

[54] HEAT EXCHANGER STRUCTURE FOR A COMPACT BOILER AND THE LIKE

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abandoned.

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165/181; 237/63; 237/66

[51] Int. Cl. **F22b 37/10**

[58] Field of Search 165/165, 180, 181, 164;
122/367 R, 367 PF, 356

[56] References Cited

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Salerno, Jr.

[57] ABSTRACT

Covers a boiling system which includes a heat exchanger comprising a plurality of substantially parallel conduits positioned between two substantially uniformly spaced boundaries, and a plurality of matrices each composed of a plurality of conductive bodies interposed between said spaced boundaries so that only one matrix is positioned between two adjacent parallel conduits. A first fluid, for example, heated gas, may impinge directly against each of the conduits and, at the same time, directly impinge against each of the matrices, while a second fluid, for example, water will pass through the parallel conduits and exchange heat with the first mentioned fluid.

23 Claims, 8 Drawing Figures

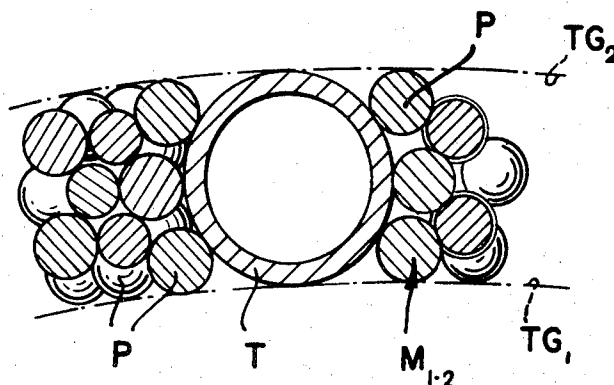


FIG. 1

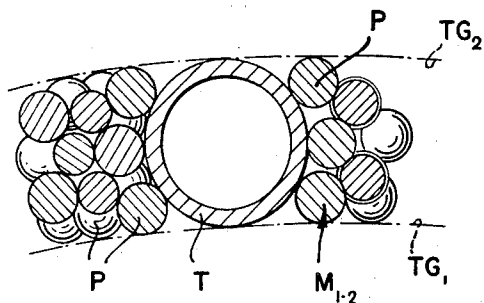


FIG. 2

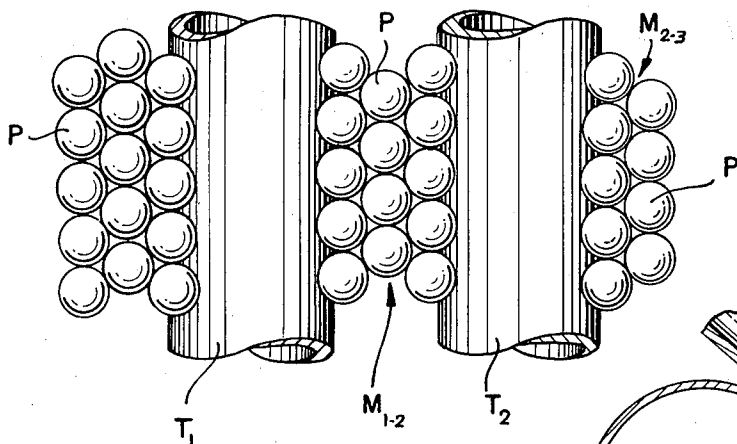


FIG. 3B

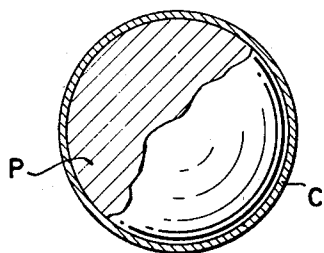
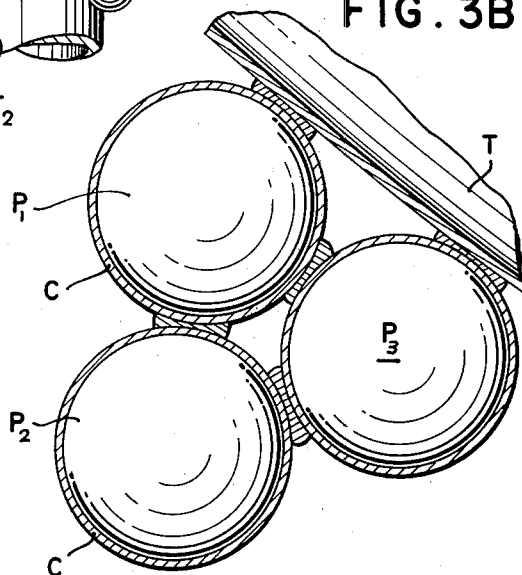


FIG. 3A

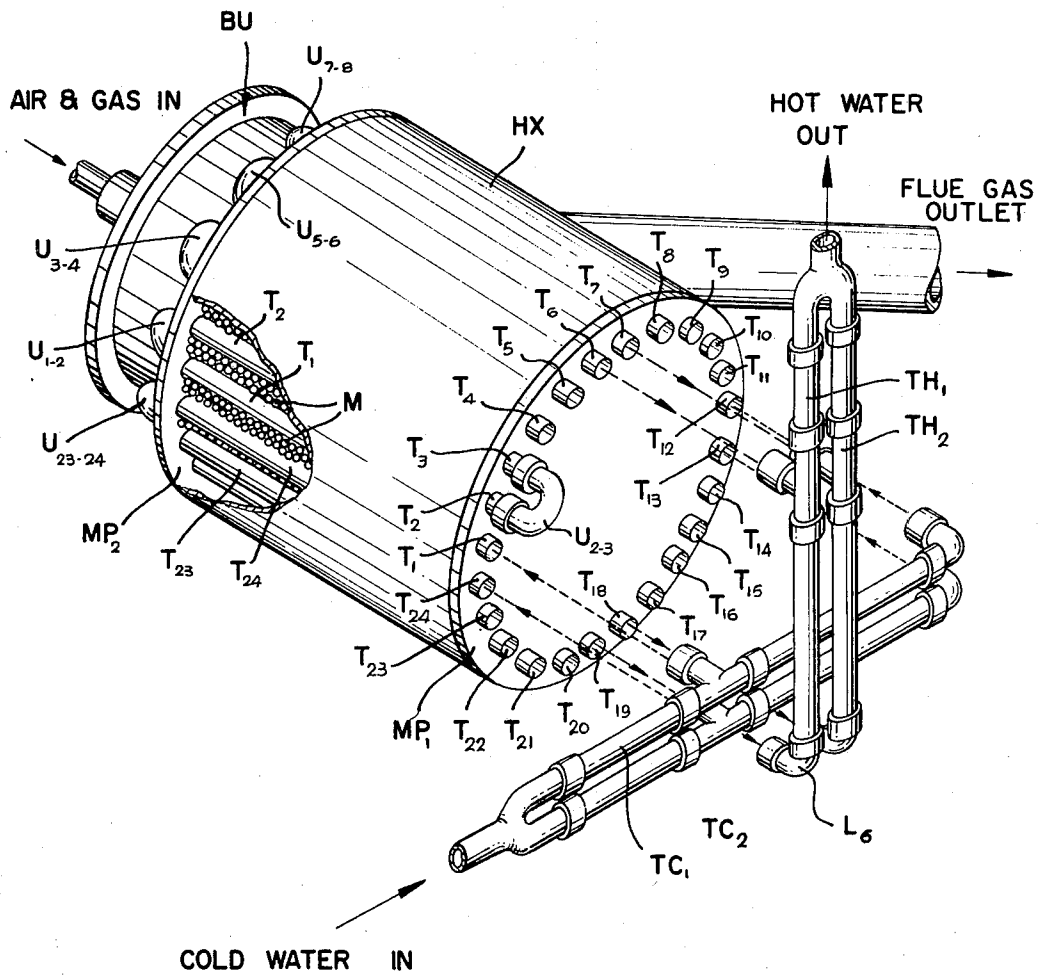
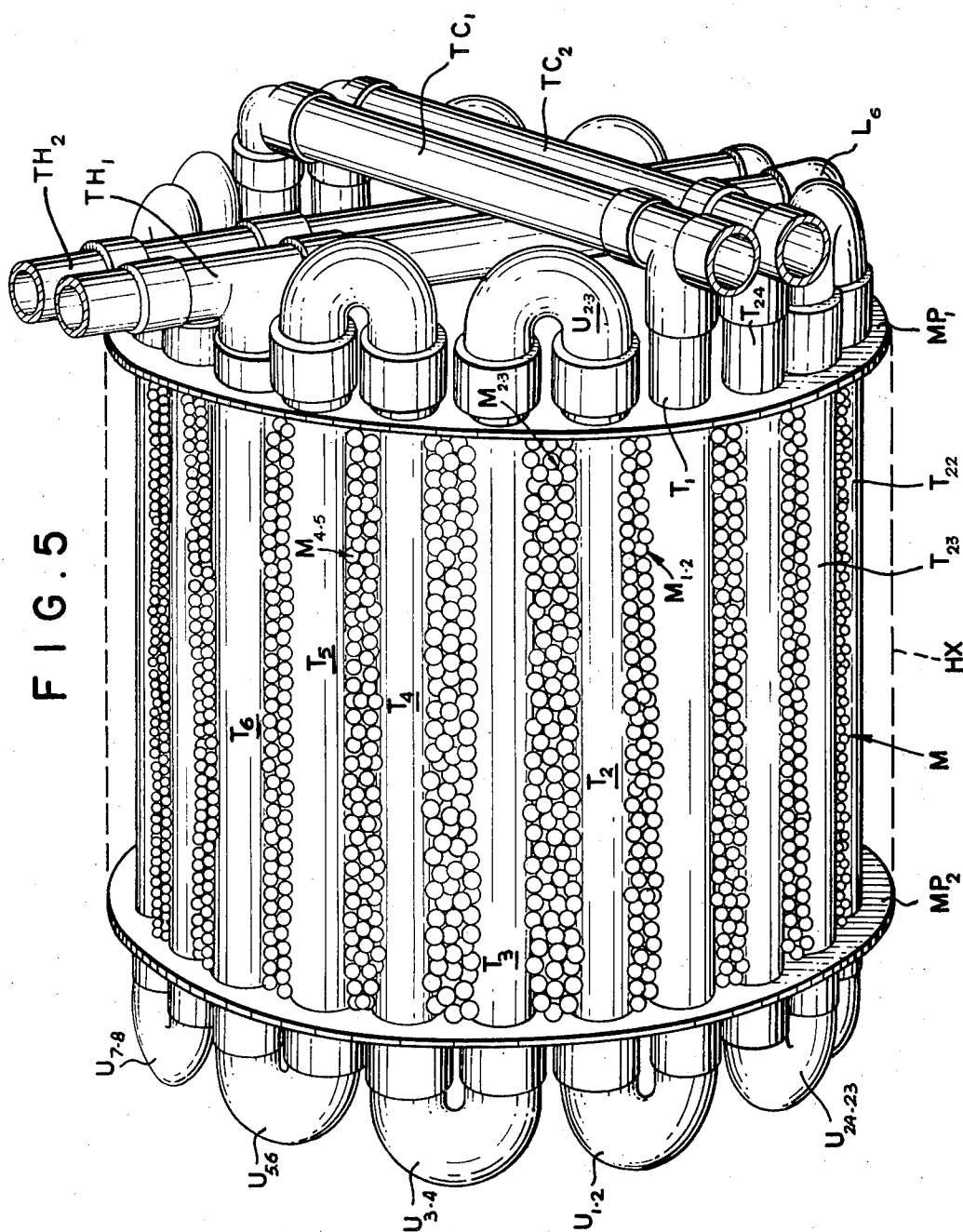
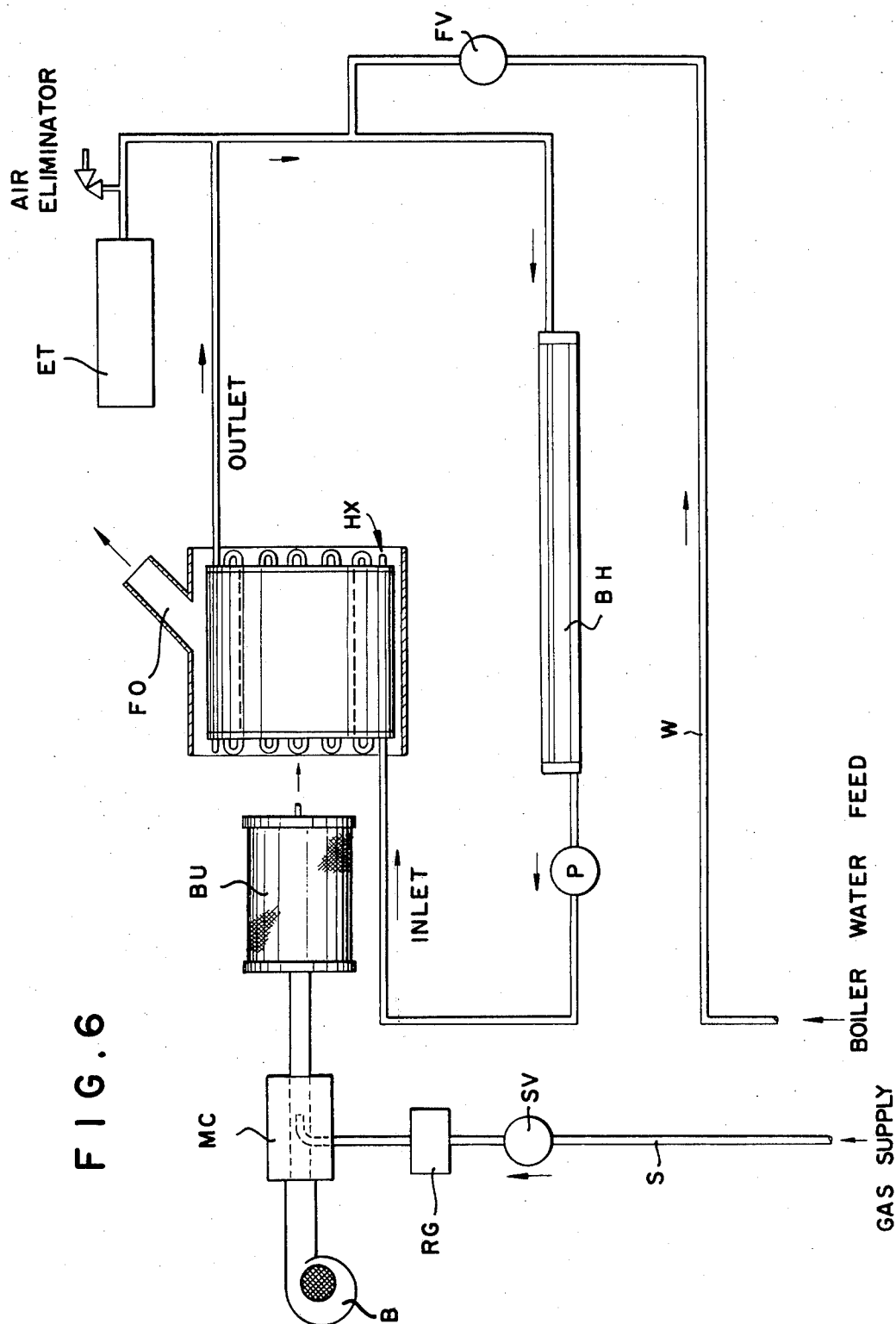


FIG. 4

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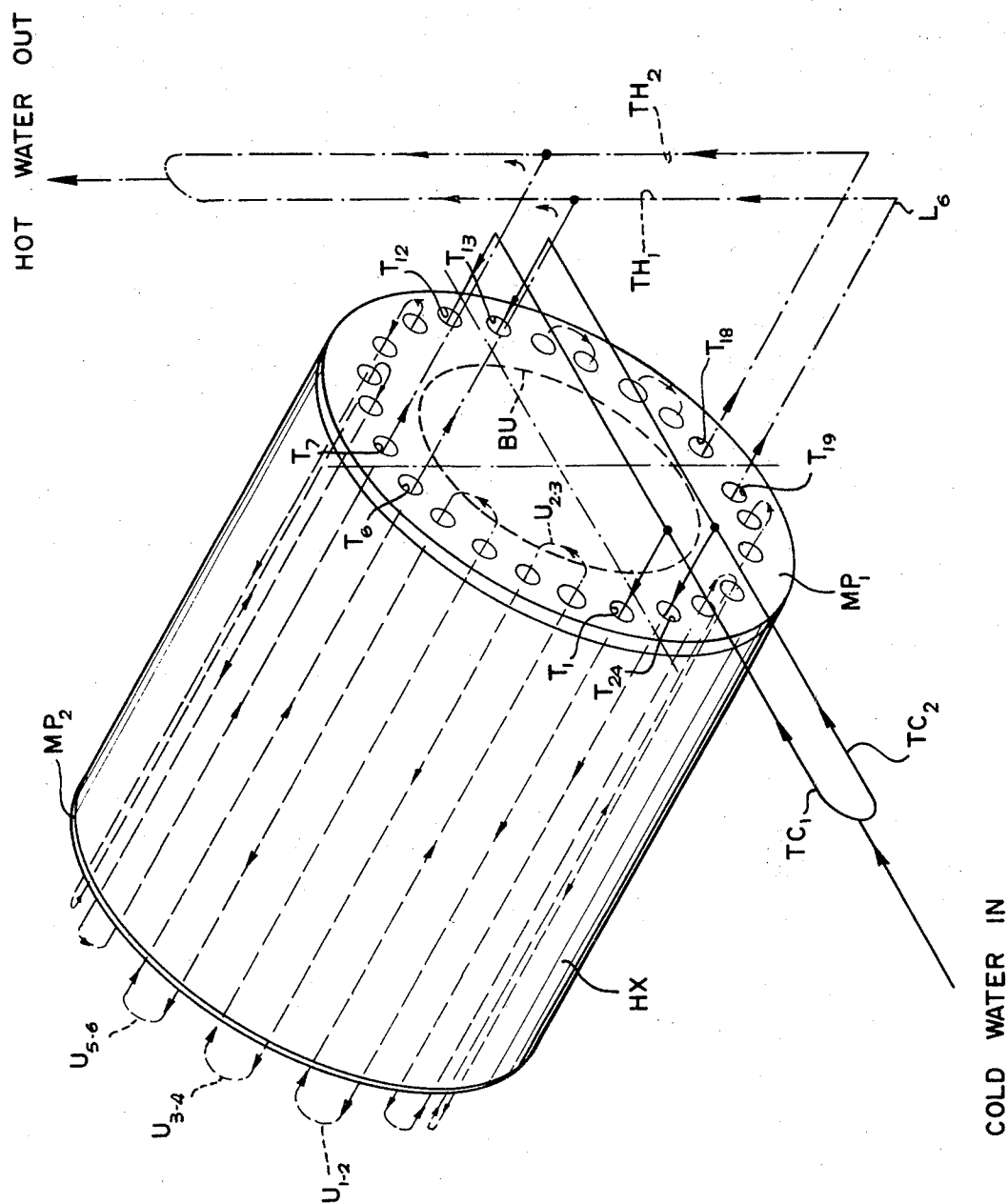


FIG. 7

HEAT EXCHANGER STRUCTURE FOR A COMPACT BOILER AND THE LIKE

This is a continuation, of application Ser. No. 16,202, filed Mar. 20, 1970, now abandoned.

The present invention relates generally to heat exchangers and, more particularly, to heat exchangers for boilers, water coolers, air conditioners, and other equipments for the transmission or reception of heat.

As is well known, a heat exchanger generally includes means whereby two fluids separated by a wall and having different temperatures are caused to transfer heat from one of the fluids to the other. A typical or conventional heat exchanger includes one or more pipes, tubes, or other conduits through which a fluid, such as water, flows and is intended to give up to or receive heat from a second fluid. Each such conduit may have, affixed to its outer surface, a plurality of fins, ribs, pins or other hardware usually provided on or near the outer surface thereof, so as to improve and increase the heat transfer capability of the conduit and thereby improve the relative efficiency of the heat transmission to or from the fluid flowing through the conduit.

Heat exchangers usually include, in addition to the conduit or conduits which carry a fluid, such as water, to be heated or to give up heat, a second or gaseous medium which may be derived from an adjacent burner or from a refrigerator or from any other source supplying the gaseous medium which is to flow around the conduit or conduits, so as to change the temperature of the fluid flowing through the conduits. A prior typical boiler, for example, having such a heat exchanger for use in a residential or commercial building, even a small residential building or an apartment of a large building, would be relatively so large and bulky that it would require considerable space to house and shelter the heat exchanger. The heat exchanger would also be so complex that it would usually require skilled manpower and considerable time to manufacture the structure and necessarily its cost would be relatively high. The efficiency of transmission of heat between a gaseous medium and a liquid medium in such a structure would be so poor that the cost of operation would be quite large. These are some of the adverse factors that suggest the serious problems facing industry generally in meeting the needs for low cost residential and commercial buildings requiring heat exchangers for boilers and other heating or cooling structures.

In accordance with the present invention, a new form of heat exchanger is provided, along with the necessary appurtenances required for building, for example, a boiler, the heat exchanger being suitable for a miniature type of boiler system, that is, a boiler structure much smaller than conventional boiler structures now made and sold for residential and commercial establishments. The heat exchanger structure, and the boiler systems of which it is a part, will be relatively easy to manufacture, small in size, light in weight, relatively free of serious or costly maintenance problems, and easily incorporated into small or miniature boiler systems, and, if desired, into larger boiler systems, whether for use in small individualized city apartments or in large or small residential or commercial buildings.

In general, the heat exchanger of this invention may include, for example, a unitary cylindrical structure comprising a plurality of circumferentially arranged parallel conduits through which fluid, such as water, may flow and, between the conduits, there will be a ma-

trix structure consisting of a plurality of separate and independent matrices each composed essentially of a plurality of pellets, preferably made of metal, integrally bonded to each other and to the side walls of the two adjacent conduits, so as to form the unitary substantially cylindrical structure. In the heat exchanger of this invention, no one of the matrices of pellets will be positioned on the lower surface, nor on the upper surface, of the several parallel circumferential conduits. In other words, none of the pellets will be positioned within the cylindrical tangential periphery defining the innermost points of the several parallel conduits, nor will any of the pellets of any matrix be positioned radially beyond the cylindrical surface defining the outermost points of the several parallel conduits. Thus, all of the pellets of all of the several matrices will be positioned between the two designated tangential cylindrical peripheries defining the uppermost and lowermost points of the several conduits. Hence, the heat exchanger will comprise a hour-glass-shaped matrix structure in which each of the several matrices will be positioned between two adjacent parallel conduits. Such a composite heat exchanger structure is easily and conveniently manufactured and assembled within a cylindrical casing for use in a boiler or other heat transfer apparatus.

In accordance with the present invention, a surface combustion burner, preferably a pressurized surface combustion burner, may be positioned within the central or axial space formed by the belt-shaped matrix structure above noted, which includes the several matrices and the corresponding interspersed parallel conduits, so that heat generated by the surface combustion burner may deliver heated gases, at relatively high temperatures and suitable pressure, directly against the inner or under surfaces of the several conduits and also, simultaneously, directly against the several matrices of pellets. Some of the gaseous heat from the burner, upon striking the undersurfaces of the several parallel conduits, will deliver heat efficiently to the fluid within the conduits. Some of the gaseous heat derived from the burner will, at the same time, be delivered to the undersurfaces of the several matrices of pellets, so that the pellets will be heated and the heat transmitted to the pellets will be conducted to the sidewalls of the parallel conduits for simultaneously heating the fluid flowing through the conduits. Moreover, the heated gases which are deflected from the undersurfaces of the several parallel conduits will necessarily traverse paths extending through the several matrices of pellets to further aid in raising the temperature of the pellets and of the fluid within the conduits. Thus, the heat of the gaseous combustion products from the burner will simultaneously and jointly attack the sides of the parallel conduits along several different fronts all cooperating to raise the temperature of the fluid flowing therethrough. The gases, after traversing the paths of the several matrices, may be discharged through a chimney or any other convenient adjacent outlet which need not have, and need not produce, a substantial draft.

The matrix structure above referred to, which may be composed of a plurality of independent matrices as indicated, each embodying a plurality of pellets bound to each other and to the parallel adjacent conduits, will form what may be described as a circularly cylindrical belt. The spacings of the pellets of each matrix are randomly arranged and do not require any predetermined

formation. The spacings between the pellets will render each matrix porous with respect to the heated gases supplied by the surface combustion burner, but notwithstanding these inherent spacings, the pellets will freely conduct heat from one pellet to another and then to the walls of the adjacent conduits and, therefore, to the fluid transmitted through the conduits. Because of the random spacings of the pellets and their relative sizes, the combustion gases may rather freely and efficiently traverse the various matrices so that a good and predetermined rate of gaseous transmission from the burner will be maintained through the circularly cylindrical belt structure. By means of this structure, a very high proportion of the heat within the generated combustion gases will be translated into heat in the fluid continuously flowing through the conduits to raise the temperature of the moving fluid to the desired temperature. The pellets of the several matrices will be fairly large so that only a few, and not too many, pellets will necessarily be interposed between the adjacent parallel conduits. The random spacings of the pellets will allow the free and efficient flow of the combustion gases through the matrix, thereby to dissipate heat to the several pellets which will conduct the heat to the walls of the adjacent conduits. The pellets are preferably constructed of the correct dimensions, that is, the correct range of diameters if the pellets are spheres, so that their random spacings will provide the porous and optically transparent linkage between the several conduits for the conduction of heat to the fluid in the conduits. No part of any matrix of pellets is positioned on the inner side of the inner cylindrical tangential surface of the parallel conduits. Nor is any part of any matrix of pellets positioned on the outside of the outer cylindrical tangential surface defining the parallel conduits. This results in a considerable saving not only in the number of pellets used, but also in the cost of the pellets and in the cost of the matrix. At the same time, the combustion gases make direct contact with the underside of the several parallel conduits so as to directly raise the temperature of the fluid traveling through the conduits.

Because of the spacings between the pellets of the matrix, the matrix will be porous to the heated gases supplied by the burner and porous also to any other rays which are necessarily generated by the gases burned by the pressurized burner. In other words, the spacings of the pellets yield the correct fluid velocities in the form of heated gases through the several matrices. Some paths through each matrix will be straight-line or uninterrupted so as to yield a desired low pressure loss.

Thus, as already suggested, the heated and pressured gases supplied by the surface combustion burner will directly and indirectly impinge upon the under-surfaces of the several parallel conduits so that a high proportion of the heat of the gaseous products of combustion will be supplied against the walls of the conduits for rapidly heating the fluid flowing through the conduits. As already also suggested, the heated gases reflected by the conduits must necessarily impinge upon the matrix of pellets and hence the reflected gases will conduct heat to the side walls of the conduits to contribute importantly to the heat supplied to the fluid within the conduit walls. A good part of the heated gases will also directly strike the matrix of pellets independently of the reflected heat, to further increase the supply of heat to

the fluid traversing the several parallel conduits. The several paths of the heated gases in supplying heat, directly or indirectly after reflection, to the fluid of the conduits, join together to quickly and efficiently raise the temperature of the fluid. This process is carried out quickly and, therefore, in a rather limited space.

This invention, together with its other objects and features, will be better and more clearly understood from the more detailed description and explanation hereinafter following when read in connection with the accompanying drawing, in which

FIG. 1 illustrates a cross-sectional view of an elemental segment of a form of matrix structure according to this invention, this figure illustrating a single conduit and parts of the two adjacent matrices of pellets;

FIG. 2 illustrates a fragmentary plan view of a portion of a matrix structure according to this invention, this illustration including two conduits together with the contiguous matrices;

FIG. 3A shows a cross-sectional view of one form of pellet which may be used in the practice of this invention together with a coating therefor;

FIG. 3B shows a cross-sectional view of a cluster of three pellets adjacent to part of a wall of a conduit;

FIG. 4 shows a perspective view of a heat exchanger according to this invention, this figure illustrating a surface combustion burner partly removed from the heat exchanger;

FIG. 5 shows another perspective view of a heat exchanger according to this invention, illustrating the inter-connected piping;

FIG. 6 shows a schematic diagram of a composite boiler system, including its heat exchanger, which is suitable for providing heat to an apartment or to a building; and

FIG. 7 schematically shows a diagram illustrating one form of conduit interconnection system for use in the heat exchanger of this invention.

Throughout the drawing, the same or similar reference characters will be employed to designate the same or similar parts wherever they occur.

Referring particularly to FIGS. 4 and 5 of the drawing for a general description of the layout of the heat exchanger of this invention, there are shown two annular supports or mounting plates designated MP1 and MP2 which may be parallel to each other and spaced from each other. Both plates MP1 and MP2 have a plurality of openings for receiving and supporting a plurality of parallel conduits T1 to T24 which may be, for example, conventional pipes of the same general diameter and of the same general length. In the illustration furnished for explanation, all of the 24 substantially parallel conduits T1 to T24 are shown positioned between, and perpendicular to, the two mounting plates MP1 and MP2. The parallel conduits T1 to T24 may be grouped into four sets of six conduits, T1 to T6, T7 to T12, T13 to T18, and T19 to T24 or in any other arrangements of series or parallel or series-parallel groups. All of the conduits may or may not be encased within a common housing HX as shown in FIG. 4. U-shaped couplers, to be presently described, may be employed to interconnect pairs of the conduits.

In FIG. 4, for example, cold water may be supplied to the two entrance conduits TC1 and TC2 and the cold water, after it has been heated by the heat exchanger HX, will be discharged from two discharge conduits TH1 and TH2 (see FIGS. 5 and 7).

The water supplied to the entrance conduit TC1 is fed simultaneously to two parallel conduits TC1 and TC 12, while the water supplied to the entrance conduit TC2 is supplied to two other parallel conduits T13 and T24. Conduit T1 is connected by a U-shaped coupler U12 to the next parallel adjacent conduit T2, while a similar U-shaped coupler U-23 interconnects parallel conduits T2 and T3. Likewise, another U-shaped coupler U-34 interconnects parallel conduits T3 and T4. Similarly, coupler U-45 interconnects conduits T4 and T5, while another coupler U-56 interconnects conduits T5 and T6. An elbow fitting L6 interconnects conduit T6 to discharge conduit TH1 through which the heated water will be discharged. Thus, the conduits T1 to T6, representing a quadrant of the parallel conduits of the heat exchanger HX, are interconnected to feed water received through the entrance conduit TC1 to the discharge conduit TH1, so that water flowing through the parallel conduits of this quadrant will receive heat furnished by the burning gases of the combustion burner BU to raise the temperature of the water to a desired thermal level to be discharged by the discharge conduit TH1. Similarly, another quadrant of parallel conduits T12 to T7 will be interconnected with each other in the heat exchanger HX and these conduits will allow the water flowing therethrough to be raised in temperature by the combustion gases furnished by the combustion burner BU. Similarly, the other quadrants of parallel conduits T13 to T18 and T19 to T24 are interconnected and these other quadrants serve to raise the temperature of the water entering the entrance conduit TC2 to a desired temperature, the heated water then being discharged by the discharge conduit TH2.

FIG. 7 schematically shows, in perspective, the four quadrants of parallel conduits interconnected between the two entrance conduits TC1 and TC2 and the two discharge conduits TH1 and TH2 for the first fluid. The fluid discharged by the latter conduits TH1 and TH2 is, as already explained, the water raised considerably in temperature by the heated gases which constitute the second fluid. The second fluid, supplied by the burner BU, is impacted directly and indirectly against all of the quadrants of parallel conduits above referred to and this second fluid must traverse the matrices of pellets of the heat exchanger HX.

As shown more clearly in FIGS. 5 and 6, the heat exchanger HX has an axial longitudinal cylindrical space for receiving a surface combustion burner BU. The burner may be partially or fully removed from the heat exchanger HX whenever desired by being slid axially out of the heat exchanger HX for repair or maintenance or replacement, and then returned to its normal position within the heat exchanger HX for normal operation. The burner BU has an opening axially positioned therein for receiving the gas to be ignited and the air to be mixed therewith in predetermined proportions so as to be properly ignited and burned by the burner BU for producing gaseous products at a relatively high temperature at the surface of the burner BU for heating the water circulated through the quadrants of parallel conduits of the heat exchanger HX. The efficient and predetermined mixture of air and gas, and the maintenance of the predetermined ratio of the two components, are important in preventing the formation of noxious components, such as carbon monoxide, which, if produced in appreciable volume, may be dangerous to persons in the building.

Now coming to the matrix construction of this invention, FIG. 3A shows one form of an elemental pellet P which may be used in the practice of this invention. The pellet may be coated by a layer of metal designated C. As shown here clearly in FIGS. 1 and 2, each conduit, such as T, has two matrices affixed to its opposite side walls. As is more clearly shown in the schematic drawing of FIG. 7, all of the conduits T1 to T24 are arranged circumferentially about the axial center of the heat exchanger HX and they are located between the two concentric tangential cylindrical peripheries or boundaries, namely, the inner tangential cylindrical periphery TG1 and the outer tangential cylindrical periphery TG2, as shown in FIG. 1. The overall matrix structure, which is composed of the plurality of separate and independent matrices M12, M23, M34, etc., is arranged so that each matrix, such as M23, is positioned between two adjacent conduits, such as T2 and T3. Thus, all of the matrices of pellets are positioned on what may be referred to as the sides or side walls of the parallel conduits T1 to T24 of the heat exchanger HX. No part of any matrix is positioned on the underside of the tangential cylindrical periphery TG1 (see FIGS. 1 and 5) nor on the outer side of the tangential cylindrical periphery TG2 which is further removed from the axis of the heat exchanger HX. No matrix of pellets completely surrounds any of the several parallel conduits in order that, in accordance with this invention, there will be free access for the heated combustion gases to the underside of the various parallel conduits. There is, therefore, a considerable and important saving in material and labor and costs by omitting pellets both from the underside of the several parallel conduits and from the outside of the several conduits.

The surface combustion burner BU is supplied with sparks or with a pilot light and produces combustion gases at, say, 2,000° to 2,500° F. and higher in the vicinity of the outer cylindrical surface of the combustion burner. The adiabatic flame temperature for natural gas burned with air is approximately 3,600° F. If natural gas is burned with oxygen, adiabatic flame temperatures approaching 6,000° F. may be attained. Under such conditions, higher heat fluxes can be obtained without any increase in the size of the equipment.

The outer surface of the heat exchanger HX is shown by a dotted line in the schematic drawing of FIG. 6. It may take the form of a porous woven fabric of a heat resistant fiber which may be cylindrical in shape and through which the gases are transmitted and ignited upon reaching close to the inner circumferential periphery TG1. The ignited gases are influenced by air pressure developed by appropriate blower equipment so that the flaming gases reach the under-surfaces of the several parallel conduits T1 to T24 of the heat exchanger HX. This direct contact with the under-surfaces of the conduits is a factor in the increased efficiency of the equipment. The burning gas also directly impinges upon, and necessary is passed through, the several matrices M12, M23, M34, etc. Very little, if any, of the combustion gases will impinge upon the outer walls of the parallel conduits T1 to T24 which are located on, or adjacent to, the outer cylindrical tangential periphery TG2 (see FIG. 1). In accordance with this invention, no pellets are positioned beyond the outer periphery TG2 because the combustion gases are relatively cooler in that region. The savings and im-

provements due to this significant omission are considerable.

By the proper choice of the size of the pellets with respect to the diameter of the conduits, a desirably tortuous path for the flow of the combustion gases is achieved without any excessive pressure loss through the matrices. By omitting pellets from all but the side-walls of the several conduits T1 to T24, the small number of pellets employed will reduce the weight of the structure, and the dimensions of the heat exchanger equipment will be relatively small.

In one embodiment of the heat exchanger HX of this invention, the various parallel conduits T1 to T24 were employed to transmit water to be heated. The conduits were made of steel and they had an outside diameter of five-eighths inch. The parallel conduits were spaced apart, having a spacing of about 1 inch between their centers. The pellets were steel balls having an outside diameter of approximately 0.174 inch and each was coated with copper. Although they were randomly arranged between the side walls of the various parallel conduits, the combination of the pellets of the matrices and the adjoining conduits were brazed to each other so that there was good thermal contact not only between the steel balls, but also between the steel balls and the several conduits to provide a belt-connected heat exchanger HX. The copper coating on each pellet was about 1/1000th of an inch in thickness. It will be understood that any desired pressure drop can be achieved in the heat exchanger merely by changing the diameter of the spherical pellet if a spherical pellet is used or by changing the spacing between the conduits, or both.

It will be apparent that the spaces between the pellets allow the flue gases of the burner BU to be deflected in their passage through the matrix. The spaces between the pellets, because of the size of the pellets, are sufficient to allow rays of light or luminous hot gases to be observed through the matrix. Lack of opacity is a feature of the matrix. Thus, linear openings permit the heated gases of the burner to move rather rapidly through the matrix to the chimney or to any other disposal point, thereby minimizing pressure loss commensurate with efficient heat transfer.

By brazing the composite structure of each matrix with the adjacent parallel conduits, a unitary mass is established for the heat exchanger HX exhibiting a thermal conductive property suitable for transferring heat efficiently from heated gases to the fluid carried through the parallel conduits. As shown in FIG. 3B, the brazing operation will cause the partly molten copper to be accumulated or collected at the points of contact of the several pellets and between the pellets and the adjacent conduits. The brazing operation can be performed in a container of dissociated ammonia, carbon dioxide or a vacuum or any other suitable atmosphere maintained at a suitable temperature for a sufficient time interval, after which the brazed product may be removed from the container.

Referring now to FIG. 6 of the drawing, there is shown a schematic diagram of the compact boiler system of this invention. Natural gas, for example, may be supplied through a conduit S which may be connected, through a solenoid valve SV and a gas regulator RG, to a mixing chamber MC. The mixing chamber MC is also connected independently to a blower BL which supplies air at a predetermined rate and at a predeter-

mined pressure into the mixing chamber MC. No venturi apparatus is required in the system. The gas supply pipe is equipped with a nozzle and pointed in the direction of the burner BL so that the emitted gas will be mixed with the air supplied by the blower BL and the ratio of the volume of gas to the volume of air is maintained constant. The arrangement for mixing air and gas, and for maintaining their proportions substantially constant regardless of variations in the pressure of the air supplied by the blower BL, is shown and described in a co-pending application of Thomas P. Konen, filed of even date, and assigned to the assignee of the present application.

The output of the mixing chamber MC is fed through a conduit MP to the input of the burner BU. The burner BU may be, for example, any form of surface combustion burner but it is preferably one of the type shown and described in a patent of W. J. Witten, U.S. Pat. 3,269,449, issued Aug. 30, 1966 and assigned to the assignee of this application.

The burner element of the surface combustion burner BU may, if desired, comprise a hollow cylindrical structure of a heat resistant porously woven fabric of heat resistant fibers, preferably of alumina ceramic and nichrome wire. This fabric may be about one-eighth inch thick and embody a weave density for dropping the pressure of the gas by about one-half inch or less of water for a gas-air flow velocity of about 20 cubic feet per minute per square foot of the burner surface. A suitable fabric for the burner surface is known as "Fiber-Frax" and is made and sold by the Carborundum Co. Such a fabric can withstand a temperature of about 2,000° F. continuously. Such a fabric is sufficient and appropriate even for the higher flame temperatures that may be produced, because of the cooling effect of the air supplied by the blower. The hollow cylinder of the fabric may be positioned within a corresponding cylinder of a wire mesh made, for example, of galvanized steel. The tubular structure of the burner may be supported and held rigid by a steel wire or by any other appropriate or well-known means.

As already noted, the burner BU is axially positioned within the heat exchanger HX which embodies the parallel conduits through which water flows, as already described. The inlet water received from a city water supply system, for example, and flowing through a conduit W, travels through a fill valve FV. The fill valve FV may be opened whenever desired in order to supply water to the boiler system initially or to supply water to replace water previously evaporated or leaked from the boiler system, as may be required. The boiler system includes a water loop which employs a pump circulator P, the parallel conduits T1 to T24 of the heat exchanger HX, and a baseboard heater BH, only one of which is shown in FIG. 6 for illustration. Naturally, any number of baseboard heaters may be connected in series or in parallel with each other if so desired. The pump P raises the pressure of the water supplied to the water loop and maintains the pressure at a substantially constant level. The same water may be recirculated through the loop which, as already noted, would include both the heat exchanger HX and the base board heater BH and this recirculation of water may continue over and over again.

It will be also noted that the water loop of the boiler system may be connected to an expansion tank ET and to a conventional air eliminator AL. The expansion

tank ET is intended to take up any change in the volume of the water necessarily resulting from changes in the temperature of the water. The air eliminator AL will remove any surplus of air or oxygen that may be developed or entrapped in the water line.

A miniature boiler system of the kind described above may be fed water of a temperature of about 150° F. and the water may be raised in temperature by the system to about 180° F. or to a higher temperature. The size of the miniature boiler may, for example, require gas capable of yielding about 100,000 BTU per hour. A desirable air-fuel weight ratio may be about 20 to 1. The stack temperature of the exhaust gas may be about 240° F. The carbon dioxide content of the exhaust gas may be no more than about 10 percent. The carbon monoxide content is virtually zero due to the combustion efficiency of the system. The matrix volume in the sample used was approximately 47 cubic inches and the weight of the pellets of each matrix was about 8 pounds. The matrix and the burner assembly together weighted under about 20 lbs. and was, therefore, easily transportable. The cylindrical heat exchanger sample had an approximate overall diameter of 8½ inches and a length of 6 inches. When packaged as a hydronic heating boiler, which included the heat exchanger, the pump, the controls and the accessories, the overall dimensions were 19 inches in width, 17 inches in depth and 14 inches in height. Smaller packages are readily designed and constructed.

For example, the pellets need not be spherical; they may be ellipsoids or any other regular or irregular shaped bodies, preferably made of metal, but plastic materials, preferably metallized, may also be employed, if desired. Furthermore, the spherical pellets may be replaced by metallic scraps or metallized plastic scraps or forms of saddles, etc. It is important, however, to have the matrix exhibit good porosity for the combustion gases and, in addition, some transparency to light and other rays that may be generated by the combustion gases. Furthermore, although the pellets have been described as made of steel and coated with copper, any other materials may suffice for the pellets and their coatings, if any. For example, the pellets may be made of aluminum, and the various pellets may be brazed to each other and to the adjacent conduits with a brazing material of copper, aluminum or any other metal so as to yield a unitary structure of relatively light weight. The term "pellet", as used in the claims, is intended to include these variants and others.

Although twenty-four parallel conduits have been shown in the illustrated heat exchanger of this invention, it will be apparent that any number of parallel conduits may be employed in the heat exchanger, whether in a circularly cylindrical assembly, or in a square or rectangular cylindrical assembly, or in any other form, but, in any case, a corresponding number of matrices of pellets of whatever shape may be brazed between the side walls of the various conduits to provide a belt-shaped structure. The combustion burner should be designed to match and coordinate with the axial space, whatever its shape, to provide a coordinated structure of minimal dimensions. A miniaturized assembly is one of the main features of this invention. Moreover, the conduits of the heat exchanger need not be arranged in quads. They may be interconnected to provide, if desired, a continuous unidirectional path for the fluid flowing through all of the various parallel con-

duits making up the heat exchanger, but any other circuitual connections, whether parallel or series-parallel, may be employed.

The temperatures above-noted which are developed by the structure in a typical installation and the fuel requirements of the burner may be changed as desired. The geometry of the conduits, the nature of the pellets and their random spacing, and the pressure of the combustion gases all contribute to determine the temperatures and pressure losses developed in the apparatus, but they may be adjusted to meet any predetermined or desired magnitudes.

It will be understood that, although the invention has been described in connection with the production of hot or heated water for illustrative purposes, it is readily adjustable for the production of steam, whether saturated or supersaturated, or for heating or changing the state of any fluid, whether gaseous or liquid. The heat exchanger HX may obviously be employed for cooling purposes, if so desired. Furthermore, as will be apparent from a reading of this specification, the fluids employed in the heat exchanger may, if desired, both be liquid or both be gaseous.

The dimensions of the several components above referred to in connection with an example for the practice of this invention were given merely for illustration and explanation and are not intended to be limitations upon the invention. Obviously, these values may be changed, as desired, to meet any conditions and to achieve any desired heat transfer relations between fluids. Obviously, the conduits and their dimensions are readily changed, either increased or decreased, to meet the exigencies of any particular problem in the practice of this invention.

While this invention has been shown and described in certain particular embodiments merely for illustration and explanation, it will be apparent that it may be organized in many different arrangements within the scope of this invention.

What is claimed is:

1. A boiler comprising a conduit network through which a first fluid is transmitted, a matrix of discrete conductive bodies which contact each other, said matrix being randomly dispersed between adjacent conduits forming said conduit network and contacting only part of the outer adjacent surfaces of said conduits forming said network, the bodies of said matrix providing tortuous light-transparent spacial paths therebetween through which a second fluid may pass, said matrix in the direction of flow of said second fluid having plural layers of said conductive bodies, said second fluid being applied directly against the outer wall of said conduit network and being indirectly applied against said outer wall through the spacial paths between the bodies of said matrix, and a burner which discharges the second fluid at an elevated temperature to transfer heat to the first fluid, whereby the second fluid will be applied substantially at the elevated temperature directly, and indirectly through the spacial paths of the matrix, against the outer wall of said conduit network.

2. A boiler according to claim 1 in which the conduit network comprises a plurality of conduits which are substantially parallel to each other in a cylindrical configuration and the burner is positioned to deliver the second fluid radially within the cylindrical configuration.

3. A boiler comprising a plurality of interconnected longitudinal conduits through which a first fluid is transmitted, a matrix structure of discrete conductive bodies which are randomly dispersed between said adjacent conduits and which contact each other to provide light-transparent paths in the spaces between said bodies, the bodies of said matrix structure contacting only parts of the outer walls of said adjacent conduits so that substantial segments of said outer walls are not in contact with any of said conductive bodies, a second fluid being applied directly against segments of the outer walls of said conduits and being indirectly applied against the outer walls of said conduits through the spaces between the bodies of the matrix structure, the spaces between the bodies of the matrix structure providing the paths through which the second fluid may be discharged, said matrix in the direction of flow of said second fluid having plural layers of said conductive bodies, and a burner discharging the second fluid above a predetermined temperature against segments of the outer walls of the conduits and against the matrix structure to transfer heat to the first fluid.

4. A boiler according to claim 3 in which the longitudinal conduits are arranged in a cylindrical pattern with the burner positioned within the inner wall of said cylindrical pattern.

5. A boiler comprising a heat exchanger in the form of a substantially hollow circularly cylindrical belt-shaped structure, said structure including a plurality of interconnected substantially parallel conduits transmitting a fluid to be heated, said conduits being linked to each other by a corresponding plurality of matrices of discrete pellets, each matrix being formed by randomly dispersed pellets separately interposed between the side walls of a different pair of adjacent parallel conduits, the pellets of each matrix being of such size and shape that, when joined to each other between the side walls of adjacent conduits, light rays will be optically transparent through said matrix, a surface combustion burner which feeds its combustion gases directly against the inner walls of the parallel conduits and directly against the matrices between said conduits so that the combustion gases directly impinge upon the walls of said conduits and directly impinge upon all of said matrices, said matrices in the direction of flow of said combustion gases having plural layers of said pellets, and an exit port for discharging said gases after they have passed through the spaces between the pellets and said matrices.

6. A boiler according to claim 5 in which the burner is located substantially coaxially within the inner wall of the circularly cylindrical belt-shaped structure, said burner feeding its heated gases substantially along radial paths directly contacting the inner walls of said parallel conduits and said matrices.

7. A boiler according to claim 5, including means associated with the burner for mixing air under pressure with gas to be burned to produce the mixture of heated gases to travel radially in paths directly contacting the parallel conduits and the matrices.

8. A boiler according to claim 7 in which the exit port is exterior to and distant from the belt-shaped structure for transmitting to the external atmosphere the discharged gases after they have traversed the matrices.

9. A boiler comprising a heat exchanger having a plurality of substantially parallel fluid-conveying conduits positioned between two substantially uniformly spaced

coaxial boundaries contiguous to said conduits and conveying fluid to be heated, a plurality of independent matrices each composed of a plurality of contacting randomly dispersed conductive bodies interposed between said coaxial boundaries and so arranged that a large section of each conduit is detached from all of said bodies of the matrices, said bodies of each matrix being of such size and shape as to provide light-transparent paths extending through each matrix through which the radiation of burning gases will be visible, each matrix coupling a small section of one conduit to a small section of another adjacent conduit so that said conduits are physically linked to each other and supported by the linkages, a surface combustion burner emitting gases as a heating fluid for impinging directly against the matrix-detached sections of each of said conduits and directly against each of said matrices, said matrices in the direction of flow of said combustion gases having plural layers of said conductive bodies, said burner feeding the heating fluid directly against detached sections of each of said conduits and directly against each of said matrices for elevating the temperature of the fluid to be heated as it is conveyed by said parallel conduits, whereby said matrices provide a medium of predetermined low pressure loss for the flow of the heating fluid.

10. A boiler according to claim 9 in which the parallel conduits are connected in series with each other so that the fluid to be heated will be exposed to the heating fluid emitted by the burner for a large time interval.

11. A boiler comprising a substantially cylindrical heat exchanger having a plurality of substantially parallel interconnected conduits spaced from each other and conveying fluid to be heated and positioned between two concentric cylindrical boundaries defining said parallel conduits, a corresponding plurality of matrices of randomly dispersed pellets which are bound to each other so that each matrix is interposed between two adjacent parallel conduits between said two concentric cylindrical boundaries so that large portions of the outer and inner walls of said conduits are detached from all of said matrices, a surface combustion burner positioned within the smaller of the two concentric cylindrical boundaries of the parallel conduits and discharging gaseous products of combustion directly impinging against the detached inner walls of said parallel conduits and directly impinging against said matrices to elevate the temperature of the fluid to be heated, said matrices in the direction of flow of said products of combustion having plural layers of said pellets, the pellets of each matrix being of such size and shape as to provide light-transparent, low pressure loss paths for the gaseous products traversing each matrix, said gaseous products being exhausted after passing through the matrices of pellets.

12. A boiler comprising a heat exchanger having a plurality of substantially parallel conduits transmitting therethrough a fluid to be heated, a corresponding plurality of matrices each composed of randomly dispersed discrete particulate bodies, the bodies of each matrix being brazed to each other so that there are spaces between said bodies to form light-transparent, low gas pressure paths and being brazed to the side walls of two of the substantially parallel conduits without being brazed to or otherwise contacting the front and rear walls of said parallel conduits, a surface combustion burner adjacent to the front walls of said paral-

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lel conduits and emitting gases to be impinged directly against the front walls of said conduits and also simultaneously directly against the front walls of said matrices, said matrices in the direction of flow of said combustion gas having plural layers of said particulate bodies, the gases emitted by the burner not impinging directly against the side walls of said conduits.

13. A boiler according to claim 12 including a common portal for discharging the gases after they have traversed the spaces between the particulate bodies of all of said matrices.

14. A boiler system comprising a surface combustion burner having a cylindrical porous surface member capable of continuously transmitting therethrough gases to be burned and transmitted in paths and capable of withstanding the heat generated by the continuously burning gases, a plurality of parallel fluid-conveying conduits together positioned concentrically about said porous surface member, a plurality of porous matrices corresponding in number to the number of parallel conduits and providing low gas pressure loss paths through said matrices, said paths being light-transparent, each matrix interconnecting the side walls between two adjacent conduits but leaving the remaining portions of said walls of said conduits adjoining said cylindrical porous surface member uncovered by any of said matrices, each matrix being composed of a plurality of randomly dispersed particulate bodies which are brazed to each other and to the interconnected side walls of the adjacent conduits, said matrices in the direction of flow of said burned gases having plural layers of said particulate bodies whereby gases burned by said burner will impinge against the uncovered portions of said walls of said conduits exposed to said porous surface member and will impinge also against said matrices.

15. A boiler system according to claim 14, in which each matrix is composed of a plurality of spherical pellets of steel each coated with copper.

16. A boiler system according to claim 14, including a blower, a source of combustible gas, and means for supplying to the combustion burner a mixture of air and gas in predetermined proportions at a predetermined pressure and for maintaining the proportions substantially constant.

17. A boiler system according to claim 16, including

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a utilization structure coupled to the parallel fluid-conveying conduits for receiving and responding to the heated fluids derived from the boiler system.

18. A boiler system according to claim 16, including means to maintain the proportions of air and gas substantially constant notwithstanding changes in the pressure developed by the blower.

19. A boiler system comprising a belt-shaped cylindrical heat exchanger having a plurality of longitudinal conduits which are connected in series with each other for transmitting a first fluid, a plurality of light-transparent matrices equal in number to said parallel conduits, each matrix being formed of randomly dispersed particulate bodies which are porous to a second fluid and being interposed only between the side walls of two adjacent conduits, means including a burner for transmitting heated gases radially to said heat exchanger so that the said second fluid in the form of heated gases will impinge directly against the undersides of said matrices and traverse the matrices with a substantially constant but relatively low loss of pressure and said matrices in the direction of flow of said combustion gases having plural layers of said particulate bodies.

20. A boiler according to claim 19 in which the burner includes a porous surface structure coaxial with the axis of said heat exchanger and producing and transmitting heated gases as a second fluid in all radial directions simultaneously against the undersides of said conduits and said matrices so as to elevate the temperature of the first fluid.

21. A boiler system according to claim 19, including means including a blower and a source of combustible gas for supplying to the combustion burner a mixture of air and gas in predetermined proportions and for maintaining the proportions substantially constant.

22. A boiler system according to claim 21, including a utilization structure coupled to the parallel fluid-conveying conduits for responding to the heated fluids flowing through said structure.

23. A boiler system according to claim 21, including means to maintain the proportions of air and gas substantially constant notwithstanding changes in the pressure developed by the blower.

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