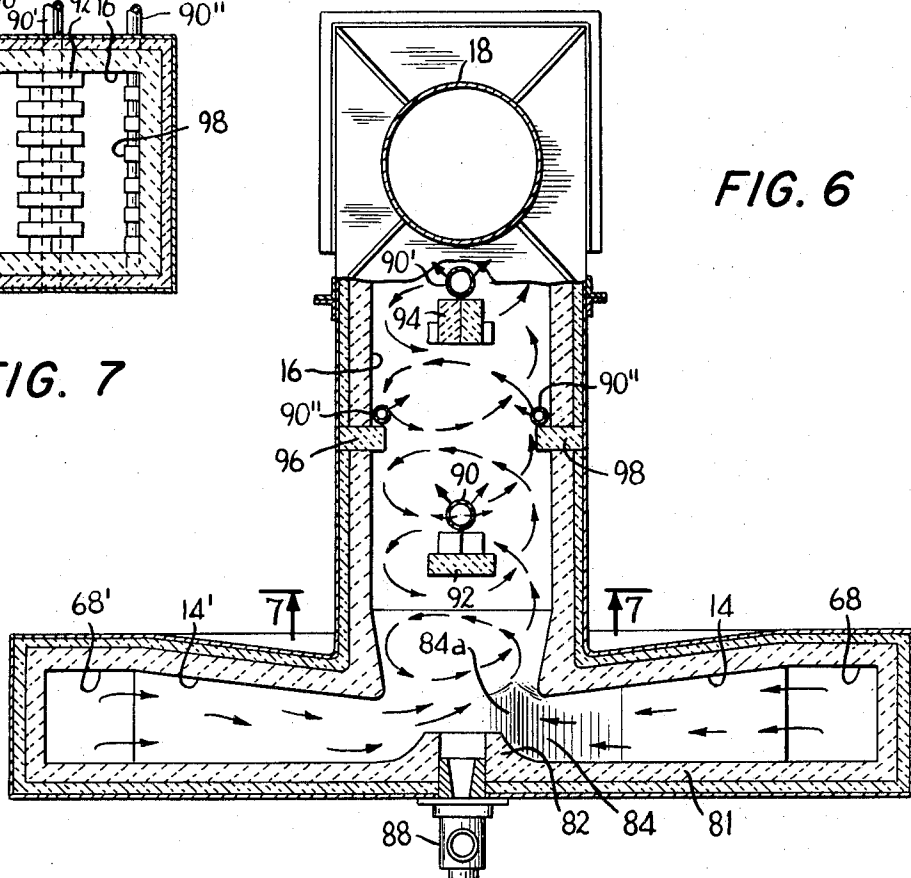


FIG. 6

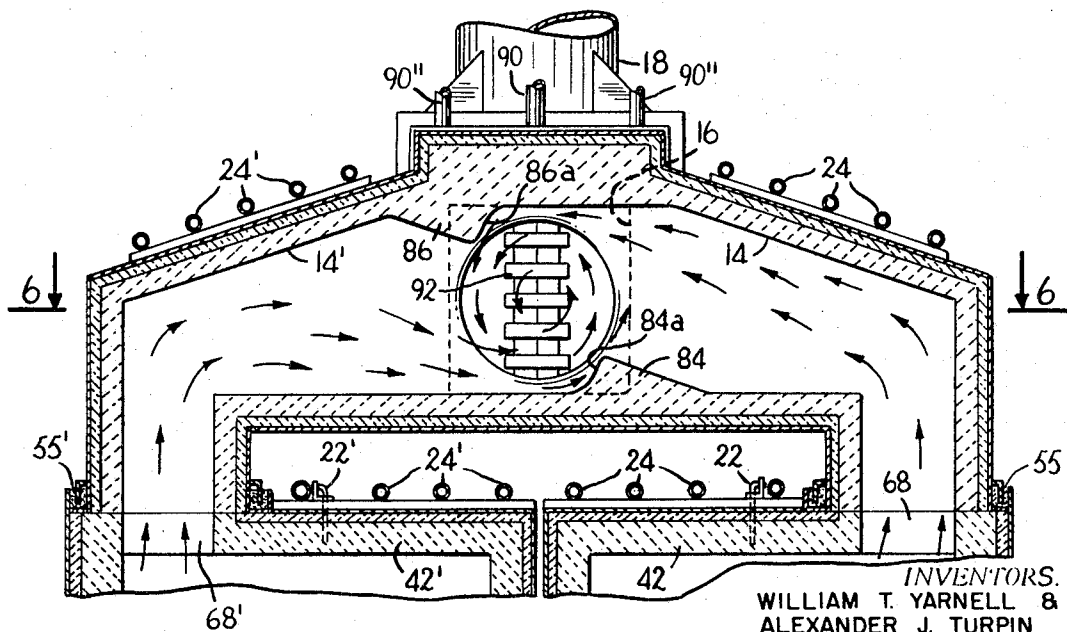


FIG. 5

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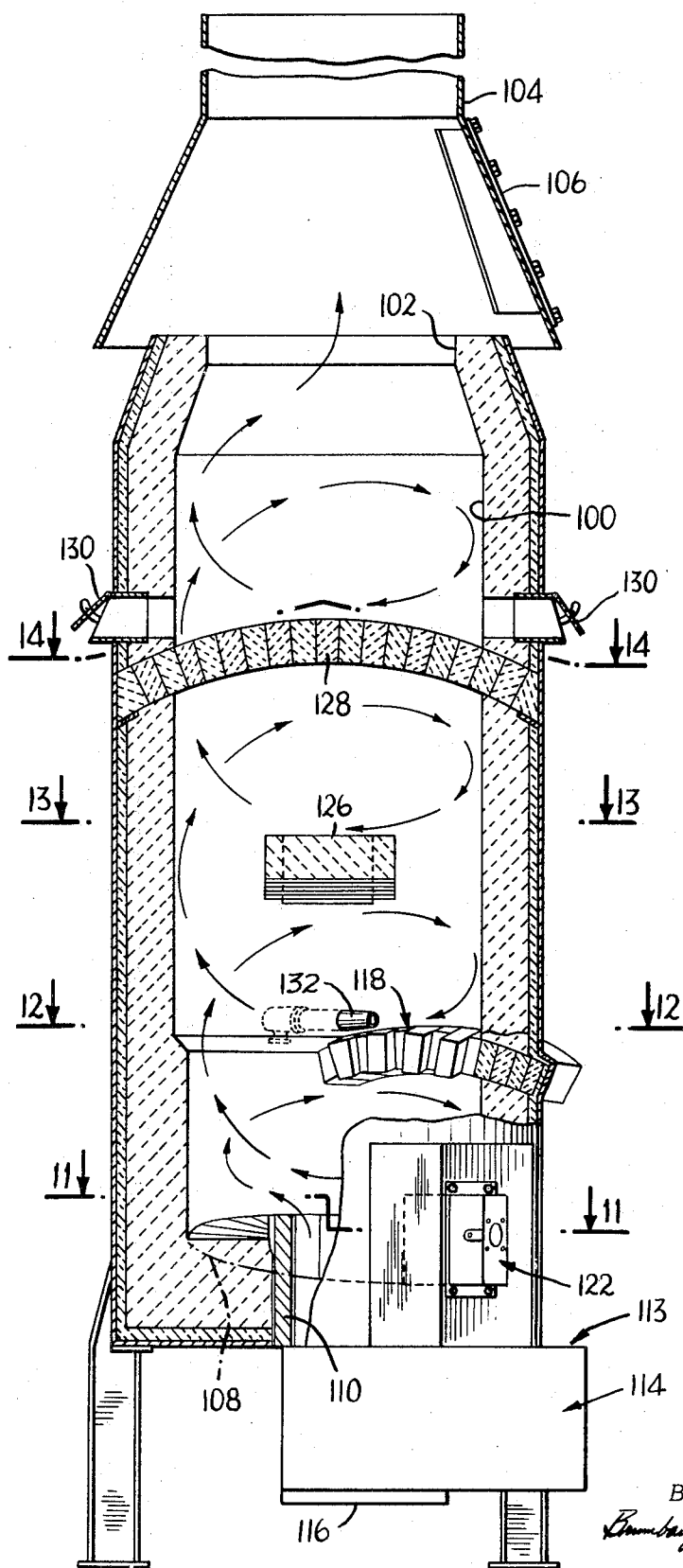


FIG. 10

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FIG. 12

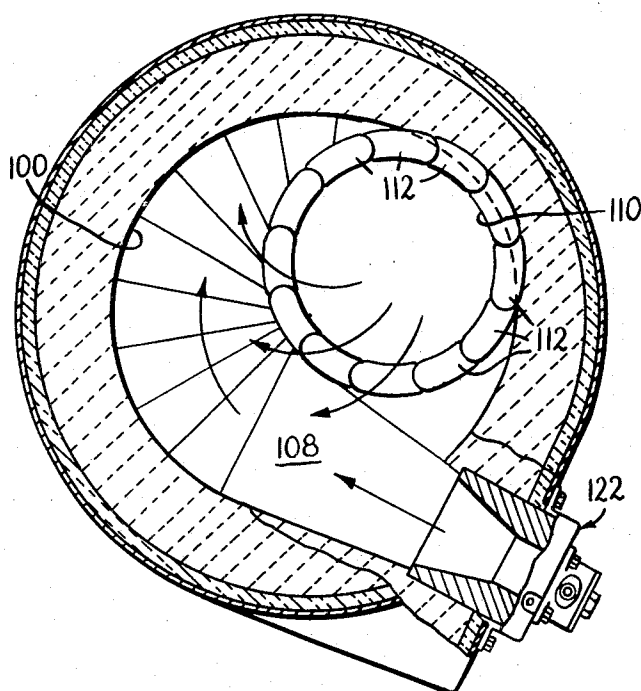
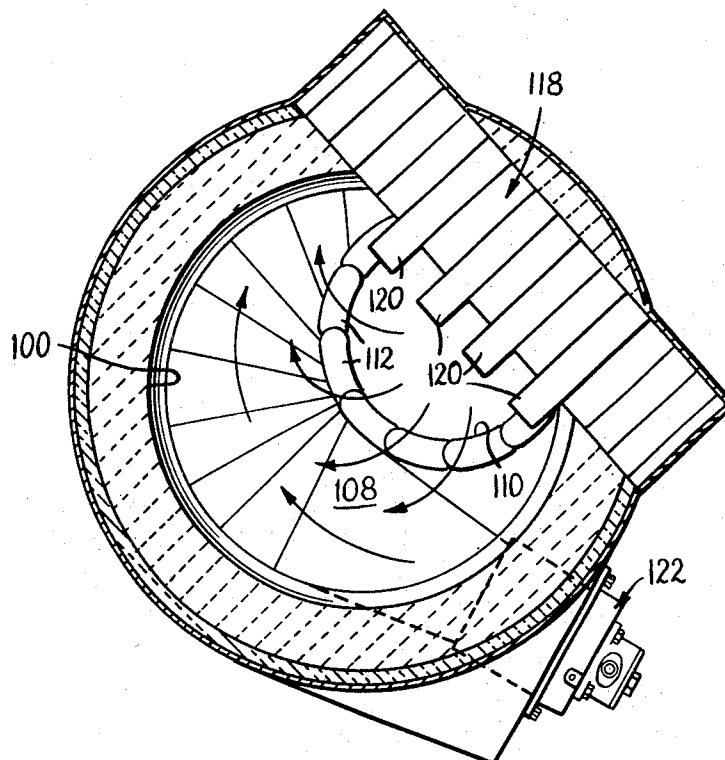


FIG. 11

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FIG. 14

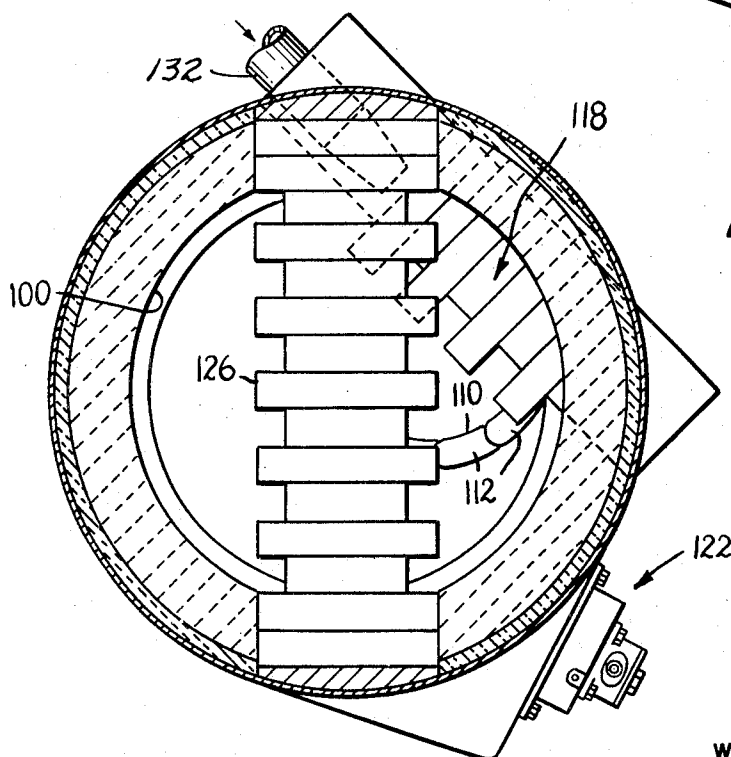
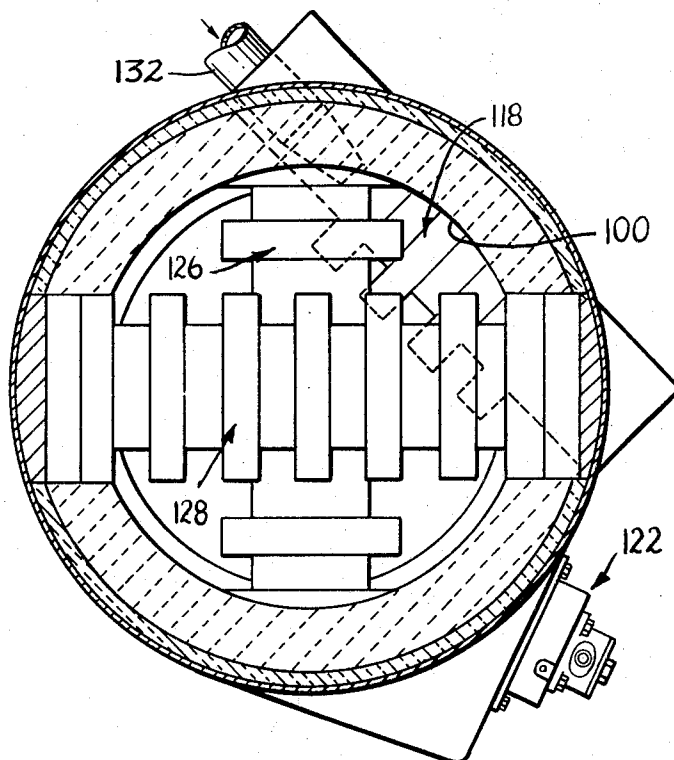


FIG. 13

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MULTI-PURPOSE FURNACE WITH SMOKE AFTERBURNER

BACKGROUND OF THE INVENTION

This invention relates to a furnace for such various purposes as burning refuse, burning away impurities to recover a desired salvage material, and melting nonferrous metals. It is thus particularly well suited for use in scrap yards where there is a need for equipment to carry on a variety of burning operations requiring different temperatures and other conditions and resulting in considerable problems in smoke control.

In recent years efforts to reduce air pollution have been accelerated, and it has become necessary for any operation combustion to provide maximum control over the discharge of air pollutants. One area requiring improvement in equipment is the field of furnaces of the incinerator type where various materials, particularly refuse, are burned. There have been numerous proposals for relatively small furnaces suited for multipurpose use and particularly for use in scrap yards where it is desired to not only destroy certain combustible materials by ordinary incineration but also to recover useful salvage material and to melt nonferrous metals. All too often, this type of equipment is not adequately designed from the standpoint of controlling the discharge of air pollutants. Moreover, the desirable and, in some instances necessary, attributes of providing good smoke control without great expense and without complicated and large-sized equipment have not, to our knowledge, been attained heretofore.

SUMMARY OF THE INVENTION

We have provided, by our invention, a novel and improved multipurpose furnace embodying features providing for combustion of substantially all of the smoke produced by various burning operations. One of the features of the furnace is the provision of what may be termed a smoke dome, a zone at the top of the furnace combustion chamber which is closed above and laterally, except for an outlet to a smoke afterburner section, and has a volume of on the order of 20 percent to 30 percent of the total volume of the chamber. In particular, the smoke dome is located entirely above the charging doors of the combustion chamber and in the top of the furnace above the normal level to which the furnace is loaded with material to be burned. Preferably, a burner providing a flame jet for assisting in burning the material, is directed into the smoke dome portion of the furnace. The smoke dome has been found to provide effective combustion of the smoke and eliminates the problems found with many furnaces of similar types of smoke leaking out through the door or air coming in through the charging door, the first case being obviously objectionable by reason of discharging pollutants to the atmosphere and the second being objectionable by reason of cooling off the upper regions of the furnace so that combustion of the smoke is reduced. We have found that the volume of the smoke dome portion of the furnace is of some importance and should be on the order of between 20 percent and 30 percent of the total chamber volume. If the volume of the smoke dome is greater than 30 percent, fuel requirements are excessive, whereas a volume of less than about 20 percent reduces the degree of combustion, probably by reducing the dwell time of the smoke in the smoke dome below that required for effective combustion.

The furnace also has a smoke afterburner section in the form of a smoke passage through which the smoke passes after leaving the furnace and in which the combustible components of the smoke that are not burned in the smoke dome are burned. The inlet portion of the smoke passage is constructed in such a way as to establish a generally spiral or helical flow of the smoke through the passage. Thus, the smoke whirls through the passage along a path providing an effective distance substantially greater than the actual linear dimension of the passage by rotating and swirling around circumferentially about the axis of the passage but with, of course, a net velocity component in the downstream direction. Con-

sequently, the dwell time of the smoke in the passage is relatively long, even though the passage has a relatively short actual length. The afterburner section is therefore of relatively small size and yet provides for adequate combustion of the smoke. In most forms of furnaces and similar equipment, an adequate dwell time in a smoke combustion region is provided by making a chamber or passage of sufficiently large size. In addition to increasing the dwell time of smoke in the passage, even though the passage is of relatively short length, the whirling flow of the smoke through the passage enhances the mixing of the smoke components and improves the combustion of combustible smoke components.

Combustion of the smoke in the smoke afterburner section is supported by adding heat from an external source, such as a flame jet; and by introducing oxygen or an oxygen-containing gas, such as air. The air is introduced in amounts at least sufficient to burn the combustibles of the smoke, as well as the fuel from the flame jet burner. Desirably, there is automatic temperature control in the afterburner section, and air is introduced whenever the temperature rises above a desired level. In such a case, the air will be introduced in an amount exceeding that required for smoke combustion, and the fuel to the burner turned down.

The smoke afterburner section further includes an arrangement of baffles in the passage for breaking up flow paths along which streams of smoke might otherwise short circuit through the passage and for creating turbulence in the flow and therefore mixing of the smoke components with the combustion-support gases. The baffles are, however, constructed so as not to substantially obstruct the flow through the passage. Preferably, the baffles are in the form of firebrick structures arranged so that portions of spaced-apart bricks form a comblike structure of alternating projections and spaces. The baffle arrangement in the smoke passage may desirably include at least one baffle structure transsecting the passage, such as one which extends between opposite walls and is generally centered on the axis of the passage.

In one exemplary form of the apparatus of the invention, there are two furnaces of substantially identical construction, each having a smoke dome of the type described above, and the two furnaces are served by a single smoke afterburner section. The smoke is conducted from the two furnaces along inlet passages to the main smoke passage which lead in transverse to the main smoke passage and enter the main passage in mutually opposed directions toward each other. The inlets to the main passage are formed so that the smoke coming from each is directed along a path somewhat offset from the axes of the passage and spaced from the other. Consequently the smoke from the respective furnaces enters in offset counter-current and thereby establishes a rotational flow. In addition, the inlet to the smoke passage is provided with formations that aid in imparting an axial component of velocity to the smoke. Consequently, the smoke is introduced into the smoke passage and thereafter flows through it in a generally helical flow pattern.

In this form of equipment, the combustion of the smoke in the passage is assisted by directing a flame jet generally along the axis of the passage. In addition an oxygen-containing gas, suitably air, is introduced into the passage downstream of the burner to support combustion of the combustible components of the smoke. The whirling flow of the smoke, coupled with the provision of baffles to break up otherwise possible short circuit streams through the passage, provides intimate mixture of the smoke components and air and provides a suitable dwell time for combustion of the combustible components of the smoke so as to burn all of the combustible components and release substantially "clear gases" to a stack. If there are non-combustible, particulate pollutants, they may be removed by suitable devices, such as wet scrubbers, cyclones, electrostatic precipitators or other smoke cleaning devices. However, the combustible components of the smoke have been completely removed when the smoke leaves the smoke afterburner section, and further removal of pollutants is limited to noncombustible components.

In another preferred form of the afterburner section, the smoke is introduced into the smoke passage through an inlet passage or opening that is generally aligned with the axis of the smoke passage but is offset from the axis. Adjacent the opening is a smoke diverter baffle which turns the smoke laterally. A flame jet is directed generally laterally into the passage, and the inlet section is provided with guide surfaces which turn the flame jet and establish the whirling, generally helical flow through the smoke passage. The whirling flow is further established by introducing air into the smoke passage generally tangentially from a nozzle above the diverter. This form of smoke afterburner section is suited for either vertical or horizontal orientation. Desirably, the inlet end of the smoke passage has an inclined surface opposite the flame jet so as to turn the flame jet somewhat in the direction of the axis of the passage so that the flame jet and smoke are given an axial component of velocity. Baffles in the form of arches or bridges transecting the smoke passage break up the flow paths, as with the similar baffle arrangements in the above-described exemplary form of smoke afterburner section. In both forms of afterburner sections, the comblike type baffles provide excellent mixing characteristics and yet they need not be of such large size or cross section as to materially reduce flow through the passage.

In addition to the important advantage of providing thorough combustion of the combustible components of the smoke produced in burning various forms of material, the equipment of the invention, particularly the afterburner equipment, offers the further advantage of being of relatively small size. This point has been discussed above, but is brought out again from the standpoint of the practicality of transporting and installing equipment. When the equipment is used with relatively small-sized combustion chambers, and particularly with two separate furnaces, it is possible for a complete installation having a very practical and efficient output level for many purposes to be transported by rail or truck, thus considerably facilitating delivery and installation at the site.

DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be made to the following description of exemplary embodiments, taken in conjunction with the figures of the accompanying drawings, in which:

FIG. 1 is a pictorial view taken from above and generally toward the front of one embodiment of the multipurpose furnace of the invention;

FIG. 2 is a pictorial view looking down and generally toward the back of the embodiment of FIG. 1;

FIG. 3 is a transverse section of the embodiment of FIG. 1 taken generally along the lines 3-3 of FIG. 1 and in the direction of the arrows;

FIG. 4 is a top view in section taken through the upper part of the furnace portion of the apparatus in FIG. 1;

FIG. 5 is a front sectional view of the smoke afterburner section of the embodiment, the view being taken generally along the lines of 5-5 of FIG. 3 and in the direction of the arrows;

FIG. 6 is a top view in section of the smoke afterburner taken generally along the lines 6-6 of FIG. 5 and in the direction of the arrows;

FIG. 7 is an end sectional view of the smoke passage of the afterburner section taken generally along the lines 7-7 of FIG. 6 and in the direction of the arrows;

FIG. 8 is a plan view and FIG. 9 is an end view in section of a grating for the bottom of the combustion chamber of the furnace apparatus;

FIG. 10 is a side sectional view taken generally along a central longitudinal plane of a smoke afterburner section of alternate form appropriate for use in the invention; and

FIGS. 11 to 14 are cross-sectional views taken at various elevations of the smoke afterburner section of FIG. 10, as designated by the section lines in FIG. 10.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

As may be seen overall in FIGS. 1 and 2, one exemplary form of furnace actually comprises two side-by-side furnaces, which are designated generally by the reference numerals 10 and 10' and are of substantially the same construction. In the following description, the parts of each furnace are designated by the same reference numerals and only one furnace is described, but the parts of the left furnace (as viewed in FIG.

1) are designated by such numerals with a prime suffix for purposes of specific reference. The two furnaces 10 and 10' are served by a single smoke afterburner section 12, the major portion of which is mounted directly on top of the furnaces 10 and 10'. Smoke from the two furnaces is conducted through openings (described below) in the tops of the furnaces into laterally oriented inlet passages 14 and 14' and is then directed through a horizontal smoke passage 16 and thence to a stack 18. The rearwardmost end of the passage 16 and the stack 18 are supported on a frame 20 located behind the two furnaces. It is preferable to construct the furnace in individual subassemblies comprising (1 and 2) the individual furnaces 10 and 10' (3) the front end portion of the smoke afterburner section 12 and the inlet passages 14 and 14', both of which are supported on top of the furnaces, and (4) the downstream end portion of the smoke passage 12 and the stack 18. Each of the four subassemblies may be of appropriate size for convenient transporting of all four by truck, and the complete furnace structure is then assembled at the site.

The furnaces and the afterburner section are preferably constructed of steel plates welded or otherwise joined to form outer shells and firebrick linings appropriately installed within the shell with a layer of insulation installed between the shell and the firebrick lining. The sidewalls and bottoms of the chambers and passages in the furnace are laid or stacked in place, preferably with ties to the shells, while the firebrick structure forming the tops of the cavities and passages of the equipment are, as may be seen, for example, in FIG. 3, suspended from hangers 22 supported by bars 24 mounted outside the shell of the various roof portions.

Referring now particularly to FIGS. 3 and 4, each of the two furnaces 10 and 10' rests on an appropriate grid-type frame work 26 arranged on a slope to provide for a sloping furnace bottom 28 which allows, when the furnace is used for melting, the tapping of the melted material through a tap hole 30. The combustion chamber, which is designated by the reference numeral 32, is generally rectilinear, except for the sloping bottom, and in the form shown in the drawings is substantially cubicle. It is defined by a front wall 34, a rear wall 36, sidewalls 38 and 40 and a top wall 42. A charging opening 44 is formed in the front wall 34, and a door 46 is appropriately mounted on the front wall for vertical movement between open and closed positions. As best observed in FIG. 1 and FIG. 4, the door 46 of each furnace is guided vertically by guide rolls 48 on each side and is suspended from a cable 49 which forms a part of powered operating mechanism 50 (see the top lift of FIG. 1) of any suitable form. Many forms of operating devices are suitable and are well known to those skilled in the art, and the one shown is therefore not described here. Extending out from the front wall 34 on each side of the door are inclined lugs 52 which coact with outwardly extending pins 54 on the door to cam the door in relatively tightly against the door frame. A sand seal 55 is provided at the top edge of the door to minimize the entry of air into or the escape of smoke from the furnace when the door is closed.

It is desirable, particularly when the furnace is to be used for melting certain materials which are known to impregnate firebrick, to provide a pan 56 in the bottom of the furnace chamber. The pan is preferably made of stainless steel and has a bottom formed so that molten material is directed toward an outlet pipe 57 (FIG. 4) extending out through the tap hole 30. It is also desirable to provide a grating in the bottom of the chamber, the grating being designated generally by the

reference numeral 58, being shown by phantom lines in FIG. 3 (not shown in FIG. 4) and being shown in detail in FIGS. 8 and 9. In particular, an appropriate grating is composed of main longitudinal side tubular members 60, a series of transverse bars 62, a center bar 64 and appropriately positioned, upwardly projecting pins 66.

It is important to note that the charging opening 44 is spaced somewhat below the top wall of the furnace chamber 32 (see particularly FIG. 3). Consequently, the uppermost portion of the furnace chamber is closed laterally and above except for a smoke outlet opening 68 formed in the top wall 42 in the front, outermost corner (relative to the two-furnace combination). The position of the upper edge of the charging opening 44 is established so that the aforementioned closed uppermost portion of the furnace chamber 32, i.e., that portion of the furnace chamber volume above the charging opening, has a volume of on the order of between about 20 percent and about 30 percent of the total volume of the chamber. The dashed line 70 in FIG. 3 of the drawing represents the dividing line between what may be termed a "smoke dome" 72 and the main portion of the chamber. The smoke dome 72 may be defined as that region of the furnace above a horizontal plane passing through the upper edge of the charging opening 44, and, as just mentioned, has a critical volume on the order of between 20 percent and 30 percent. It has been found that the optimum volume for the smoke dome is somewhere around 25 percent to 28 percent of the total volume of the furnace combustion chamber 32.

The smoke dome of the furnace, according to the invention, confines the smoke for more complete mixing and burning of combustible smoke components, and by closing it off, especially from entry of cold air around the door, the gases in the smoke dome stay at a relatively high temperature and are burned very effectively.

The source of heat for the furnace chamber is a burner 74 which is installed through the outermost sidewall 38 of each furnace and directs a flame jet into the combustion chamber. The furnace is, preferably, equipped with automatic temperature control equipment, and for this purpose an appropriate temperature sensor 76 is installed in a suitable place in the furnace chamber, such as through the back wall (see FIG. 4). The temperature information detected by the temperature sensor 76 for each furnace 10 and 10' is utilized in a control unit, located in a control box 78 positioned on the outside of the end wall of one furnace 10, to control the burner 74 of the respective furnaces and also to control a damper 80 installed in the outermost end wall of each furnace. Various automatic temperature controls for furnaces of this and similar types are known to those skilled in the art, and therefore the details of a particular control system need not be described here.

In operation, the material to be burned in is charged in through the charging opening 44 of each furnace, and the burners are turned on and the draft doors opened to initiate combustion of the material. As soon as the temperature in the furnace comes up to the desired level for the particular material being burned, such level being preestablished by presetting the control unit 78, the burner is turned down, the draft is closed and combustion of the materials proceeds with a relatively low burner fuel supply. The burner and draft are automatically controlled to maintain the desired temperature. The smoke evolving from the combustion of the material rises into the smoke dome portion of each furnace where the combustible components are burned, but the burning in the smoke dome of the combustible components is not complete in many burning operations. Consequently, the smoke passes from the furnace through the outlet opening 68 and is conducted into a smoke afterburner section for further combustion of the combustible components, so that substantially "clear gases" are discharged from the apparatus.

Referring next particularly to FIGS. 5, 6 and 7, the smoke afterburner section 12 of the furnace comprises an inlet passage 14 or 14' coming from each of the two furnaces and conducting smoke into a main smoke passage 16. As

shown in FIG. 5 each of the inlet passages 14 and 14' includes a vertically disposed portion communicating with the smoke outlet opening 68 of the furnace it serves and a horizontal portion extending in from the vertical portion and entering the main smoke passage 16 from directions which are substantially perpendicular to the axis of the main smoke passage. It should be noted that the axis of the smoke passage 16 is substantially horizontal and extends substantially perpendicular to the front of the two-furnace combination, although, as will be described below, this particular arrangement is only exemplary.

The inlet passages 14 from the respective furnaces into the main smoke passage 16 and the inlet portion of the smoke passage are constructed in such a way as to generate a spiral or helical flow of smoke through the smoke passage. More particularly, a wall 81 constituting the end wall of the main smoke passage 16 and the front wall of the inlet passages 14 and 14' is formed with a projection 82 having, as is best seen in FIG. 6, portions which curve around from alignment with the inlet passages 14 to general alignment with the main smoke passage 16 and which help to turn the smoke into a direction aligned with the axis of the smoke passage. At best seen in FIG. 5, the lower wall of the inlet passage 14 has an inclined portion 84 which directs the smoke coming through the inlet passage 14 in an upward direction, while the top wall of the inlet passage 14' has a downwardly inclined portion 86 serving to direct the smoke coming through the inlet 14' generally downwardly. Accordingly, as depicted by the arrows in FIG. 5, the smoke entering from the right passage 14 is guided up while that coming from the left passage 14' is guided down with the result that the smoke swirls in a generally circular path upon entry into the smoke passage. In this regard the downstream wall portions of the projections 84 and 86, such portions being designated by the reference numerals 84a and 86a, are curved so that they assist in guiding the smoke into a whirling flow by impingement of the smoke on them as it enters from the opposite opening. The combination of the turning effect of the wall formation 82, which imparts an axial component to the smoke and the formations 84 and 86, which create a whirling motion, results in the aforementioned helical flow pattern of smoke through the main smoke passage 16. The openings from the smoke inlet passages 14 to the main smoke passage 16 are of lesser cross-sectional area than the main passage so that the smoke is first accelerated upon entry to assist in establishing the helical flow pattern and then slows as it starts through the passage.

The burning of the combustibles of the smoke which were not burned in the smoke domes of the respective furnaces is carried out in the smoke passage 16, preferably by adding heat from an external source and also by introducing oxygen or an oxygen-containing gas, for example air, into the smoke passage 16. The additional heat is provided by a burner 88 installed in the front wall 81 of the smoke afterburner section and preferably located to direct the flame jet substantially along the axis of the passage 16. The burner may be controlled automatically to maintain a desired temperature in the passage 16, a suitable temperature measurement and control system being provided as a part of the main control unit. The location of the burner at the inlet end of the passage 16, since it is at a point in the passage where the flow is turbulent and mixing conditions are good, provides very efficient burning of the combustibles in the smoke. Smoke combustion is completed by introducing air through one or more inlet pipes located in the passage 16 downstream from burner 88. The embodiment shown in the drawings includes air inlet pipes 90, 90' and 90'' located behind baffles (described below). The pipes have series of holes distributed along them and positioned to direct air streams into the passage in the directions, represented generally by arrows, to provide good mixing. The burner 88 is preferably of the excess air type in which only the fuel is controlled while the air is on full at all times. When the temperature in the smoke passage rises to a desired maximum level, the fuel to the burner is modulated downward to say

one-fifth of its maximum, but the burner air is kept full. In addition the air supply to the pipes 90, 90' and 90'' is modulated upward to introduce an excess of air over that required to burn completely the smoke. Consequently, the temperature is maintained at the set, controlled maximum with excess air while the smoke is burned. At a controlled maximum temperature, depending on the amount of smoke, the air to the pipes 90, etc., is modulated up or down and the fuel to the burner is inversely modulated to maintain the controlled temperature by supplying excess air for burning the smoke. In general, the temperature range may be any appropriate spread near the maximum that can be endured without undue wear and tear on the equipment while ensuring complete smoke combustion.

It is important that the gases passing through the passage 16 be maintained in a relatively turbulent flow condition to provide good mixing between the smoke and the air coming in through the pipe 90. To this end, the passage 16 is provided with baffles (see FIGS. 5, 6 and 7 of the drawings) including, first, vertical posts 92 and 94 built up from firebrick laid in different directions so as to form comblike projections extending laterally (i.e., perpendicular to the axis of the passage 16). One post 92 is located near the inlet to the passage 16 and the other 94 is located somewhat downstream of the first near the outlet. The baffle arrangement also includes, second, spaced-apart, vertical columns 96 and 98 of projecting firebricks extending in from the sidewalls of the furnace, one column 96 extending in from one side and the other 98 extending in from the opposite wall at a point opposite the first column 96.

As represented by the arrows in FIG. 6, the baffle structures break up the overall flow pattern in the passage 16, and the individual structures, by virtue of their comblike form, individually break up flow streams and prevent short circuiting of smoke through the passage 16. The projecting comb brick ends heat up quickly and provides a rapid heat transfer surface to absorb the heat for the burner and fast transfer to the smoke and air mixture, thus performing two functions, temperature and turbulence. The combination of the helical form of overall flow of the smoke through the passage 16 and the mixing effect of the baffles with their higher temperature projecting brick ends ensures intimate mixture of the smoke with the incoming air and very effective burning of the combustible components of the smoke. Experience with furnaces that have already been built has demonstrated that all of the combustibles in smoke from various materials burned in the furnaces is burned before reaching the stack 18.

It will be apparent to those skilled in the art that the afterburner portion of the apparatus of the invention may be used with various forms of furnaces, including many types not having a smoke dome. In other words the afterburner section constitutes a basic feature of the furnace of the invention and may be used with various types of combustion equipment. An afterburner section of the type shown in FIGS. 1 to 6 can also be used with a single furnace having two spaced-apart outlets so as to provide for utilization of the counterflow entry principle to create a whirling or helical flow pattern through the smoke passage.

FIGS. 10 and 14 show an alternative form of smoke afterburner based on the principles of the invention and operating in a manner similar to the embodiment of FIGS. 1 to 7. Referring first to FIG. 10, it is constituted by a generally cylindrical, vertically or horizontally disposed structure defining a smoke passage 100. Like the first embodiment, it includes an outer metal shell, a layer of insulation, and a layer of firebrick, the details of which need not be described. The upper end of the passage 100 is open to provide an outlet opening 102 that allows smoke to rise into a stack 104 through a tapered inlet hood 106. The lower end of the passage 100 is closed by a bottom wall 108 having, however, an inlet opening 110 for admitting the smoke to be burned in the passage. The opening 110 is, as may be seen best in FIG. 11, circular, of substantially lesser cross-sectional area than that of the passage, and offset from the center axis of the passage. It is built up of interlocking

firebricks 112 and leads in from an inlet section 113 below the bottom 108 of the passage 100. Entry to the inlet section may be either laterally through one entry 113 in the end of an inlet compartment 114 or vertically up through an alternate entry 116, and the entry 113 or 116 which is not used may be appropriately closed off.

Above the inlet opening 110 to the smoke passage 100 is a diverter baffle structure 118 in the form of an arch transecting a segment of the wall of the passage 100 and projecting out into overlying relation to a portion of the inlet passage 100. The portion of the arch structure 118 within the passage 100 includes alternating short and long firebricks so as to create spaced-apart, outwardly extending projections 120 yielding a comblike effect. As the smoke rises up through the inlet opening 110, it impinges on the under surface of the diverter baffle structure 118 and is turned somewhat into a lateral direction, i.e., given a lateral component of velocity.

The combustion in the afterburner section of combustible components of the smoke is supported by a burner 122 installed just above the bottom 108 of the smoke passage 100 and disposed so that it directs a flame jet in a direction across the lower end of the smoke passage 100 and offset from the center line or axis of the section. The bottom wall 108 of the passage structure is inclined slightly upwardly in a curved path away from the burner 122 so that the flame jet is not only turned by the lateral cylindrical wall of the passage 100 but is also given a component of velocity in the axial direction of the passage. As represented by the arrows, the flame jet imparts to the incoming smoke a circumferential component of velocity so that the flow of smoke into and upwardly through the passage is generally along a helical path. As the smoke enters from the inlet 100 and is diverted laterally toward the flame jet, the flame jet turns it into a whirling flow which persists as the smoke rises up through the passage 100.

Somewhat above the lower end of the passage 100 and above the diverter baffle 118 are baffle structures 126 and 128, each of which is in the form of an arch transecting the passage 100 and formed of firebrick of alternating longer and shorter length so as to create comblike projections at opposite sides of each arch structure. The baffle structures 126 and 128 are spaced-apart vertically and are oriented perpendicular to each other so that they interrupt and divert the flow of smoke at different angles and provide a broken flow path. Like the first embodiment, however, the baffle structures are of a size such that they do not materially impede the flow of smoke through the passage 100, even though they provide effective breaking up of flow streams through the passage 100 which might otherwise tend to short circuit smoke through it.

Dampers 130 located just above the upper baffle 128 and generally opposite each other in the walls of the smoke passage 100 admit air to complete combustion. Also, air is blown in through a nozzle 132 located above the diverter baffle 118 and oriented to direct a stream of air generally tangentially to the outer part of the smoke passage, thereby to assist in establishing a whirling flow in the passage. As in the other embodiment of the smoke afterburner section, the nozzle, dampers and burners are preferably controlled by a suitable control system so that the temperature within the afterburner passage is kept at a desired level appropriate to burn the combustible components of the smoke.

Thus, it is apparent that the embodiment of FIGS. 10 and 14 operates in much the same manner as the embodiment of FIGS. 1 to 7, in that the smoke enters and is conducted through a smoke passage in a generally whirling, helical flow path, and the flow path is interrupted by comblike baffle structures which ensure mixing of the smoke with the burning gases of a flame jet and with an oxygen-containing gas. The flow pattern of gases through the passage 100 is interrupted so that short circuiting is substantially prevented and the whirling, turbulent flow conditions provide a relatively long dwell time for smoke in the passage, even through though the passage is of relatively short length so that efficient and substantially complete combustion of combustible components of the

smoke is accomplished before it is discharged to the stack. Thus, the smoke afterburner of the embodiments of FIGS. 10 to 14 provides complete combustion of the combustibles and releases substantially clear gases to the stack.

From the foregoing, it will be readily apparent to those skilled in the art that the above described embodiments are merely exemplary and that numerous variations and modifications of them may be made without departing from the spirit and scope of the invention.

We claim:

1. Combustion apparatus comprising a smoke afterburner section in the form of a smoke passage serving at least one furnace where smoke-producing combustibles are burned, an inlet to the passage to communicate it with the furnace, an outlet from the passage to communicate it to a stack or the like, and a smoke combustion zone in the passage between the inlet and outlet, the passage having formations in the region of the inlet arranged to establish a whirling generally helical flow pattern in the smoke passing through the passage, means for adding heat to the smoke in the passage in the region of the inlet, means for introducing an oxygen-containing gas into the combustion zone of passage to support combustion of smoke components therein, and means for breaking up flow paths through the passage to effect turbulence and mixing of the gases therein without substantially obstructing flow through the passage including at least one baffle structure having a multiplicity of spaced-apart elements projecting into the passage and providing irregular surfaces that break up the gas flow through the passage and become heated to an extent sufficient to promote combustion of gases in the passage.

2. Apparatus according to claim 1 wherein there are independent baffle structures spaced from each other axially of the chamber.

3. Apparatus according to claim 2 wherein the spaced-apart elements of the baffle structures are composed of firebricks arranged to create comblike spaced lugs alternating with spaces.

4. Apparatus according to claim 1 wherein the passage has two inlets entering at angles to the axis of the combustion zone, the respective inlets also entering in juxtaposed relation so as to assist in generating a whirling motion in the smoke.

5. Apparatus according to claim 4 wherein the passage has a wall at the inlet end adjacent the inlets and formed with surfaces upon which the smoke entering from the inlets impinges and by which it is turned generally axially of the passage.

6. Apparatus according to claim 4 wherein the inlet portion of the passage includes curved wall portions disposed such that smoke entering through the respective inlets impinges thereon and is turned thereby into a whirling flow at the said inlet portion.

7. Apparatus according to claim 4 wherein the means of adding heat to the smoke includes a flame burner disposed at the said inlet portion and arranged to direct a flame jet generally axially of the passage.

8. Apparatus according to claim 1 wherein the inlet is a passage generally aligned with the combustion zone but having an axis offset from the axis of the said zone.

9. Apparatus according to claim 8 wherein there is a projecting structure disposed in the passage for impingement thereon of smoke entering from the passage thereby to divert the smoke in a generally lateral direction adjacent the inlet end of the passage.

10. Apparatus according to claim 9 wherein the means for adding heat to the smoke includes a flame burner disposed at the inlet portion of the passage and disposed to direct a flame jet generally transversely of the passage and along a path displaced from the axis of the passage thereby to assist in generating a whirling flow of the smoke entering from the inlet.

11. Apparatus according to claim 10 wherein there is a generally transverse end wall at the inlet end of the passage, the end wall having at least a portion inclined relative to the flame jet such that the flame jet is given a component of velocity in the axial direction of the passage.

12. Apparatus according to claim 1 further comprising an initial smoke burning zone between the combustion section of the furnace and the afterburner section, the said initial smoke burning zone being the uppermost portion of the furnace cavity and being substantially completely closed laterally and above except for the said inlet to the afterburner section, but being in free communication to the remainder of cavity below it, whereby the smoke is entrapped therein, the said smoke burning zone having a volume on the order of from about 20 percent to about 30 percent of the total volume of the furnace cavity.

13. Combustion apparatus comprising a smoke afterburner section in the form of a smoke passage serving at least one furnace where smoke-producing combustibles are burned, the passage having an elongated smoke combustion zone having a transverse wall at its inlet end and having an outlet to communicate it with a stack or the like, a pair of inlet passages communicating the smoke passage with the furnace and having openings to the furnace disposed generally opposite each other at the inlet end of the smoke passage but being offset from the smoke passage axis in opposite directions, the openings being of substantially lesser area than the cross-sectional area of the smoke passage, the inlet passages including elongated portions adjacent the smoke passage disposed generally transversely to the axis of the smoke passage to establish smoke flow paths therein generally transverse to the smoke passage axis, smoke flow guide formations adjacent the openings arranged to guide the smoke from the inlet passages into the smoke passage in a whirling generally helical path, the smoke flow in the passage thereby having both circumferential and axial components of velocity, a flame burner adjacent the inlet to the smoke passage and disposed to direct a flame jet substantially along the axis of the smoke passage, means for introducing an oxygen-containing gas into the smoke passage to support combustion of smoke components therein, and means in the smoke passage for breaking up flow paths therethrough to effect turbulence and mixing of the gases without substantially obstructing flow through the passage including at least one baffle structure projecting into the passage from the walls and transecting the passage between opposite walls thereof.

14. Apparatus according to claim 13 wherein the baffle structure is composed of firebricks arranged to create comblike spaced lugs alternating with spaces.

15. Apparatus according to claim 14 wherein there are at least two baffle structures spaced longitudinally of the smoke passage.

16. Apparatus according to claim 14 wherein the major axis of the smoke passage is generally horizontal and the structure generally centrally of the transverse dimension.

17. Apparatus according to claim 16 further comprising a baffle structure constituted by a generally vertical arrangement of spaced-apart elements extending inwardly from a wall of the passage.

18. Apparatus according to claim 13 further comprising an initial smoke burning zone between the combustion section of the furnace and the afterburner section, the said initial smoke burning zone being the uppermost portion of the furnace cavity and being substantially completely closed laterally and above except for the said inlet to the afterburner section, but being in free communication to the remainder of cavity below it, whereby the smoke is entrapped therein, the said smoke burning zone having a volume on the order of from about 20 percent to about 30 percent of the total volume of the furnace cavity.

19. Apparatus according to claim 18 wherein there are two furnaces, each having an initial smoke burner zone, each furnace communicating with one of the inlet passages to the afterburner section.

20. Apparatus according to claim 19 wherein the two furnaces are side by side, and the afterburner section is a structure mounted on top of the furnaces, the smoke passage being generally centered with respect to the two furnaces taken together and disposed horizontally and wherein the inlet

passages to the smoke passage extend in toward the smoke passage from adjacent an outer corner of the respective furnace.

21. Combustion apparatus comprising a smoke afterburner section in the form of a smoke passage serving at least one furnace where smoke-producing combustibles are burned, the passage having an elongated smoke combustion zone having a generally transverse wall at its inlet end and having an outlet to communicate it with a stack or the like, an inlet passage in the said generally transverse wall communicating the smoke passage with the furnace, the inlet passage being offset from the axis of the smoke passage but being generally aligned with the smoke passage so as to introduce smoke thereto in a direction generally aligned with the passage, the opening from the inlet passage to the smoke passage being of substantially lesser area than the cross-sectional area of the smoke passage, a smoke flow guide formation in the smoke passage adjacent the opening to divert the smoke laterally and establish a transverse component of velocity therein, a flame burner disposed to direct a flame jet in a direction offset from the axis of the smoke passage and generally transverse to the smoke passage adjacent the opening thereby to establish a whirling motion in the smoke, means for introducing an oxygen-containing gas into the smoke passage to support combustion of smoke components therein, and means in the smoke passage for breaking up flow paths therethrough to effect turbulence and mixing of the gases without substantially obstructing flow through the passage including structure projecting from the passage walls and transecting the passage.

22. Apparatus according to claim 21 wherein there are at least two structures spaced from each other axially of the smoke passage and transecting the passage at different angles.

23. Apparatus according to claim 21 wherein the structures are formed of firebricks arranged to create comblike spaced

lugs alternating with spaces.

24. Apparatus according to claim 21 wherein the smoke passage is disposed with its axis generally vertical and the structures are arches.

25. Apparatus according to claim 24 wherein the arches are formed of firebricks arranged to create comblike spaced lugs alternating with spaces.

26. Apparatus according to claim 21 wherein the end wall of the smoke chamber includes a portion inclined relative to the flame jet such that the flame jet is given a component of velocity in the axial direction of the passage.

27. Apparatus according to claim 21 further comprising an initial smoke burning zone between the combustion section of the furnace and the afterburner section, the said initial smoke burning zone being the uppermost portion of the furnace cavity and being substantially completely closed laterally and above except for the said inlet to the afterburner section, but being in free communication to the remainder of cavity below it, whereby the smoke is entrapped therein, the said smoke burning zone having a volume on the order of from about 20 percent to about 30 percent of the total volume of the furnace cavity.

28. Apparatus according to claim 1 further comprising means for controlling the temperature in the smoke passage including means for monitoring the temperature in the smoke passage, means responsive to the monitored temperature for controlling the heat-adding means to vary the quantity of heat added to the passage, and means responsive to the monitored temperature for controlling the introduction of oxygen-containing gas into the passage to increase the amount above that required to burn the smoke when the temperature in the passage exceeds a predetermined value.

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