

Dec. 27, 1966

J. W. NORRIS

3,294,082

SERPENTINE-TYPE HEAT EXCHANGE ASSEMBLY

Filed Aug. 19, 1964

4 Sheets-Sheet 1

Fig. 1
PRIOR ART

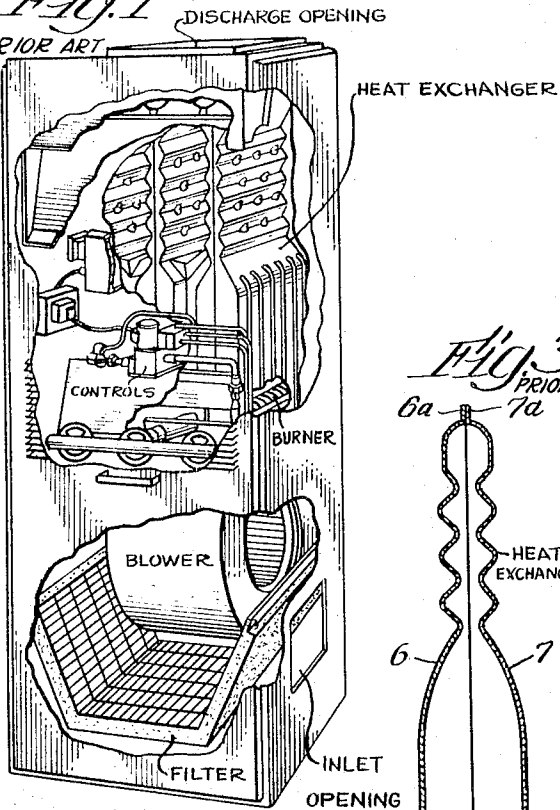


Fig. 3
PRIOR ART

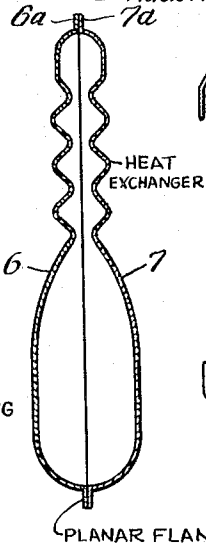


Fig. 2
PRIOR ART

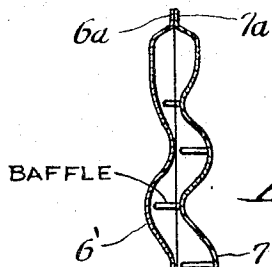
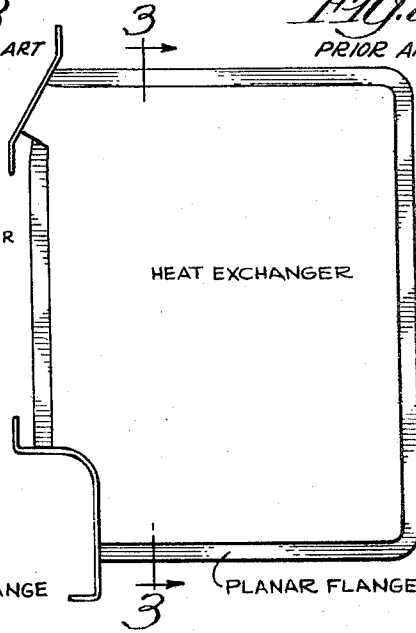
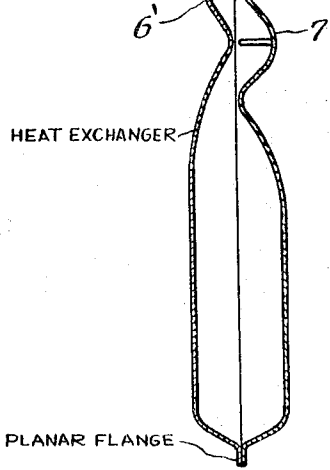


Fig. 4
PRIOR ART



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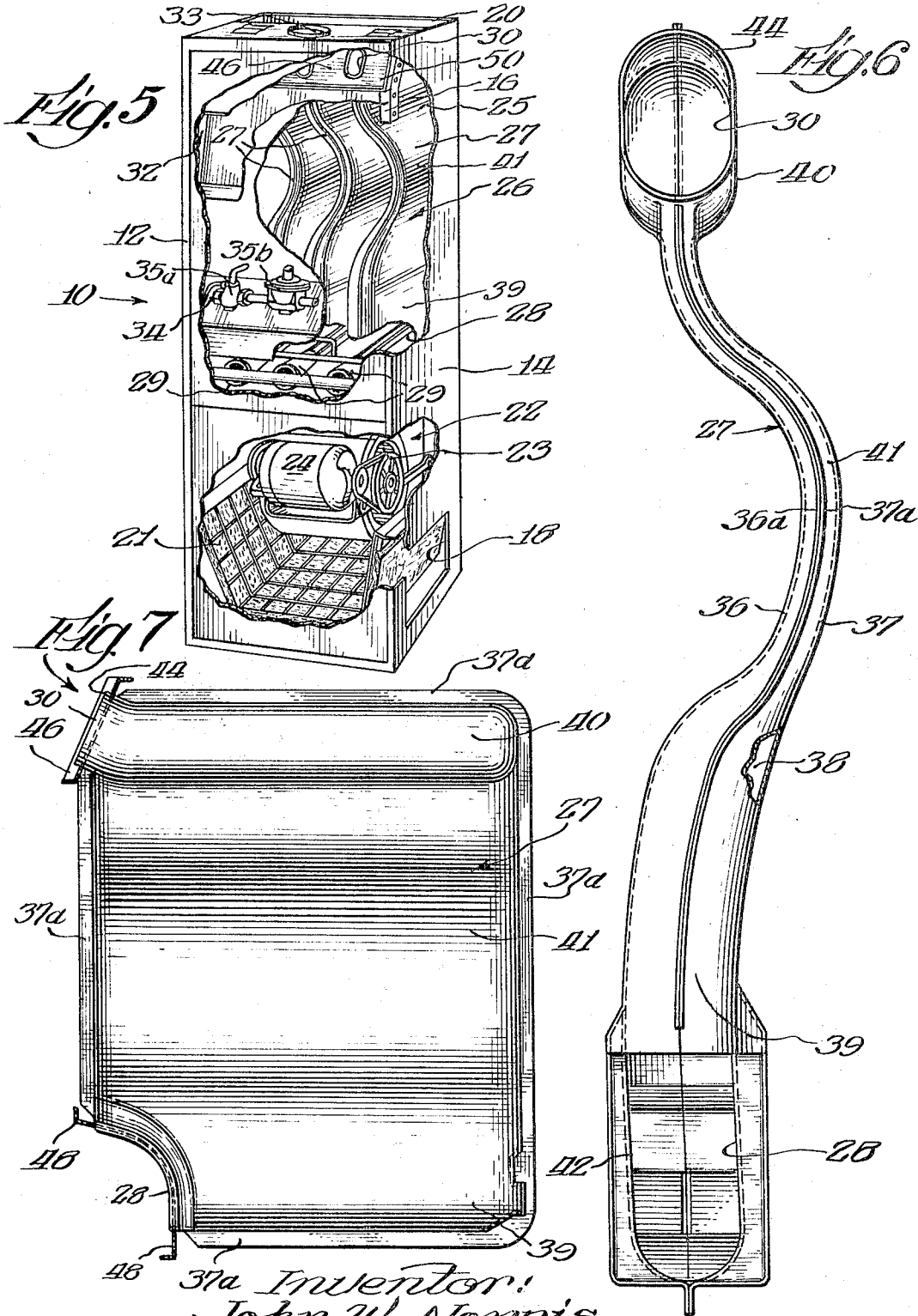
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SERPENTINE-TYPE HEAT EXCHANGE ASSEMBLY

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4 Sheets-Sheet 2



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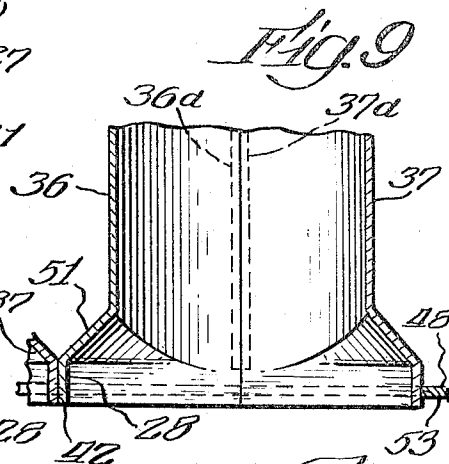
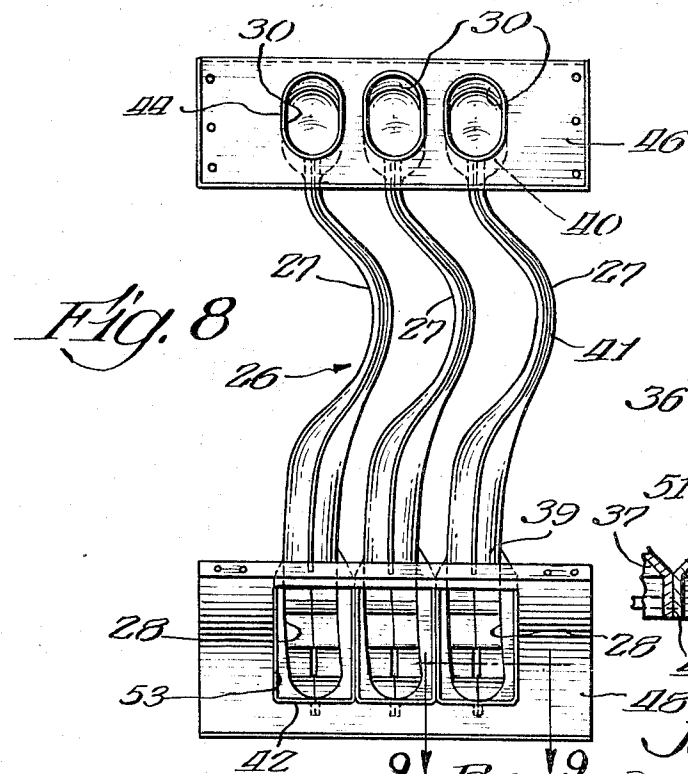
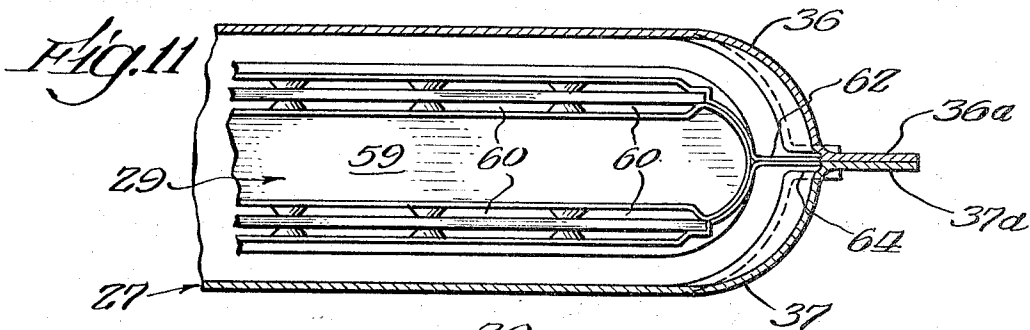
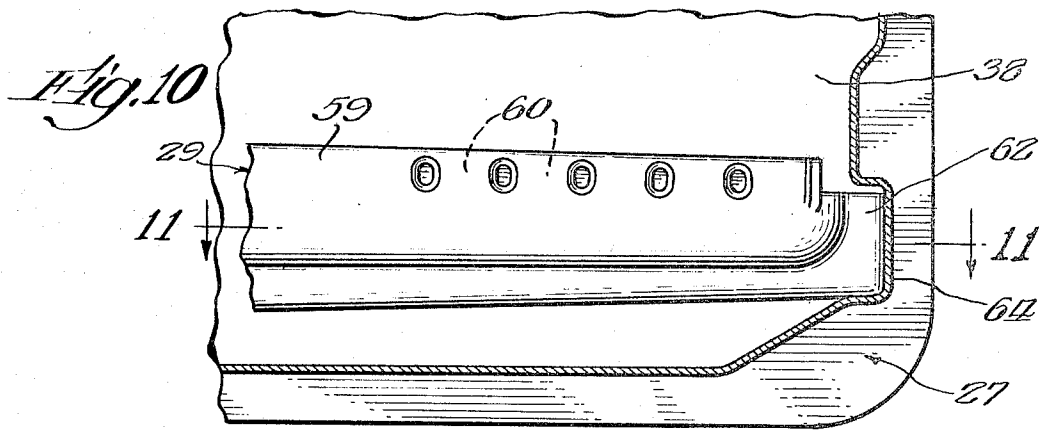
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SERPENTINE-TYPE HEAT EXCHANGE ASSEMBLY

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4 Sheets-Sheet 3



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SERPENTINE-TYPE HEAT EXCHANGE ASSEMBLY

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4 Sheets-Sheet 4

Fig. 14

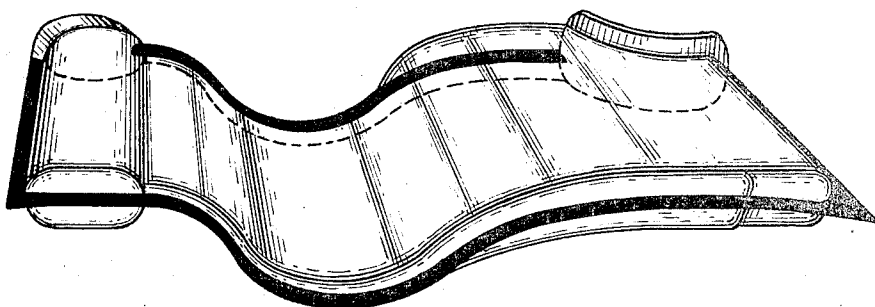
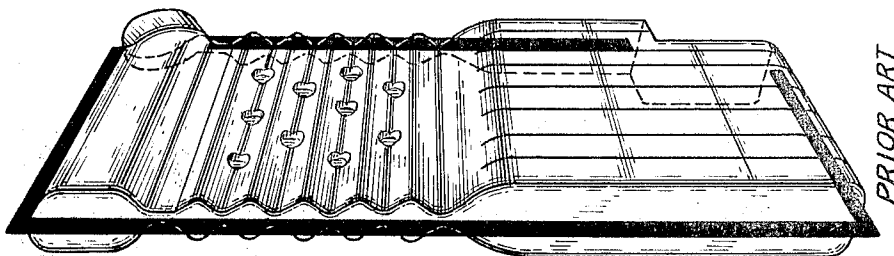
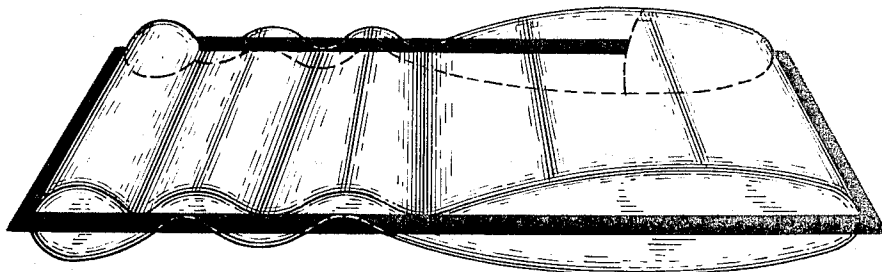


Fig. 13



PRIOR ART

Fig. 12



PRIOR ART

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3,294,082

SERPENTINE-TYPE HEAT EXCHANGE ASSEMBLY
John W. Norris, Marshalltown, Iowa, assignor to Lennox Industries Inc., a corporation of Iowa
Filed Aug. 19, 1964, Ser. No. 391,363
10 Claims. (Cl. 126—116)

This application is a continuation-in-part of my co-pending application, Serial No. 293,001, filed July 5, 1963 for Furnace Having Serpentine-Type Heat Exchanger, now abandoned.

This invention relates generally to gas-fired furnaces, and more particularly to an improved gas-fired furnace having a unique heat exchanger construction.

The purpose of a gas-fired furnace is to heat and circulate air. Conventional furnace structure is shown in FIGURES 1-4 of the attached drawing. FIGURE 1 shows a typical gas-fired furnace. A cabinet encloses an air filter, a blower or fan for circulating the air, a heat exchanger and controls. Burners inserted in the individual heating sections burn the fuel, which in turn heats the metal of the heat exchanger. Air from the blower circulates over the outside of the metal surfaces comprising the heat exchanger and this air picks up warmth from the hot metal. An opening or openings in the blower end of the unit cabinet allow air to enter. The discharge end of the cabinet is connected through a discharge opening to ducts that carry the heated air to the occupied space.

The heat exchangers most commonly used in gas-fired furnaces today, are of the "clamshell" type. Normally, each individual section will take a gas input somewhere in the range of 25,000 B.t.u./h. to 40,000 B.t.u./h. By putting multiples of these individual "clamshell" sections together in a cluster, furnaces of varying sizes can be achieved with one good set of tools for building the individual clamshell sections. In other words, one set of clamshell tools puts the manufacturer in a position to build a complete range of furnace sizes by putting as many of these individual sections in one cluster as he wishes.

In actual use, burners in gas furnaces are turned on and off frequently, as commanded by a room thermostat, in order to produce the amount of heat needed in the building. The gas fire in average gas furnaces is not modulated. Instead, the burners go from completely off to completely on at full maximum input. Modern room thermostats will cause the gas burner to stay on approximately three minutes at a time. It is then turned off and turned back on again when more heat is needed. With a demand for 50% of the maximum heat capacity, burners would normally be on for three minutes and then off for three minutes. This means ten complete cycles per hour. Normally these cycles will vary from six to fifteen per hour.

Each time the burner starts, the temperature of the metal in the heat exchanger will rise from approximately room temperature to 700° F. to 900° F. When the burner goes off, this heat exchanger metal rapidly cools back down to approximately room temperature. The temperature over the surface of the metal of the heat exchanger will vary from a maximum, usually near the center of the clamshell area, to a minimum around the perimeter or the outside edges of the clamshell.

When metal heats it expands. It is this cyclical operation of the typical gas burner that creates rapid metal expansion and contraction, five to fifteen times per hour, every hour of every day that a furnace is heating. This rapid and extreme expansion and contraction has caused clamshell-type gas furnaces of conventional design to fracture and crack open and has also caused internal ticking noises at the same time. It is these problems

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in the conventional clamshell gas furnace section that are obviated by my completely new clamshell heat exchanger of serpentine shape.

To understand why clamshell failure and ticking or creaking noises occur in conventional clams, one must understand how all of the conventional clamshell sections heretofore known have been made. It is only by understanding this that it will become clear that my new serpentine section shape is unique and does overcome the problems that have been very common throughout the gas furnace industry heretofore. FIGURES 2 and 3 show one conventional clamshell-type heat exchanger as made heretofore. Each individual section is made of two die-formed cup-shaped halves 6 and 7 with flanges 6a and 7a surrounding the perimeter of each half. The two halves are brought together and welded into one solid piece. In conventional clamshells, the joining flanges have always been flat and have been disposed in one plane. When welded, these flanges form a rigid, flat "picture frame" that surrounds the perimeter of the heating section. This rigid "picture frame" is in one flat plane. The heat exchanger configuration and the necessity for ties from side to side created by the vertical, rigid, flat, plane joint or center line are responsible for failures in conventional clamshell heat exchangers.

There are reasons why the welded joint between the two halves of conventional clamshells has always been flat. Each half is formed in a drawing die. In manufacture a flat sheet of steel is held around its perimeter under a hold-down ring on the drawing die. A punch moves through the hold-down ring and stretches the metal out into the cup shape that becomes a clamshell half. It is easier to make a drawing die with a flat (in one plane) hold-down ring than to make a hold-down ring that is curved or not in one flat plane. Frequently these clamshell sections are designed so that the right and lefthand members are identical except where the burners enter at the bottom in the front and the flue gas leaves at the top. One set of expensive drawing dies will then make both a right and lefthand member for testing, at least during the experimental and development period of the furnace. When two clamshell members or half sections with flat perimeter flanges are joined, it is simple to automate the welding process that joins these two members. With this flange joint in one plane, automatic welding can be used with simple and inexpensive welding fixtures.

While FIGURES 2 and 3 show the conventional type of clamshell section in general use throughout the gas furnace industry today, there have, in the past, been other attempts to build clamshell gas furnace sections, using flat center-line flanges for joining the two halves, but varying the shape of the right and lefthand sides in an effort to produce serpentine flow for gases up through the section. FIGURE 4, is an example of such construction. Again, the welded joint attaching flanges 6a and 7a of the left and right clamshell halves 6 and 7 is in one flat plane. To obtain the rigidity or strength required in the section shape to prevent serious distortion when heating and cooling, the sides of this type clamshell (FIGURE 4) are usually bulged out between two and three inches away from the center line and then curved back to the center line. When the flat center line flanges of these two members are joined, there does appear to be a serpentine shape for gas flow, but the space between the two halves at the minimum, is from two inches to three inches wide in clamshells of customary heating capacity. This is far too much spacing and too much area for proper control of the flow of combustion gases. This spacing is preferably as small as

$\frac{5}{16}$ " to $\frac{1}{2}$ " to retard and control the flow of combustion gases properly.

To accomplish desired flow control of combustion gases in a serpentine clamshell of the type shown in FIGURE 4, it was necessary to install horizontal baffles at each of the peaks and valleys of the serpentine shape. These baffles were expensive to insert. Further, the baffles reduced the efficiency of heat transmission and because they tended to divert the hot gases from rubbing properly against all heating surfaces. Also, there was a motion difference or movement between the baffles and the external clamshell heating surfaces which created strain and ticking noises. The reason for this motion difference was that the baffles were hotter, having hot gases on both sides, whereas the clamshell heating surfaces had cooler air on one side.

Furthermore, the heat exchanger shown in FIGURE 4 is rigidly surrounded by a flat (in one plane), rigid, welded steel "picture frame." Such frame confines the clamshell surfaces that it frames. These sections are not free to expand and contract with changes in temperature.

The bottom of each clamshell section contains a gas burner. Immediately above this burner, there must be an enlarged "combustion chamber section" to allow mixing of the air and gas to complete the combustion process. The gas flame should not impinge comparatively cool metal surface until the combustion process is complete. If the flame did impinge, some of the carbon monoxide in the initial combustion process would cool and escape without being completely burned to carbon dioxide. Once the combustion process is complete the area for passage of these hot combustion gases should be narrowed so as to produce good rubbing of the hot gases against the metal surface of the heating section. These narrowed gas passage also serve the second purpose of restricting and controlling the flow of combustion gases and the mix of air with the gas flame. If these passages are too large, too much air is drawn in with the fire which dilutes the combustion mix, reduces CO_2 and reduces the efficiency of combustion. If these gas passages are too small, inadequate air is drawn into the furnace for combustion which results in incomplete combustion with carbon monoxide (CO) which is not only inefficient but, of course, also dangerous.

Therefore, all gas clamshell sections must be constructed so that the restricted areas above the combustion zone maintains a fixed size whether the furnace is hot or cold. If these restricted gas passage areas change in size as the furnace heats and cools, control of combustion is lost and the furnace cannot maintain the efficiencies required for furnace approval by the American Gas Association.

Accordingly, in conventional clamshell sections, an effort must be made to prevent serious change in shape of the section as it heats and cools within the severe and drastic temperature changes from a low of about 70°F . or less to an average high of about 800°F . in the hottest spots. Stiffening ribs are therefore usually die-formed into the enlarged combustion area above the burner in order to minimize extreme shape changes. Since the conventional clamshell section is made with a flat (in one plane) center line, any bulging outward in the combustion zone will restrict the free area for air flow between the multiple clamshell sections. Further, because of the straight in-one-plane center line, any bulging or shape change in the combustion zone will be substantially the same on both the right and left halves: if the bulge is from the inside of the clamshell out, the area between clamshell sections for air flow is restricted; if the bulge is in toward the burners, the area for gas and combustion air flow is restricted and there is danger of flame impingement.

Within the intermediate portion of the clamshell above the combustion zone, it is essential to control shape very rigidly. Commonly, deep ribs in the metal are die-formed

from front to back in order to accomplish the needed rigidity. With this heavily-ribbed or deep drawn shape, however, the furnace designer cannot be sure of which way this portion of the clamshell is going to move when heating. Although some such portions will move out and some others will move in, there is common to all such shapes the strong tendency for motion. Because of this tendency for movement, all conventional gas furnace clamshell sections have been tied in some manner between the right and left sides in the intermediate portion thereof where the control of the flow of combustion gases is critically essential. Ordinarily, the clamshell halves are connected intermediate their ends by die-forming "dimples" in each half and then spot-welding or fastening the right and left members together at these dimples. Another method of fastening sometimes used is a metal spacer welded from side to side inside these clamshell members at the restricted gas flow control area.

These conventional clamshell sections all have a welded joint or frame that joins the right and left halves that is in one flat plane. It is rigid and vertical. The deep die-drawn or die-formed metal sections are heavily ribbed in restrain motion. The right and lefthand halves are then tied together to further restrain motion. The gas burner in the base of each section will increase the temperature of the metal in the heat exchanger about 700°F . in little more than one minute. The metal must expand. Its motion is restrained through the built-in rigidity in the section. Through the cyclical operation of the burners (on and off many times each hour), the metal is ultimately fatigued and it cracks. Examples in the gas furnace industry of these cracks and failures occurring after just one year of operation are very common. Furthermore, restraining and tying down these sections results in creaking and ticking noises in the metal section which are very objectionable, in residential use in particular. These internal stresses within the metal itself are responsible for these internal ticking and creaking noises.

In addition to these problems, the vertical in-one-plane center line of joint between the right and left halves of the clamshell, results in vertical motion between the burner entrance at the bottom of the clam and the flue gas outlet at the top of the clam every time the section heats and cools. This heating section must be tied into a surrounding cabinet. If the attachment, top and bottom, is rigid, the metal of the cabinet will be strained and oil canning and banging noises are the common result. In order to overcome this, with conventional clamshell sections, some manufacturers have used expensive padded, sliding attachments between the heating section and the cabinet in order to prevent the inevitable noises that come when one of these vertical straight center line conventional sections moves up and down as it heats and cools. It is common to find as much as $\frac{1}{16}$ " to $\frac{3}{32}$ " vertical motion between the bottom and top attachment points where the clamshell attaches to the furnace cabinet.

An object of this invention is to provide a gas-fired furnace with a unique heat exchanger configuration which is defined herein as "serpentine-type," and wherein the center line between the right and left halves of the heat exchanger section is not flat and in one rigid plane, but instead curves widely away from the plane extending through the burner section and gas gathering section of the heat exchanger section.

Another object of the present invention is to provide a furnace with a heat exchanger assembly of a new serpentine-type, wherein the intermediate portion between the combustion chamber and the flue gas chamber is offset from a plane passing through the two chambers and the entire intermediate portion is curved from top to bottom.

A further object of the present invention is to provide a furnace with a new serpentine-type heat exchanger assembly wherein the metal walls of each heat exchanger section can readily move in and out as they expand and contract with the thermal cycling of the burner, and thus

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avoid internal stresses in these metal walls because ties between the left and right walls are unnecessary.

Another object of this invention is to provide a new serpentine-type heat exchanger assembly adapted to be vertically disposed within the cabinet of a furnace, such heat exchanger assembly including a section having an intermediate portion offset from a vertical plane through such section, with the intermediate portion flexing to absorb the natural expansion and contraction of the section in use, without causing an appreciable change in internal shape. Combustion quality is controlled without having to tie the right and left sides or walls of the section.

Still another object of the present invention is to provide a unique serpentine-type heat exchanger, in which heat exchanger the gas passage above the combustion chamber in the heat exchanger is restricted so as to force the hot gases to reach a high velocity and remain at a high velocity until discharged through the top of each heat exchanger section, thereby increasing the heat transfer from the hot gas to the metal walls of each heat exchanger section. In this manner a higher output capacity with respect to the metal used in the heat exchanger assembly is achieved, thus providing a more efficient construction.

Another object of the present invention is to provide a new serpentine-type heat exchanger assembly constructed and arranged so that the walls in a heat exchanger section can readily move relative to one another in response to heating and cooling of the section without appreciable internal shape change, and without the necessity for ties between the sides, whereby internal stress and strain and the creaking or ticking noises resulting from such stress and strain, are substantially eliminated.

Another object of the present invention is to provide a novel serpentine-type heat exchanger construction comprising one or more serpentine-type sections which are manufactured relatively easily and are inexpensively affixed to one another to form a heat exchanger assembly.

Still another object of this invention is to provide a serpentine heat exchanger having at least one widely curved intermediate portion between the gas burner section and the flue gas gathering section thereof.

A further object of the present invention is to provide a new serpentine-type heat exchanger assembly for a gas furnace, which heat exchanger assembly may be rigidly affixed to the cabinet of the furnace only at the top and bottom thereof, the heat exchanger assembly being constructed and arranged so as to absorb the natural expansion and contraction that comes from temperature change.

Further objects and advantages of this invention will become apparent as the following description proceeds, and features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to and forming part of this specification.

A preferred embodiment of the invention is shown in the accompanying drawings in which:

FIGURE 1 is a perspective view with parts broken away of a conventional gas forced-air furnace;

FIGURE 2 is a side elevation of a conventional heat exchanger;

FIGURE 3 is a cross-sectional view taken generally along line 3—3 of FIGURE 2;

FIGURE 4 is a cross-sectional view of another conventional heat exchanger;

FIGURE 5 is a perspective view, with parts broken away for purposes of clarity, of a gas furnace embodying a heat exchanger assembly of the present invention;

FIGURE 6 is a front elevational view of a single heat exchanger section having a serpentine-type configuration in accordance with the present invention;

FIGURE 7 is a side elevational view of a heat exchanger assembly utilizing the serpentine-type sections of FIGURE 6;

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FIGURE 8 is a front elevational view of the heat exchanger assembly of FIGURE 7;

FIGURE 9 is a fragmentary cross-sectional view on an enlarged scale, taken generally along the line 9—9 of FIGURE 8, illustrating the connection of a heat exchanger section to the lower planar support member;

FIGURE 10 is a fragmentary detail view illustrating the assembly of a gas burner within a heat exchanger section of the assembly of FIGURES 7 to 9;

FIGURE 11 is a cross-sectional view taken generally along the line 11—11 of FIGURE 10;

FIGURE 12 is a rear perspective illustration of one form of clamshell heat exchanger, known heretofore, having a "picture-frame" flange;

FIGURE 13 is a rear perspective illustration of another form of clamshell heat exchanger, known heretofore, having a "picture-frame" flange; and

FIGURE 14 is a rear perspective illustration of my new serpentine heat exchanger clearly showing the widely curved intermediate portion and the widely curved side flanges.

Referring now more particularly to FIGURE 5 of the drawing, there is illustrated a gas furnace 10 having a cabinet or housing 12 defined by a plurality of wall members 14. The wall members are suitably supported on internal frame means 16, and the cabinet is provided at its one end with an inlet opening 18 and at its other end with an outlet opening 20. It will be understood that the inlet opening 18 is adapted to be communicated with the return air duct from a room being conditioned, and the outlet opening 20 is adapted to communicate with the supply duct to the room to be conditioned. Air drawn through the inlet opening 18 by conventional blower means 22 passes through a "hammock-type" filter 21, which may comprise a frame of wire mesh to which is affixed a filter material. Typically, the blower means 22 may comprise a squirrel-cage type of fan 23 operatively driven by a suitable electric motor 24. The blower means is supported within the cabinet 12 by means of a sulky mounting assembly of the type which includes a rigid steel frame floatingly mounted upon rubber cushion connectors.

Provided within the cabinet 12 is a passageway 25 within which the heat exchanger assembly 26 of the present invention is disposed. The heat exchanger assembly 26 is comprised of a plurality of novel heat exchanger sections 27 each formed in a serpentine configuration with the intermediate section between the top and bottom offset from a plane connecting the top and bottom portions of the heat exchanger assembly.

Defined in the top and bottom of each heat exchanger section are openings 28 and 30 respectively. An individual gas burner means 29 extends into each bottom opening 28 and each top opening 30 is adapted to communicate with a chamber 32 which is connected with a duct 33 for conducting the flue gases from the furnace.

Gas is supplied to each of a corresponding plurality of burner means 29 by a conduit 34, in which a suitable gas manual shut-off valve 35-a and a regulator 35-b are operatively connected. The furnace is also provided with the usual electrical controls, not shown.

Turning now to FIGURES 6, 7, 8 and 9, there is further illustrated the novel heat exchanger assembly of the present invention. Each heat exchanger section 27 is preferably formed from sheet metal wall members 36 and 37, which are primarily rolled to shape. I have found that internal stresses caused by conventional drawings and stretching operations is greatly reduced by rolling the sheets to form. The ends 36-a and 37-a of each wall member (see FIGURES 6 and 11) are offset in such a manner as to terminate at a mid point between the two wall members and to provide flanges for affixing the two wall members to one another, as for example, by a

single weld. If desired, a double weld construction may be used.

Defined within each heat exchanger section is a unitary chamber 38 having three parts: a lower combustion part 39, an upper flue gas collection part 40, and an intermediate part 41 communicating the combustion part 39 with the flue gas collection part 40. As is clearly seen in FIGURE 6, the center line between the right and lefthand halves of the clamshell section is not flat and in one rigid plane, but instead curves widely out away from the straight line drawn from the burner part 39 up to the gas gathering section 40 at the top of the finished clamshell. There are no flat (in-one-plane) portions or areas on any part of my serpentine heat exchanger. Every square inch is curved from bottom to top. From front to back, the metal is straight. Every part of both right and left halves is a section of a cylinder.

An important feature of this invention is that adjacent portions of the right and left surfaces of the heat exchanger section are essentially parallel. The center point of the circle that creates the "section of a cylinder" is on the same side of the center line of the completely assembled clamshell section for both the right and lefthand sides of this section. While the right and left sides are essentially parallel for a small extent, the right and left wall members gradually converge upwardly. The centers for the circles on the right and left halves of the section are located a little apart. These centers are always on the same side of the center line of the finished, welded together clamshell section.

If heat is applied to the center of a perfect metal cylinder, the metal expands. It always moves out from the center. The metal expands easily because there is nothing to restrain it. Likewise, if heat is applied to a section of this cylinder, as the metal expands it will always move out away from the center of curvature. By having the centers of curvature of both right and left halves on the same side of the center line of the completed section, the two halves or two sides (right and left) will always move in the same direction on heating. These two sides move together in unison and in harmony so that the internal distance between the right and left sides does not change appreciably. Thus, I am able with my serpentine heat exchanger construction to maintain proper area for control of gas flow through the heating and cooling cycles and to do it without any ties from side to side or any ribs or dimples or spacers whatsoever. In other words, in my construction, the surfaces are free to move in and out on heating and cooling without restraint of any type.

The wide curvature in the center line that joins the right and left halves is a very essential part of this construction. The combustion process is completed in the enlarged area 39 above the burner. Above the area 39, the spacing between the right and the left sides 36 and 37 is narrowed to approximately $\frac{3}{4}$ ". The spacing of the sides in this intermediate section further tapers or narrows down to $\frac{1}{2}$ " or a little less at the top where the gases spill into the flue gas gathering section 40 at the top of the clamshell. Internal width in the combustion zone is a little over 2". This comparatively narrow serpentine intermediate section is quite flexible even at the front and back where the flanges for the right and the left sides are joined. Besides providing complete flexibility, which means durability in gas furnace sections, this very narrow intermediate gas flow control area in my heating section provides more efficient heat transfer than found heretofore in conventional clamshell shapes.

There are sound reasons for this highly efficient use of metal heating surface. By reducing and restricting gas flow area above the combustion zone, hot gases are speeded up to achieve maximum heat transfer from hot gas to metal heating surface in this intermediate area. In addition to high gas velocity, there is also direction

change as the gases curve around through the serpentine section. When these individual sections are joined together into clusters of two or more sections for the completed furnace, the air that flows over the outside of the heated sections is also kept in intimate contact with all of the steel at all times. These curved sections nest together so there is direction change to the air flowing over the outside. This results in maximum heat transfer from gas to metal and from metal to air. Fewer square feet of metal surface will do more heating in this serpentine type of section.

Even in the enlarged combustion zone in the lower part of these serpentine sections, both right and left sides are sections of cylinders with the center of curvature for both sides on the same side of the center line of the finished and completed section. As these surfaces heat, they move together. Since the sides move in unison, a constant cross-sectional area is maintained in the heat exchanger above the gas burner so that combustion quality is controlled at all times. This movement of the sides in unison also maintains a constant free area between the multiple clamshells in a cluster so that there is no restriction to air flow through the furnace on heating or cooling.

Because of this construction, the natural desire for the metal to move on heating and cooling is not restrained in any way. There are no stiffening ribs. There are no dimples or spacers that tie right and left sides together. I maintain constant internal size in all parts of my new heat exchanger section. Excellent combustion and flow control of the hot combustion gases are maintained at all times. Maximum heat transfer is achieved with a minimum amount of metal. I maintain constant free area for air flow over the outside of these heating sections.

With this complete freedom to move as desired—with the direction always controlled and always known and the right and left sides always moving together—I have completely solved the industry-wide durability problem in the clamshell sectional type gas furnace. There is no restraint to the natural desire for this metal to move. There is no fatigue because there is no internal strain. There are no internal ticking and creaking expansion and contraction noises. If there were much desire for vertical motion between the burner inlet and the flue gas outlet, bottom and top, there would be enough flexibility in the wide curvature of the center line of this serpentine section to take up the desire for vertical motion. This makes it possible to attach the upper and lower portions of these sections to the furnace cabinet rigidly. There is no strain or oil canning in the cabinet. There is no noise. In my novel serpentine heat exchanger section there is about .004" up and down motion as compared with over $\frac{1}{16}$ " in the conventional vertical section that uses a flat picture frame center joint between halves that is in one plane. The growth in the metal in my serpentine heat exchanger section occurs laterally more than vertically, so it makes this serpentine heat exchanger section easy and inexpensive to mount within the furnace cabinet and still preserve complete quietness and durability.

The wall members converge toward one another between the chamber 39 and the chamber 40. This is for the purpose of increasing the velocity of the gases moving from combustion chamber 39 to collection chamber 40, as will become more apparent hereinafter.

The openings 28 and 30 in each heat exchanger section are defined by flanges 42 and 44, respectively, formed on the wall members 36 and 37. As is more clearly evident from FIGURES 7, 8 and 9, the flanges extend through suitable openings in the support plate members 46 and 48 and are connected to the plate members, as for example, by welding, to form a heat exchanger assembly 26. It will be understood that two or more heat exchanger sections may be affixed to the plate members

46 and 48, respectively, to form a unitary heat exchanger assembly, the number of heat exchanger sections being dependent upon the desired heating capacity.

As is indicated in FIGURE 5, the plate members 46 and 48 may be secured to the frame means 16 by suitable fastening means 50, as for example, sheet metal screws. By this construction the heat exchanger may be rigidly affixed to the frame means at the top and the bottom. The relatively great curvature of the intermediate section 41 functions as a "spring" to absorb the natural vertical expansion and contraction that results from temperature change. In this manner the need for an expensive glass fiber gasketing requiring in the conventional clamshell-type heat exchanger to allow sliding movement between the end of the heat exchanger and the opening therefor, so as to prevent gas leakage and minimize noise, has been obviated. In the furnace of the present invention, this costly and space-taking gasketing feature has been eliminated. Manufacture and assembly of the furnace have thus been greatly simplified.

Referring to FIGURE 9, it is seen that the flange 42 defining the bottom opening 28 is formed at the end of an outwardly tapering section 51. The flanges 42 on adjacent heat exchanger sections 27 about one another and are affixed to one another and to the edge defining the opening 53 within the plate member 48. Thus it will be seen that over the main part of the length of each heat exchanger assembly there is space provided between adjacent heat exchanger sections and air flowing upwardly over the heat exchanger assembly in the furnace illustrated may pass through the passageways defined between the heat exchanger sections as well as over the exterior walls of the sections of the heat exchanger assembly.

Considering now FIGURES 10 and 11, there is illustrated the connection of a gas burner 29 within a heat exchanger section 27. Each burner comprises an elongated body 59 having a plurality of openings 60 formed therein along the length thereof. The body 59 converges rearwardly at the end so as to define a support projection 62. The support projection 62 is adapted to extend into a socket 64 defined in the wall members 36 and 37 at the rear of each heat exchanger section 27. Thus, it will be apparent that each gas burner 29 is affixed at the forward end to the conduit supplying gas thereto and at the rear is carried in a socket 64 in each heat exchanger section 27.

In the event it is desired to increase the heating capacity of each heating section without unduly increasing the width of such section and also increasing cabinet size, the heat exchanger may be provided with more than one serpentine curve between the lower and upper portions of the heating section. The center line of each curve is offset to one side of a plane through the heat exchanger. Maximum heat exchange surface can therefore be provided without substantially increasing the size of the furnace cabinet.

Operation

The practical operation of the furnace will now be set forth so that the unique advantages and features of the structural arrangement heretofore described will be made more apparent. Upon actuation by the furnace controls in response to a demand for heating, gas will flow through conduit 24 to the burners 29 in each heat exchanger section 27 of the heat exchanger 26 and will be burned therein. The hot gases will pass upwardly from the combustion portion 39 of chamber 38 through the restricted passageway defined between the end of the combustion chamber and the beginning of the intermediate chamber 41. The velocity of the upwardly moving gas will be increased and will remain at the high velocity until discharged from the opening 30 at the top of the heat exchanger section 27 into flue gas collection chamber 32. The flue gases are discharged from the furnace through duct 33. There is an efficient transfer of heat

from the gases to the walls of the heat exchanger section resulting from the high velocity of the gas and the desirable contact or friction between the hot gases and the steel heating surfaces. Heat transfer from the gases to the metal wall members 36 and 37 is also enhanced by the change in direction of the gas flow in the intermediate portion 41 of the chamber 38.

The blower means 22 is actuated to draw air to be treated through the inlet opening 18, hammock filter 21, and over the heat exchanger assembly 26. The air passes over all sections of the heat exchanger and is warmed. The warmed air passes through the outlet openings 20 from the cabinet 12 into a supply duct to be carried to the room to be heated.

Now referring to FIGURES 12-14, I will summarize the differences between conventional clamshell heat exchangers and my serpentine-type heat exchanger presented here. Conventional clamshell sections, exemplified in FIGURES 12 and 13 each have a center line joint between right and left sides that is flat and in one plane. The enlarged combustion zone above the burner is either flat and ribbed (FIGURE 13) in an effort to prevent its bulging in or out on heating and cooling, or it is bulged out slightly from the center or burner and bulged out on both the right and the left sides (FIGURE 12). Upon heating, the cross sectional area above the burner changes and the free area between clamshell members changes. Above the burner in the intermediate portion (between bottom and top) where the flow of combustion gases must be controlled, the horizontal ribs can either be opposite as shown in FIGURE 13, or nested as shown in FIGURE 12. The rigid, flat picture frame that joins the right and left sides, confines the metal within this rigid, flat frame so that the sides are not free to move during heating and cooling. It is essential in all of these conventional shapes to create ties or baffles between right and left sides to control free area for control of the flow of combustion gases. Combustion zones have been ribbed in an effort to control shape in that area. Any internal baffles used within a clamshell section are a source of noise and strain. The baffle within the clamshell section has hot gas on both sides. The temperature of the baffle is much higher than heating surface metal temperature which has comparatively cool air on its outside. As a result of the difference in temperature, there is a difference in motion between the baffles and the walls of the clamshell section which can create strain and ticking noises.

The heat exchanger sections 27 of the present invention are each affixed to plate support members at the top and the bottom and are free to move with respect to one another intermediate the ends. Thus, the extreme curvature of the intermediate portion, which acts as a "spring" to absorb the natural vertical expansion and contraction that comes from temperature change, is free to perform its function. Although each heat exchanger section 27 is preferably made from a pair of wall members 36 and 37, it will be apparent that it may be fabricated from a plurality of wall members.

The wall members of each heat exchanger section are formed from sheet metal which has been primarily rolled to shape, and the internal stresses caused by forming the metal in dies is obviated. It has been ascertained that these internal stresses, due in part to the method of forming the small members and in part to the manner of connecting the wall members to one another, have been major contributing factors to damage and malfunction of conventional vertical type clamshell heating sections.

As the motion resulting from temperature change is in the same direction in both wall members of the heating section, the shape change that comes from heating will not materially alter the area of the passageway that must control the flow of combustion gases. Both sides move in and out together, thus maintaining efficient control of combustion under all temperature conditions without any cross ties or braces. Cross ties and support

braces are no longer required between adjacent sections of the heat exchanger assembly. Elimination of the cross ties or braces previously required in clamshell-type heat exchangers reduces the cost of fabrication, contributes materially to quieter operation of the unit by obviating the undesirable ticking noises which accompanied expansion and contraction of conventional type heat exchangers, and reduces stresses between adjacent heat exchanger sections and internal stresses within each heat exchanger section.

By the present invention there has been a recognition of the problems which contributed to failures of previous vertical, flat clamshell-type heat exchangers constructions. The present invention represents a departure from conventional thought and results in a novel serpentine-type heat exchanger assembly that may be readily mounted within conventional furnace cabinet structures. By reason of the serpentine shape of the heat exchanger, there is effected a more efficient heat transfer between the gases being burned within the heat exchanger and the metal walls of the heat exchanger. In addition, the efficiency of the furnace has been further increased by virtue of the change in direction of the air that flows over and about the curved intermediate sections of the heat exchanger assembly. Unlike conventional clamshell-type heat exchangers having a "picture-frame" type seam which lies in substantially a single plane and wherein the walls do not necessarily always move in the same direction, the walls defining the intermediate portion of the serpentine heat exchanger of this invention always move in the same direction laterally of a vertical plane through the serpentine heat exchanger, thereby making side to side ties unnecessary, and minimizing undesirable stresses in the heat exchanger, which tend to cause ticking and creaking noises and ultimately result in failure of the heat exchanger.

As aforementioned, the sides of the novel heat exchanger move in unison outwardly from the central plane of the heat exchanger and not upwardly or downwardly as in a conventional clamshell gas heating section. As a consequence, the serpentine heat exchanger can be welded to a solid support panel with no resulting strain or noise or cabinet "oil canning."

The present construction results in a furnace having a higher output capacity in ratio to the metal used in the heat exchanger assembly, thus resulting in a more efficient furnace design.

Although a preferred embodiment of the invention has been illustrated, wherein the conventional or normal upflow-type of flow through a furnace is provided, it will be understood by those having skill in the art that the heat exchanger assembly of the present invention may likewise be used in furnaces having horizontal air throughput or a downflow air throughput. As it will be obvious that various changes and modifications may be made in the invention without departing from the concepts thereof, it is intended in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What I claim is new and desire to secure by Letters Patent of the United States is:

1. A clamshell-type heat exchanger assembly comprising a plurality of heat exchanger units each including left and right sides of sheet metal each having spaced apart portions and perimetric flanged edges joined together to form a generally upright passage, said sides being elongated in depth and height, said passage including a lower combustion chamber longitudinally extended from front to rear along a first axis, an upper flue gas collection chamber longitudinally extended from front to rear along a second axis, and an intermediate chamber longitudinally extended from front to rear, the depth and height of the heat exchanger being relatively great with respect to the width thereof, the intermediate por-

tions of the sides defining the intermediate chamber being curved and the flanged edges of the intermediate portions being joined in a surface curved widely out away from a generally upright plane through the axis of the combustion chamber and the axis of the flue gas collection chamber, the heat exchanger units being adapted to be rigidly affixed in a furnace cabinet adjacent the tops and bottoms thereof, whereby the intermediate portions of the sides of each unit flex in the same direction in unison with respect to a respective plane in response to expansion and contraction to maintain substantially constant internal transverse cross-sectional areas in the intermediate chamber of each unit.

2. A clamshell-type heat exchanger assembly comprising a plurality of heat exchanger units each including left and right sheet metal wall members having perimetric flanged edges joined together to form a generally upright passage, said wall members comprising lower generally curved portions spaced apart to define a combustion chamber extending from front to rear, intermediate generally curved and substantially parallel wall portions defining an intermediate chamber extending from front to rear, and upper generally curved portions spaced apart to define a flue gas collection chamber extending from front to rear, the depth and height of each exchanger unit being relatively great with respect to the width thereof, the flanged edges of the intermediate wall portions being curved and being joined in a surface curved widely out away from a generally upright plane through the axis of the combustion chamber and the axis of the flue gas collection chamber, the intermediate wall portions being movable in the same direction in unison in response to expansion and contraction during heating and cooling thereof to maintain substantially constant transverse cross-sectional areas in the intermediate chamber for proper gas flow control, while at the same time allowing freedom of movement for expansion and contraction during heating and cooling, means connected to the top and to the bottom of each heat exchanger unit for supporting the units in side-by-side spaced-apart relationship, the intermediate wall portions being complementary so as to provide a direction change to air that is adapted to flow generally vertically over the heat exchanger assembly.

3. A clamshell-type heat exchanger assembly comprising a plurality of heat exchanger units each including left and right sheet metal wall members having perimetric flanged edges joined together to form a generally upright passage, said wall members comprising lower generally curved portions spaced apart to define a combustion chamber extending from front to rear, intermediate generally curved and substantially parallel wall portions defining an intermediate chamber extending from front to rear, and upper generally flat curved portions spaced apart to define a flue gas collection chamber extending from front to rear, the depth and height of each heat exchanger unit being relatively great with respect to the width thereof, the flanged edges being joined at the front and rear of each unit along a serpentine curved surface wherein the wall members defining the combustion chamber curve in one direction and the wall members defining the intermediate chamber curve in the opposite direction, the flanged edges of the intermediate wall portions being curved widely out away from a generally upright plane through the axis of the combustion chamber and the axis of the flue gas collection chamber, the intermediate wall portions being movable in unison with respect to said upright plane in response to expansion and contraction during heating and cooling thereof to maintain substantially constant transverse cross-sectional areas in the intermediate chamber, means connected to the top and to the bottom of each unit for supporting the units in side-by-side spaced-apart relationship, the intermediate wall portions being complementary and nesting together so as to provide a direction change to

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air that is adapted to flow generally vertically over the heat exchanger assembly.

4. A clamshell-type heat exchanger as in claim 2 wherein the wall members defining the intermediate chamber in each unit converge upwardly toward one another for maintaining high velocity of the gas flow through said intermediate chamber to promote heat transfer between the gas and the wall members.

5. A clamshell-type heat exchanger assembly as in claim 3 wherein the combustion chamber in each heat exchanger unit is wider than the intermediate chamber and the wall members defining the combustion chamber and the intermediate chamber converge between the combustion chamber and the intermediate chamber to increase the velocity of the gas burned in the combustion chamber after the combustion process is completed to promote efficient heat transfer between the gas and the wall members.

6. A clamshell-type heat exchanger as in claim 3 wherein each heat exchanger unit has a first front opening providing access to the combustion chamber and a second front opening providing access to the flue gas collection chamber, and means defining a socket in the wall members defining the combustion chamber and at the rear of the heat exchanger unit for receiving and supporting an end of a gas burner within said combustion chamber.

7. A clamshell-type heat exchanger assembly as in

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claim 3 wherein the wall members defining the combustion chamber and the intermediate chamber are formed as sections of a cylinder.

8. A clamshell-type heat exchanger assembly as in claim 2 wherein the left and right sheet metal wall members of each unit defining the combustion chamber and the intermediate chamber are formed as sections of cylinders and the centers of curvature for adjacent segments of both wall members are on the same side of said widely curved surface in a completed heat exchanger unit.

9. A clamshell-type heat exchanger assembly as in claim 3 wherein the flanged edges are joined by a single welded seam.

10. A clamshell-type heat exchanger assembly as in claim 2, wherein said wall members are primarily rolled to shape to minimize stretching of the wall members and are then welded at the edges to form said chambers.

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