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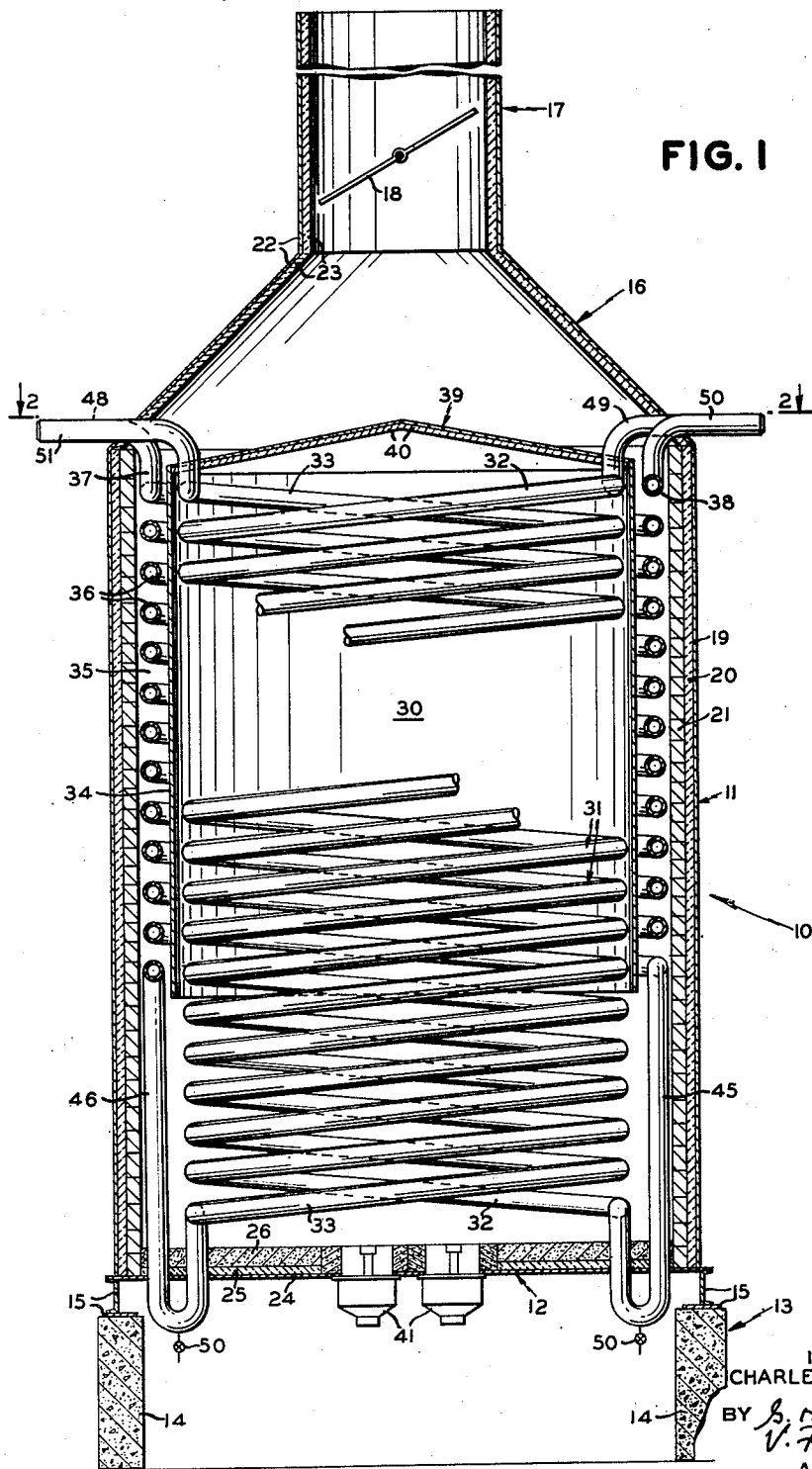
C. K. MADER

2,823,652

HELICAL COIL HEATER

Filed Nov. 30, 1954

2 Sheets-Sheet 1



INVENTOR
CHARLES K. MADER
BY *J. H. Palmer*
V. F. Davico
ATTORNEY

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FIG. 2

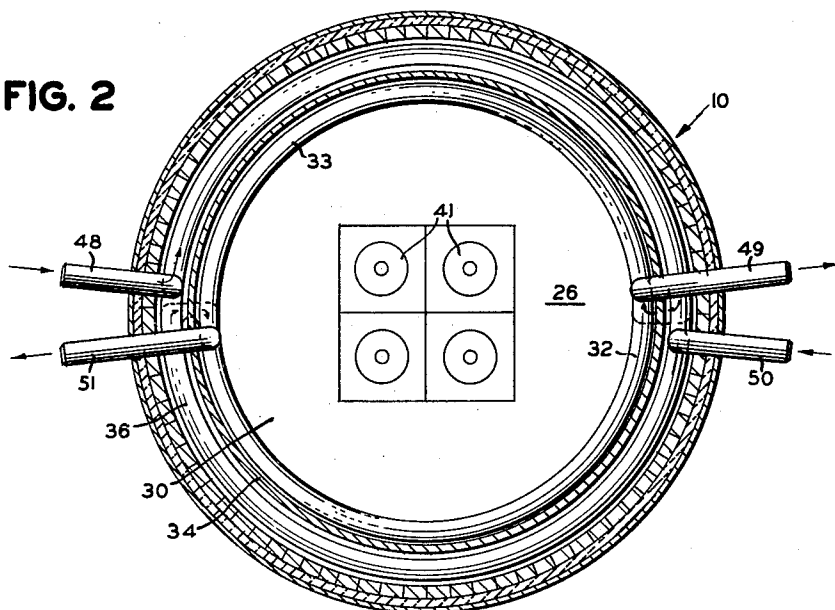
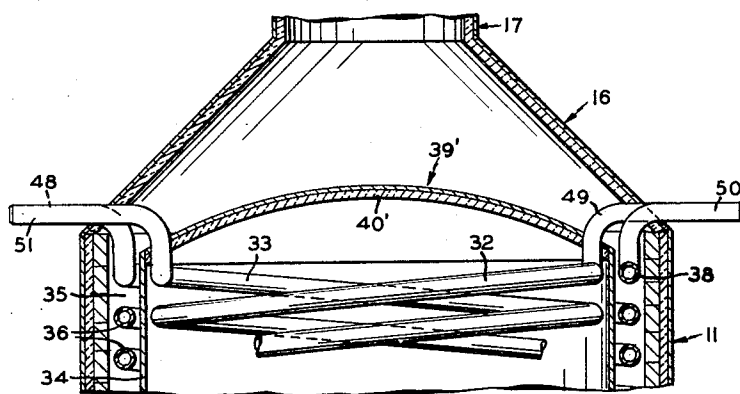


FIG. 3



INVENTOR.

CHARLES K. MADER

BY

S. H. Palmer
V. F. Davis
ATTORNEYS

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HELICAL COIL HEATER

Charles K. Mader, Suffern, N. Y., assignor to The M. W. Kellogg Company, Jersey City, N. J., a corporation of Delaware

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7 Claims. (Cl. 122—250)

This invention relates to apparatus for heating fluids and more particularly to furnaces for use in the petroleum and chemical industries which include helical coils through which the medium to be heated is circulated.

Helical coil heaters and furnaces are well known in the petroleum and chemical arts. These heating apparatus generally comprise a vertically disposed insulation lined, cylindrical metal shell which houses one or more vertically disposed helical tubular coils through which the medium to be heated is circulated. These apparatus are bottom fired and the combustion products flow upward axially of the shell to exit at the top through a reduced portion that leads to a damper controlled cylindrical stack. The heating of the medium circulated through the helical coil is accomplished substantially entirely by the radiant heat which the coil absorbs from the combustion products so that the combustion products enter the stack at comparatively high temperatures. This results in the efficiency of the heaters being quite low, usually the efficiency of this type of heater ranges from about 50 to about 55%. Helical coil heaters and furnaces are, however, in widespread use primarily because of the low cost thereof which results from the simplicity of construction and the ease and speed with which they can be erected.

I have found that the exit temperature of the combustion products can be materially reduced to thereby materially increase the efficiency of helical coil heaters without commensurably increasing the complexity and the cost thereof by providing for the removal of heat from the combustion products by convection heating of the medium circulated through the heater as well as by radiant heating thereof as heretofore.

In accordance with my invention I dispose a cylindrical baffle member about the upper portion of the radiantly heated helical coil section, said cylindrical baffle member extending from the top of said radiant coil section to the region of the middle thereof, or below, as preferred. The cylindrical baffle member has its top end closed by a deflecting head so that the combustion products instead of flowing in a straight line from the burners to the stack have their flow direction reversed by said deflecting head so that they will flow downwardly to the bottom of said cylindrical baffle member whereat their flow is again reversed upwardly toward the stack. I dispose a helical tubular coil section, through which the medium to be heated is circulated, in the annular space between the cylindrical baffle member and the furnace wall. This coil section is in the direct path of the combustion products on their way to the stack after the last mentioned flow reversal and is heated by direct contact with said combustion products in said annular space to thereby additionally cool said combustion products. The radiant coil section, as well as the convection coil section, may comprise a single coil or a plurality of coils connected as required to provide the desired heated stream, or streams. In accordance with one aspect of my

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invention the radiant coil section and the convection coil section are formed of an identical number of separate coils. The separate coils of each of said sections are of the same length and are disposed parallel to one another.

Each of the separate coils of the convection coil section is connected to a corresponding separate coil of the radiant coil section so that a plurality of substantially identical flow paths are formed. Thus, regardless of conditions existing at the heat producing means of the furnace and the flow of combustion products through the furnace, the separate flow paths will be subject to substantially identical heating conditions with the result that equal heat distribution is obtained.

It is a principal object of this invention to provide a high duty, compact, helical coil heater of simple and cheap construction which includes both a radiant heating section and a convection heating section and which is of relatively high efficiency.

It is also a principal object of this invention to provide a helical coil heater which includes a radiant coil and a convection coil, the latter coil surrounding the former coil and arrangements being provided to circulate the combustion products first upward to heat the radiant coil by radiation, then downward to the bottom of the convection coil, and finally upward in direct contact with the convection coil to heat the convection coil by convection to thereby provide a compact simple structure capable of high duty at relatively high efficiency.

The further objects, features and advantages of the invention will be apparent from a consideration of the following detailed description thereof taken with the accompanying drawings in which:

Fig. 1 is a vertical section through a furnace including a present preferred embodiment of my invention;

Fig. 2 is a section taken on line 2—2 of Fig. 1; and

Fig. 3 is a sectional view similar to Fig. 1 showing a somewhat modified construction.

The furnace of my invention is of general application and may be used in the steam generation, the petroleum, and the chemical arts for heating fluid circulated there-through and whether such heating is merely for the purpose of raising the temperature and/or changing the phase of the fluid or is for the additional purpose of obtaining a treating effect or reaction. For the purpose of this application, the invention will be disclosed in connection with a heater of the character employed in the petroleum art for the preheating of a feed stock, as for instance a crude feed heater for preparing the stock supplied to a distillation column.

As shown in the drawings and particularly in Figs. 1—3 thereof, the furnace 10 includes a cylindrical body section 11 whose bottom is closed by a floor 12. The furnace 10 is positioned on a foundation structure 13 which as shown, is formed of a concrete or masonry base 14 and the steel structural members 15. The cylindrical section 11 mounts a conical section 16 on its top end. The stack 17 is in turn mounted on the small upper end of the conical section 16. A suitable damper 18 is provided in stack 17 to control the flow of the combustion gases leaving the furnace 10.

Section 11 includes an outer wall 19 formed of light weight steel plate. The section 11 is arranged to provide a suitable heat barrier between the inner space of the furnace and the steel wall 19 thereof. This heat barrier comprises a suitable thickness of high temperature, heat insulating material 20 which is covered by a thickness 21 of refractory brick such as fire brick. The insulation material 20 is preferably porous and may be formed of any convenient material such as asbestos block insulation, insulating concrete, and the like. The insulation material 20 is of a thickness of about 2". The fire brick

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21 may be of any suitable conventional composition and of a thickness of about $4\frac{1}{2}$ ". The conical section 16 as well as the stack 17 includes an outer wall 22 formed of light steel plate. The walls 22 are internally covered with a depth of the refractory insulating concrete 23 which may be applied in any convenient way, as for instance, pneumatically by the "Guniting" method. The insulating concrete 23 may be of any suitable conventional composition. The floor 12 includes an outer floor plate 24 which is also formed of light weight steel plate. The floor plate 24 is protected from the heat of the internal space of the furnace 10 by a depth of porous insulation 25 similar to porous insulation 20 and a depth 26 of refractory insulating block material, preferably fire brick of the same kind as the fire brick layer 21.

Within the internal space 30 of the furnace 10 and concentrically spaced from the wall of the body section 11, is disposed the helically wound tubing coil 31. The tubing 31 may be formed as a single coil or may be formed as a plurality of parallel coils, as shown the tubing 31 comprises two parallel coils 32 and 33. The coils 32 and 33 are the radiant coils of the furnace. A cylindrical baffle 34 is disposed concentric relative to and encircles the upper portion of the radiant heating coils 32 and 33. The baffle 34 is spaced from the wall of the body section 11 to provide an annular passageway 35 therebetween in which is disposed the helically wound tubing 36 which defines the parallel convection coils 37 and 38. The lower end of the baffle 34 is open whereas the upper end is closed by a dome structure 39. The cylindrical baffle 34 is preferably formed of thin plate of a heat resistant alloy steel of a composition such as to successfully resist the oxidation and corrosion effects of the high temperature combustion products. The chromium-nickel-iron alloy known as 18-8 stainless steel is suitable for this purpose. The dome 39 is also formed of thin stainless steel plate but its inner surface is covered with a thickness 40 of a hard, refractory, insulating material such as insulating concrete, of any preferred composition, applied in a convenient manner as for example pneumatically as by the "Guniting" method. The dome closing the upper end of the baffle 34 may be in the form of the conical dome 39 of Fig. 1 or it may be in the form of the dished dome 39' of Fig. 3 to which a depth of insulating concrete 40', similar to the depth 40, is applied. Centrally arranged and extending through the floor 12 of the furnace 10 is a plurality of burners 41 which may employ oil or gas as the fuel to supply the required heat for the desired service. Any required number of burners 41 may be employed, four burners 41 are shown in the present preferred embodiment of the invention. These burners 41 employ oil and/or gas as the fuel.

The highly heated products produced by the combustion of the fuel at burners 41 pass upwardly centrally in the internal space 10 of the body section 11 and in so doing supply heat to the coils 32 and 33 preponderantly by radiation. By the time the combustion products reach the top of the coils 32 and 33 their temperature has been reduced to such a point that the further absorption of heat therefrom by radiation only is not economical. When the combustion products reach the dome 39 they are deflected outwardly and their direction of flow reversed downwardly to the bottom end of the cylindrical baffle 34. In flowing from the dome 39 to the bottom end of the cylindrical baffle 34 heat is absorbed from the combustion products by the coils 32 and 33 both by radiation and by convection. The heat transfer during this traverse of the products of combustion materially increases the efficiency of the radiant section. The increase in efficiency may be as much as 15%. After the products of combustion reach the bottom end of the cylindrical baffle 34 their direction of flow is reversed upwardly and their last traverse through the heater is upwards through the annular space 35 wherein they intimately contact the

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surface of the coils 37 and 38 to give up some of their contained heat thereto preponderantly by convection. When the products of combustion leave the tops of the coils 37 and 38 they have been cooled to such a degree that further heat absorption therefrom cannot be carried without unduly complicating the heater and greatly adding to its cost. The products of combustion after leaving the coils 37 and 38 pass to the conical section 16 and from thence to the atmosphere through the stack 17. The flow conditions are in part controlled by manipulation of the damper 18.

The fluid heating coils may be arranged in any manner required to produce the desired results. Thus in the installation described the various coils 32, 33, 37 and 38 may be interconnected in any desired manner. As shown, the coils 32 and 33 are disposed in parallel relation; this is also true of the coils 37 and 38. Also as shown, the coils 32 and 37 are connected in series by means of the vertical leg 45 while the coils 33 and 38 are connected in series by the vertical leg 46. The legs 45 and 46 may each include a valved drain line 50 provided for draining purposes. It is to be noted that each line 50 is positioned at the lowest point of its respective coil system so that in effect each coil system is self-draining. The medium to be heated by the series connected coils 32 and 37, crude oil in this case, is supplied through the inlet line 48 of convection coil 37; the heated oil leaves this series of coils through the outlet line 49 of the convection coil 32. The medium to be heated by series connected coils 33 and 38, also crude oil, is supplied through the inlet line 50 of the convection coil 38 and the heated oil leaves this series of coils through the outlet line 51 of the radiant coil 33. If the conditions require it, reversal of this stated flow may be made.

It is to be noted that the coils 32 and 33 are parallel nested coils, and that this is also true of the coils 37 and 38. It is also to be noted that as disclosed the coils 32 and 33 are of the same length while the coils 37 and 38 are also of the same length. Thus the flow path made up by the coils 33 and 38 and the leg 46 is substantially identical both as to length and exposure to the heated combustion products as the flow path made up by the coils 32 and 37 and the leg 45. This arrangement makes it possible to obtain equal heat distribution in the two streams flowing through the defined flow paths. While two parallel streams are disclosed as many as six parallel streams may be heated by employing the proper arrangement of parallel coils. With the arrangement disclosed, the mentioned uniform heat distribution will take place even though the burners 41 are not adjusted for equalized heat flow throughout the cross section of the furnace; as a matter of fact, even if one of the burners 41 were to stop functioning the heat distribution would not be disturbed.

Not by way of limitation but rather by way of further explanation of the size of the furnace 10 disclosed and the duty it performs in service, the furnace 10 includes a section 11 which is approximately 12 feet $9\frac{1}{2}$ inches high and of a diameter of approximately 12 feet four inches. The conical section 16 is some 5 feet high whereas the stack 17 is some 64 feet high.

The radiant coils 32 and 33 are formed of tubing having an outside diameter of about $4\frac{1}{2}$ inches and have a combined length of approximately 450 feet with an exposed surface, exposed for heat absorption, of about 532 square feet. The convection coils 37 and 38 are also formed of a tubing having an outside diameter of about $4\frac{1}{2}$ inches and include a combined length of about 400 feet with an exposed area of about 470 square feet. The radiant section was designed for a heat transfer rate of 10,000 B. t. u. per hour per square foot of tube area. In operating this furnace as a preheater for a crude oil feed, fuel oil of a 17,130 B. t. u. content was used as the fuel and supplied to the burners 41 at the rate of 654 pounds per hour. The heat liberated was 11,200,000 B. t. u.

per hour. The combustion products entered the annular passageway 35 (the convection section) at a temperature of 1520° F. and left the furnace at a temperature of 900° F. The overall furnace efficiency was about 69.7% while the radiant section efficiency was 49%.

In furnaces of this character wherein the whole duty is performed in a radiant section, in order to keep stack losses down to a reasonable value, the heat transfer rate is averagely about 6000 B. t. u. per hour per square foot of tube area (based on outside tube area). With such a heat transfer rate the combustion products leave the radiant section at about 1420° F. and the overall furnace efficiency is about 52%. If in furnaces in which the whole duty is performed in the radiant section, a heat transfer rate of 10,000 B. t. u. per square foot of tube area per hour is employed, the combustion products pass to stack at about 1610° F. with a resultant furnace efficiency of about 45%. Thus by reason of the return flow through the radiant section and the flow through the convection section, applicant is able to operate at a heat transfer rate of 10,000 B. t. u. per hour per square foot of tube area and yet obtain a radiant section efficiency of 49% and an overall efficiency of 69.7%. The return flow through the radiant section reduces the temperature of the combustion gases to 1520° F. and this accounts for a 4% rise in efficiency while the flow through the convection section reduces the temperature to 900° F. and accounts for a 20.7% rise in efficiency.

Although many changes can be made by those skilled in the art without departing from the scope of the invention, it is intended that all matter contained in the above description and appended claims and shown in the accompanying drawings shall be interpreted as illustrative and not limitative.

I claim:

1. A heater comprising in combination a body section including a refractory cylindrical wall defining a central space, refractory wall means closing one end of said cylindrical wall, helically wound tubing through which the medium to be heated is circulated, disposed within said central space concentric with and spaced from said refractory cylindrical wall, cylindrical baffle means positioned in said central space between said tubing and said cylindrical wall and extending from the region adjacent the other end of said cylindrical wall for a substantial distance in the direction of said one end of said cylindrical wall to provide an annular flow passageway radially outwardly of said helically wound tubing, means closing the end of said cylindrical baffle adjacent said other end of said refractory cylindrical wall, further helically wound tubing through which medium to be heated is circulated, positioned in said annular flow passageway and concentrically disposed relative to said cylindrical wall, means extending through said refractory wall means for introducing high temperature combustion products into said central space, and means for providing a pressure differential between said central space and the external space whereby said combustion products flow along said central space and impart heat by radiation to said first helically wound tubing and when they reach said means closing one end of said baffle means have their direction of flow reversed until they reach the open end of said baffle means whereat the flow again goes forward in the original direction and said combustion products contact said further helically wound tubing to impart heat thereto by direct contact therewith.

2. A heater comprising in combination a body section including a vertically disposed refractory cylindrical wall defining a central space, refractory wall means closing the bottom end of said cylindrical wall, vertically disposed helically wound tubing through which the medium to be heated is circulated, positioned within said central space concentric with and spaced from said refractory cylindrical wall, cylindrical baffle means concentric with said cylindrical wall positioned between said tubing and said

cylindrical wall and extending from the region adjacent the top end of said cylindrical wall for a substantial distance in the direction of the bottom end of said cylindrical wall to provide an annular flow passageway radially outwardly of said tubing, means closing the top end of said cylindrical baffle, further helically wound tubing through which medium to be heated is circulated, positioned in said annular flow passageway and concentrically disposed relative to said cylindrical wall, means opening through said refractory wall means for introducing high temperature combustion products into said central space, and means for providing a pressure differential between said central space and the external space whereby said combustion products flow upward along said central space and impart heat by radiation to said first helically wound tubing and when they reach the means closing the top end of said baffle flow downward until they reach the open bottom end of said baffle whereat the flow again goes upward and said combustion products contact said further helically wound tubing to impart heat thereto by direct contact therewith.

3. A heater comprising in combination a body section including a vertically disposed refractory cylindrical wall defining a central space, refractory wall means closing the bottom end of said cylindrical wall, vertically disposed helically wound tubing through which the medium to be heated is circulated, positioned within said central space concentric with and spaced from said refractory cylindrical wall, said tubing extending for substantially the full length of said cylindrical wall, a cylindrical metal shell concentric with said cylindrical wall positioned between said tubing and said cylindrical wall and extending from adjacent the top end of said cylindrical wall to the region of the middle thereof to provide an annular flow passageway radially outwardly of said tubing, a metal dome member closing the top end of said cylindrical shell, the concave side of said dome lined with refractory insulating material, further helically wound tubing through which medium to be heated is circulated, positioned in said annular flow passageway and concentrically disposed relative to said cylindrical wall, centrally disposed burner means opening through said refractory wall means for introducing high temperature combustion products into said central space, and means for providing a pressure differential between said central space and the external space whereby said combustion products flow upward along said central space and impart heat by radiation to said first helically wound tubing and when they reach said dome member flow downward until they reach the open bottom end of said shell whereat the flow again goes upward and said combustion products contact said second helically wound tubing to impart heat thereto by direct contact therewith.

4. A heater comprising in combination a vertical refractory lined cylindrical wall defining a central space, a metal shell positioned in said central space concentrically to said cylindrical wall and extending from the region of the top end of said cylindrical wall to the region of the middle thereof, a dome closing the upper end of said metal shell, the inner concave side of said dome being lined with cementitious refractory material, said shell being spaced from said cylindrical wall to provide an annular flow passageway, a refractory lined floor closing the lower end of said cylindrical wall, centrally disposed burner means opening through said floor and adapted to project combustion products upwardly and axially along said central space, said combustion products adapted in their movement through said central space to flow upwardly until they contact said dome to thereby have their flow direction reversed downwardly until they pass the open lower end of said metal shell whereat a further flow reversal occurs and said combustion gases flow upwardly through said annular flow passageway, tubing coiled to a diameter to fit within said metal shell and adapted to conduct therethrough the medium to be heated, positioned

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concentrically within said metal shell and said cylindrical wall, said coiled tubing extending from the top region to the bottom region of said cylindrical wall and further coiled tubing also adapted to circulate the medium to be heated therethrough positioned in said flow passageway between said cylindrical wall and said shell.

5. A heater as defined in claim 4, in which at least one of said coiled tubing and said further coiled tubing comprises a plurality of nested parallel coils of substantially equal length.

6. A heater as defined in claim 4, in which each of said coiled tubing and said further coiled tubing comprises a plurality of nested parallel coils, the parallel coils of said coiled tubing being all of substantially the same length, and the parallel coils of said further coiled tubing being all of substantially the same length.

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7. A heater as defined in claim 4, in which said coiled tubing comprises a plurality of nested parallel coils of substantially equal length, said further coiled tubing comprises a like plurality of nested parallel coils of substantially equal length, and each nested coil of said coiled tubing is connected to a nested coil of said further coiled tubing to provide a plurality of identical flow paths for the medium to be heated.

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