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2,169,601

HEATING SYSTEM

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Fig. 1.

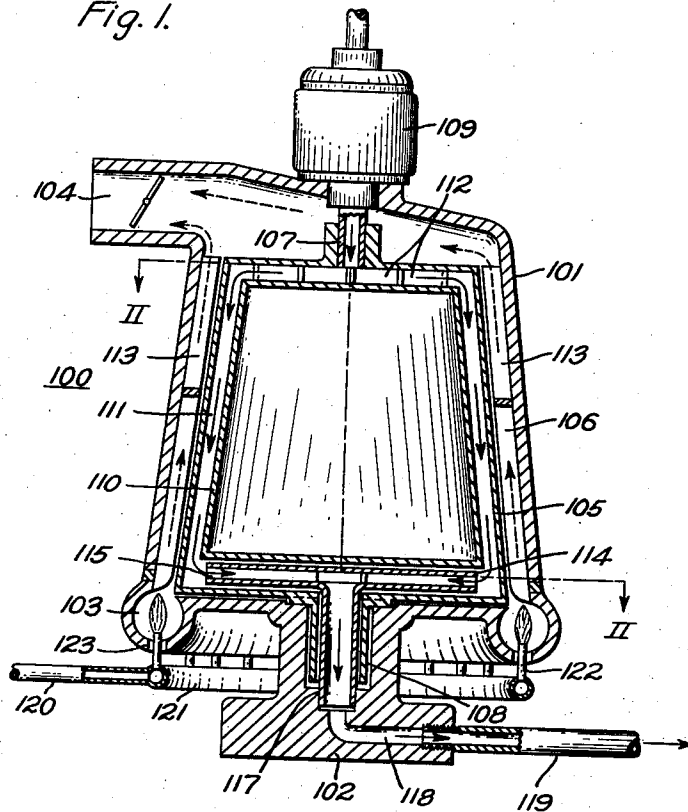
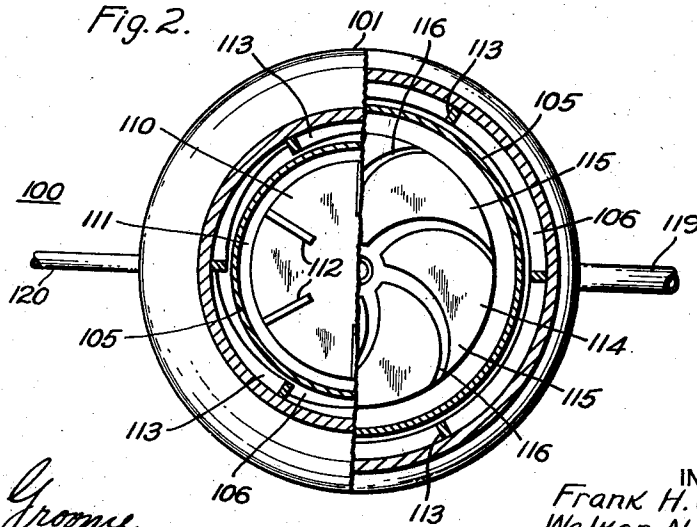


Fig. 2.



WITNESS

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HEATING SYSTEM

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Our invention relates to heating systems and it has particular relation to specialized apparatus for this purpose.

One object of our invention is to provide an improved method of and apparatus for heat exchange through a surface between fluid media.

Another object of our invention is to provide a method of transferring energy from one stream of fluid medium to another which comprises the steps of transferring heat therebetween through an intervening conducting wall and adding an increment of mechanical energy to at least one of said streams during the flow thereof on opposite sides of said wall.

A further object of our invention is to provide in a heat exchanger an inherent characteristic of producing a usable increment of mechanical energy as a by-product of the heat exchange proper.

Another object of our invention is to provide a heat exchanger wherein a high relative velocity of heat transferring media with respect to a heat-transferring surface is obtained in large part by means of moving said heat-transferring surface.

A further object of our invention is to provide a heat exchanger in which the velocity of flow of one or both fluids through said exchanger is a relatively small component of the total relative velocity of the fluids with respect to the heat-transferring surface.

Another object of our invention is to provide a heat exchanger of such character as to produce pressure that will cause one or both of the media to flow through circulatory systems external to the exchanger.

A further object of our invention is to produce a surface heat exchanger having extremely small temperature gradients across the paths of the heat-transferring media.

Another object of our invention relates to a water or other liquid heating system in which the temperature difference between different points in the liquid is utilized in producing mechanical energy, a portion of said mechanical energy being expended to produce circulation within the system.

Other objects of our invention will become evident from the following detailed description, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a view, mainly in longitudinal section, of a heat exchanger constructed in accordance with the principles of our present invention; and

Fig. 2 is a view, in transverse section, taken along the line II—II of Fig. 1.

Referring to Fig. 1 of the drawing, the structure there shown comprises a heat exchanger 100 adapted for the transfer of heat between fluid media, having an outer shell or casing 101 which may be of frusto-conical shape, with a suitable base or support 102, the lower part of said casing forming a toroidal space or envelope 103 and the upper part forming a laterally-projecting exhaust outlet 104. A rotating drum 105 which may be of frusto-conical shape, located within and spaced from casing 101 so as to form an annular passage 106 leading from space 103 to outlet 104, is supported at its upper and lower ends by hollow shafts 107 and 108, respectively, shaft 108 having a suitable bearing in base 102 and shaft 107 projecting through and having suitable bearings in an electric motor or other driving means 109, or being otherwise suitably coupled thereto. A second drum 110 which may be of frusto-conical shape located within and spaced on all sides by a passage or space 111 from drum 105, rotates with drum 105 by reason of being attached thereto by means of impeller blades 112 at its top.

A plurality of helical baffles 113 located within the annular space 106 are suitably affixed to casing 101 and project radially toward drum 105 terminating at a short distance therefrom as required for working clearance. A stationary hollow member 114 having curved blades or guide vanes 115, with passages 116 therebetween, positioned in the space between the lower ends of the rotating drums 105 and 110 is supported by a stationary hollow shaft 117, which projects through the hollow shaft 108 and is secured in base 102 communicating with passage 118 therein and discharge pipe 119 therefrom.

One of the most common applications for such a heat exchanger lies in the transfer of heat from the products of combustion to a liquid medium. For such an application the toroidal space 103 may serve as a combustion chamber for gaseous fuel supplied by a pipe 120, burner manifold 121 and burner tips 122, the latter projecting into space 103, air for combustion entering through holes 123 through which the tips project. Such application is not limited to the use of gaseous fuels, but can obviously be adapted to the use of any desired fuel.

In operation the moving drums 105 and 110 are rapidly rotated by motor 109, causing the outer surface of drum 105 to have a high relative velocity with respect to the casing 101 and helical baffles 113. Products of combustion or

other heated media flow, as indicated by the dotted arrows, from the annular space 103 upward in annular space 106, which is divided into a plurality of helical passages by the baffles 113, the latter being so pitched that the products of combustion follow, in general, the direction of rotation of the drum. The friction between the products of combustion and the rapidly moving surface of drum 105 tends to cause said products of combustion to rotate with the drum. By virtue of the small clearance between the baffles 113 and the drum 105 the only appreciable mass rotation possible for the products of combustion is that accomplished in traversing the helical passages. The friction between the moving surface and the products of combustion thus exerts a positive force driving the latter in the desired direction. A further result of this friction is violent eddies in the gases within the passages. The availability of this positive driving force on the products of combustion permits the annular space 106 to be very shallow which, in turn, reduces the temperature difference across the gas passage.

After flowing through the passages 106 the gases pass out the discharge port 104 which may be connected with a suitable discharge pipe or stack.

A second medium, such as a liquid, to which heat is being transferred through the wall of the drum 105 from a medium such as the products of combustion in the passage 106, may be introduced into the annular space 111 between the drums 105 and 110 by means of the hollow shaft 107, where it is acted upon by the impeller blades 112, receiving therefrom a rotary motion causing it to flow rapidly outward, as indicated by the solid arrows, from the axis to the periphery of the drums and through the annular space 111, flowing thence into the space containing stationary member 114 where it is acted upon by stationary blades 115 causing it to flow back toward the axis of rotation, and out through hollow shaft 118 and discharge pipe 119 to the place of application.

Obviously, a medium such as liquid could be caused to flow through the device in the manner described by means of an external source of hydrostatic pressure or by gravity without the use of impeller blades 112, stationary member 114 and blades 115; however, since many applications of such a heat-transferring apparatus cause it to be associated with an external circulatory system through which the liquid must be forced against the resistance thereof, it is desirable, from the standpoint of economy and simplicity, to have incorporated within the heat-transferring device means for producing the pressure head required to overcome the resistance of said circulating system. We find a heat exchanger of the type herein described is remarkably well fitted to serve this secondary purpose of producing such pressure.

Considering the liquid medium in the space between drums 105 and 110 adjacent to the periphery of stationary member 114 we find that by suitable proportionment in the design of the various parts of the rotating members and appropriate design of said stationary member, the medium can be made to arrive at this point with any desired degree of rotational velocity up to the full velocity of the drums. Since the liquid can thus be brought to this point having any desired degree of kinetic energy due to its rotation, suitable means such as stationary member

kinetic energy into hydrostatic pressure of the medium.

A fluid rotating adjacent to the periphery of stationary member 114 and at the same time approaching said periphery will strike the extremity of blades 115 and be deflected into the passages 116 between said blades of the member 114, the entrant velocity being approximately equal to the linear velocity of rotation just prior to entry. By suitable proportionment of the passages within member 114, the entrant velocity may be progressively decreased with the attendant conversion of the decrement of velocity energy into hydrostatic pressure as the fluid traverses the member, such pressure being available at the discharge outlet 119.

In order more clearly to explain the nature of the flow of the liquid up to its entry into the stationary member 114, let it be assumed that the impeller blades 112 are omitted from the structure or in some manner made inactive, also that the earth's gravitational force is inactive with respect to the fluid. If then a quantity of the fluid is caused to enter drum 105 through shaft 107 there will be no forces acting to cause the fluid to flow outward and downward between the drums except the centrifugal force due to rotation of the fluid. The fluid upon entering the drum may be considered as having no rotational velocity and there will be on that account a high relative velocity of the rotating surfaces with respect to the mass of the liquid. Contact with the rotating surfaces will impart to the liquid in unit time a certain degree of rotation depending upon the viscosity of the liquid and the proportions of the passage.

As soon as the liquid begins to rotate, the centrifugal force due to such rotation will cause it to move outwardly from the axis of rotation. This action will carry the liquid into zones of constantly increasing surface velocity. The linear velocity of rotation of the liquid is thus continuously accelerated by virtue of the relative velocity existing between the liquid and moving surfaces, reaching a maximum at the periphery of the stationary member 114. However, so long as the liquid is moving away from the axis of rotation, its linear velocity of rotation cannot attain the linear velocity of rotation of the contiguous surfaces.

It, therefore, follows that the flow of the liquid within the apparatus does not depend on outside forces such as gravity or hydrostatic pressure.

It has been found in the transfer of heat between gaseous and liquid media through a surface that the chief limitations lie upon the gaseous side rather than the liquid side of the surface. While the rate of heat transfer is improved by having a high relative velocity between the liquid and the surface, it is not necessary or desirable to have the extremely high order of relative velocity that is desirable between the surface and the gas. We find that the total relative velocity between the liquid and the surface which is the vectorial sum of the relative velocity due to rotational slippage, and the relative velocity between the liquid and the surface arising from the progress of the liquid in an axial direction as it passes through the apparatus, is of a very high order when the apparatus is operating without impeller blades 112. For that reason it is advantageous to make use of impeller blades 112 which increase the rotational velocity of the liquid and reduce the rotational slippage, thus delivering the liquid with a higher degree of kinetic

energy to be converted into hydrostatic pressure by the stationary member 114.

At a given angular velocity the degree of rotational slippage at the smaller or top radius of the drum 105 is governed by the design of the impeller blades 112, and the rotational slippage of the fluid as it progresses along the drums is governed by the width of the passage 111, the rate of change of the drum diameter, the viscosity of the liquid and the volume of liquid flowing through the apparatus in unit time. It is then possible to produce any desired total relative velocity between the liquid and the surface, within very wide limits, by suitable proportionment of the first four of these controlling factors; viscosity of the liquid, of course is incapable of arbitrary adjustment.

The friction between a surface and a fluid moving relative thereto is associated in such a way with heat transfer that an increase in frictional resistance due to increased velocity will increase the rate of heat transfer, other things being equal. Thus, the power or mechanical energy that is consumed in overcoming frictional resistance between the heat-transferring surface and a fluid moving relatively thereto is useful in improving the rate of heat transfer. But the power of energy consumed in imparting velocity energy to a fluid to cause it to flow along a stationary surface is of no value in improving heat transfer and is to that end wasted, or at best may be only partially recovered by means of additional costly apparatus.

Further, the frictional resistance due to the high relative velocity existing between surface and fluid is useful in our invention as a means of adding an increment of mechanical, that is pressure and/or velocity, energy to the fluid stream.

The desirability of heat transfer between streams of fluid moving in counterflow relation is well known in the art. The method and apparatus comprising our invention effects such counterflow heat exchange. It will be noted that, while the actual motion of the one stream of fluid with respect to the other stream of fluid is rather in the nature of cross-flow than counterflow, still there is substantially no temperature gradient in an angular direction about the axis of rotation in either stream, and the maximum of temperature gradient in either stream exists in a plane containing the axis of rotation and in a direction parallel to the heat transfer surface; this is the condition of counterflow heat exchange.

A further desirable feature of our apparatus lies in the fact that it is suited to the use of fluid passages that are narrow or shallow in a direction normal to the heat exchange surface. By virtue of the fact that a fluid is transferring heat with a surface, there exists in the fluid a temperature gradient in a direction normal to the surface. The magnitude of the gradient, in addition to depending on the thermal conductivity of the fluid, also depends on factors which will bring remote parts of the fluid close to the surface. There is in our apparatus a considerable degree of agitation in the fluids due to high relative velocities with respect to the surface which constantly brings new portions of the fluids into contact with the surface. There is also operating a positive force which selectively acts to bring those parts of the fluid most differing in temperature from the surface into contact with the surface; this force is

centrifugal force. Considering that heat is being transferred from the outer to the inner medium, those parts of the inner medium most remote from the surface are cooler and more dense than those parts immediately next the surface; being more dense, the cooler parts are caused by centrifugal force to displace the warmer parts at the surface. The reverse condition existing upon the side of the outer medium causes parts of the fluid cooled at the surface to move away from the surface to be replaced by warmer parts. All of these factors operate to make the said temperature gradient across the fluid passages a minimum. In view of this small temperature gradient, the fact of narrow passages makes possible an extremely small total temperature difference across the passages. Such small temperature difference materially reduces the overall temperature head required to secure a given heat transfer, other factors being equal; or, stated in other words, it permits the use of a smaller heat exchange surface for a given overall temperature difference and a given heat load.

One notable feature of such a novel heat exchanger is that by virtue of the high frequency and short period of contact between any fluid particle and the surface, it can be used as a direct fired apparatus for heating liquids that are easily damaged by heat, as for example milk, fruit juices, or other liquids containing animal or vegetable matter.

Another extensive field of application for the direct fired form of apparatus with its means for producing positive liquid pressures, lies in its use as a heating boiler for hot water or similar systems of heating buildings or the like where both the small physical size of the apparatus as compared with stationary equipment and the assurance of rapid and positive circulation of the liquid through piping systems are of especial value.

While the apparatus has been shown as a direct fired heat exchanger having means for positively moving the products of combustion and means for creating considerable hydrostatic pressure in a liquid which is being heated, it will be appreciated that this is only one of many possible modifications of our system of heat exchange.

While we have shown and described one embodiment of our invention, we do not wish to be limited to the particular structural details thereof, since modifications may be made without departing from the spirit and scope of our invention. We desire, therefore, that only such limitations shall be imposed thereon as are indicated in the appended claims.

We claim as our invention:

1. In a heat exchanger for the transfer of heat, a wall of heat conducting material in the form of a surface of revolution adapted to be disposed between streams of fluid mediums, a stationary wall spaced from said surface, a plurality of baffles secured to the stationary wall and extending to a point adjacent said surface, said baffles being curved at an angle to the axis of rotation of said surface of revolution and in the general direction of rotation thereof whereby the rotation of said surface cooperates with said baffles to produce a high relative velocity in a stream of fluid positioned between the stationary wall and said surface.

2. In a heat exchanger for the transfer of heat, a wall of heat conducting material in the form

of a surface of revolution adapted to be disposed between streams of fluid mediums, means including stationary baffle means for effecting relative rotation of said wall and one of said streams to secure a high relative velocity of said last-named stream with respect to said wall, a second wall spaced from said first named wall, said baffle means being supported from said second wall and being curved at an angle to the axis of rotation of said surface of revolution and in the general direction of rotation thereof, and means for effecting a counter-current flow between streams of fluid positioned on opposite sides of said wall.

3. In a heat exchanger for the transfer of heat between streams of fluid mediums, three closely spaced walls, the intermediate wall being of heat-conducting material, two of said walls being rotatable and formed as surfaces of revolution, said streams adapted to flow on opposite sides of said intermediate wall and being confined by the respective other walls, means for simultaneously moving said intermediate wall and one other of said walls, and a plurality of baffles on the remaining wall open to said intermediate wall and guiding one of said streams, said baffles extending at an angle to the axis of rotation of the moving walls and being curved in the direction of rotation thereof.

4. In a heat exchanger for the transfer of heat between a gaseous stream and a liquid stream, three walls in the form of surfaces of revolution, about a vertical axis the intermediate one being of heat-conducting material, means for causing said liquid stream to flow downwardly between said intermediate wall and one other wall, means for causing said gaseous stream to flow upwardly between said intermediate wall and the remaining wall, means for rotating the two walls enclosing said liquid stream, and impeller means between said two walls for acting on said liquid stream.

5. In a heat exchanger for the transfer of heat between a gaseous stream and a liquid stream, three walls in the form of surfaces of revolution, about a vertical axis the intermediate one being of heat-conducting material, means for causing said liquid stream to flow downwardly between said intermediate wall and one other wall, means for causing said gaseous stream to flow upwardly between said intermediate wall and the remaining wall, means for rotating the two walls enclosing said liquid stream, impeller means between said two walls for acting on said liquid stream, and a plurality of baffles on the remaining wall for guiding said gaseous stream.

6. In a heat exchanger for the transfer of heat between streams of fluid mediums, three spaced walls, the intermediate one being of heat-conducting material, said streams flowing on opposite sides of said intermediate wall and being confined by the respective other walls, means for simultaneously moving said intermediate wall and one other of said walls, and helical baffle means on the remaining wall open to said intermediate wall and being curved at an angle to the direction of movement of said intermediate wall for progressively guiding one of said streams angularly with respect to the other.

7. In a heat exchanger for the transfer of heat between streams of fluid mediums, three spaced walls, the intermediate one being of heat-conducting material, said streams flowing on opposite sides of said intermediate wall and being confined by the respective other walls, means for simultaneously moving said intermediate wall and one other of said walls, and a plurality of

baffles on the remaining wall open to said intermediate wall, said baffles being curved at an angle to the direction of movement of said intermediate wall, whereby the stream partly confined by said remaining wall is induced to follow the movement of said moving intermediate wall along said baffles.

8. In a heat exchanger for the transfer of heat between streams of fluid mediums, three spaced walls, the intermediate one being of heat-conducting material, said streams flowing on opposite sides of said intermediate wall and being confined by the respective other walls, means for simultaneously moving said intermediate wall and one other of said walls, and helical baffle means on the remaining wall open to said intermediate wall, and being curved at an angle to the direction of movement of said intermediate wall whereby the movement of said intermediate wall frictionally drives the stream confined between it and said remaining wall along said helical baffle means.

9. In a heat exchanger for the transfer of heat between streams of fluid mediums, three spaced walls, the intermediate one being of heat-conducting material, said streams flowing on opposite sides of said intermediate wall and being confined by the respective other walls, means for simultaneously moving said intermediate wall and one other of said walls, and stationary means comprising curved vanes for receiving and guiding the stream confined between said moving walls to thereby convert the kinetic energy of said stream into hydrostatic pressure.

10. Heat exchange apparatus comprising two spaced movable walls in the form of similar surfaces of revolution with a common axis and adapted to confine a fluid stream therebetween, a third wall positioned to confine a separate fluid stream in heat exchange relation with said first named stream, a fluid outlet adjacent said axis, and stationary means disposed between said movable walls comprising spaced curved vanes for receiving and guiding said first named stream towards said outlet to thereby convert the kinetic energy thereof into hydrostatic pressure.

11. In a heat exchanger for the transfer of heat between streams of fluid mediums, traveling in substantially opposite senses, a wall of heat conducting material constituting a surface of revolution, disposed between said streams, means for moving said wall around an axis and transversely to said streams to increase the velocity of one of the streams relative to that of said wall, baffle means curved at an angle to the direction of movement of said wall for confining and guiding one of said streams, said one stream receiving the mechanical energy to sustain its flow from said moving wall by virtue of its frictional drag thereon and being guided by said baffle means, a second wall constituting a surface of revolution movable around said axis for confining and guiding the other stream and imparting to it a rapid movement along with the first named wall, and means located between said walls for subsequently retarding said other stream to transform a substantial part of its kinetic energy into hydrostatic pressure thereby to change both the temperature and the pressure of said other stream.

12. In a heat exchanger for the transfer of heat between streams of fluid mediums, traveling in substantially opposite senses, a wall of heat conducting material constituting a surface of revolution disposed between said streams, means

for moving said wall around an axis and transversely to said streams to increase its velocity relative thereto, means including angularly disposed baffle means for confining and guiding one of said streams, said one stream receiving mechanical energy to sustain its flow from said moving wall by virtue of its frictional drag thereon and being guided by said baffle means, impelling means and a second movable wall constituting a surface of revolution movable around

said axis and coacting with said first named wall to impart a rapid movement to the other stream, and stationary means located between said walls for thereafter receiving and retarding said other stream to transform a substantial part of its kinetic energy into hydrostatic pressure thereby to change both the temperature and the pressure of said other stream.

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