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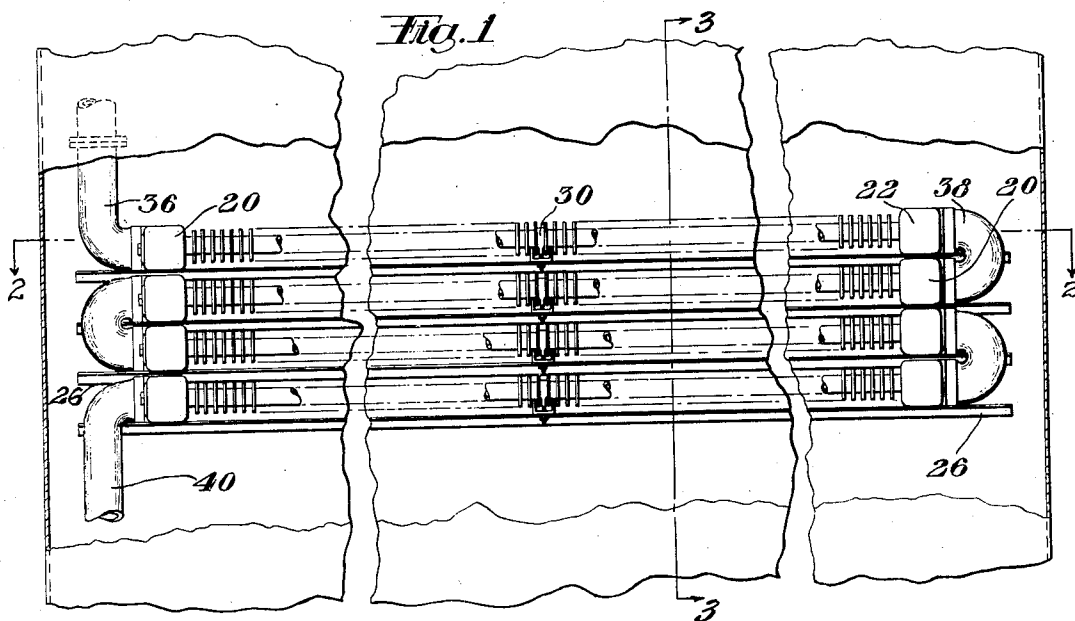
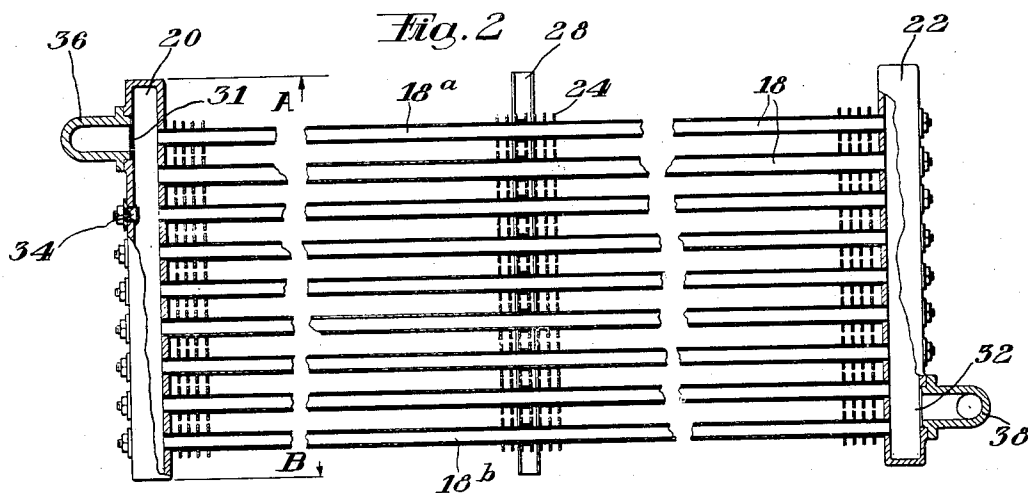
G. C. DERRY

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HEAT EXCHANGE APPARATUS AND METHOD OF OPERATING THE SAME

Filed July 21, 1928

2 Sheets-Sheet 1



Witness
Serge O. Ryby.

Inventor
Gardner C. Derry
by his Attorney
Vernon F. Hildner & Co.

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2 Sheets-Sheet 2

Fig. 3

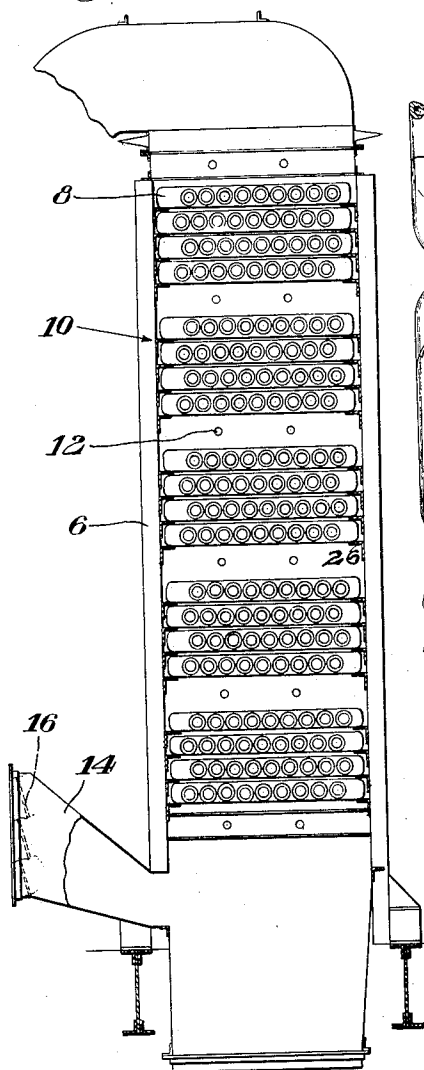


Fig. 4

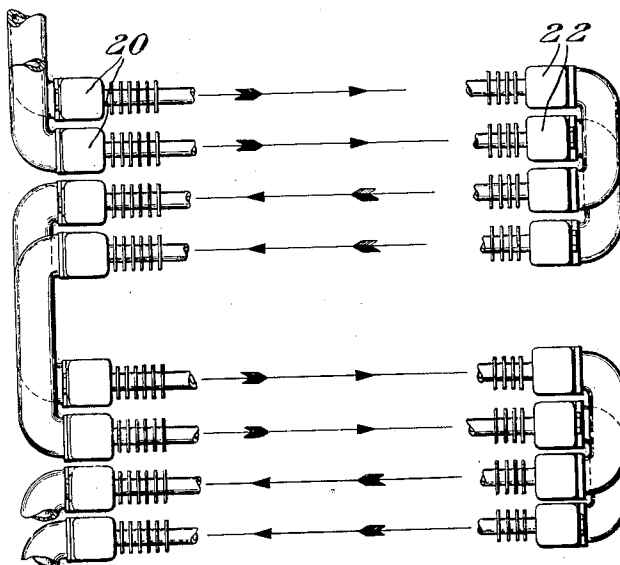
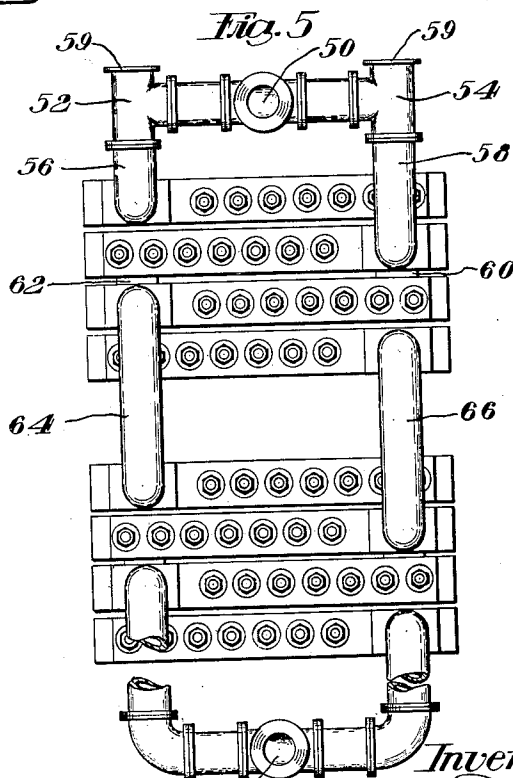


Fig. 5



Witness

George O. Ryby

Inventor

Gardner C. Derry
by his attorney
Van Emmerik Fishelstein & Ray

UNITED STATES PATENT OFFICE

GARDNER C. DERRY, OF SHARON, MASSACHUSETTS, ASSIGNOR TO B. F. STURTEVANT COMPANY, OF HYDE PARK, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS

HEAT EXCHANGE APPARATUS AND METHOD OF OPERATING THE SAME

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The present invention relates to heat exchange apparatus and to methods of operating such apparatus, and more particularly to that type of apparatus and method of operating which are especially adapted for use where it is desired to effect a transfer of heat between a gas and a liquid as, for example, an economizer for heating boiler feed water.

The objects of the present invention are to provide a heat exchange apparatus of the above type and a method of operating the same whereby a compact and inexpensive construction may be secured, capable of being quickly and easily installed and repaired, of high capacity and efficiency in operation, and suitable for use under widely varying conditions of gas and fluid flow.

With these objects in view, the present invention comprises a heat exchange apparatus in which provision is made for the proper distribution of flow of the liquid in its passage through the apparatus. This includes a plurality of series-connected sections, each section consisting of a pair of headers and a plurality of tubes through which the liquid flows in parallel. A feature of the invention consists in a construction whereby the liquid is distributed substantially equally among all of the tubes in each section. This is carried out in the preferred form of the invention by arranging the inlet and outlet of a section at diagonally opposite corners thereof, in order that the length of the path of flow from inlet to outlet through any tube will be equal to the path through any other tube. The resistances to flow by all paths in a section will therefore be substantially equal, and a substantially equal division and flow of the liquid is assured.

Where the apparatus is of such size that the resistance of series-connected sections would be large, the invention contemplates dividing the sections into a plurality of branches or paths having a common supply and discharge whereby the liquid flows through the separate branches or paths in parallel.

In order to secure most efficient operation

of the economizer, not only must the rate of flow through the several branches or paths be substantially the same, but each branch must be subjected to the same heating effect. The former is secured by making the paths or branches alike or symmetrical with respect to each other so that the same capacities are obtained and the same resistances developed. The latter condition is fulfilled by arranging the paths or branches so that each traverses substantially the same portions of the heated gases as all the others.

Another feature of the present invention is the prevention of internal convectional circulation and this advantage is secured by increasing the velocity at certain points in each branch or path yet without increasing the velocity through the main portions of the branches or unduly raising their resistance. Such increased velocity at these points effectively prevents any reversal of flow under the relatively weak convectional forces. This is a feature of advantage since it adapts the economizer for use with down flow of water and up flow of gas as well as up flow of water and down flow of gas.

Other features of the invention consist in certain novel features of construction, combinations and arrangements of parts, hereinafter described and particularly defined in the claims.

In the accompanying drawings illustrating what is now considered the preferred form of the invention as embodied in an economizer for heating boiler feed water, Fig. 1 is a side elevation of a unit of the economizer with a portion of the casing broken away; Fig. 2 is a horizontal sectional view of a single section of the economizer taken on the line 2—2 of Fig. 1; Fig. 3 is a diagrammatic sectional end elevation showing the arrangement of the sections in the casing; Fig. 4 is a detail view in side elevation showing a modified arrangement of the sections; and Fig. 5 is an end elevation of the apparatus shown in Fig. 4.

The illustrated embodiment of the invention comprises an economizer having a plurality of horizontal sections through which water passes to the boiler and over which the hot gases from the boiler flow to heat the

water. The economizer casing is arranged over the boiler, the gases passing upwardly through the economizer, and the water flowing downwardly through the economizer in counter-current to the gases.

Referring to Fig. 3, the casing or flue 6 for the gases includes a plurality of economizer sections 8, each section consisting of a front and a rear horizontal header and a plurality of horizontal tubes, as will later be described in detail. The sections 8, of which there are twenty in the illustrated embodiment of the invention, are arranged in five groups or units 10, of four sections each, spaces between the units being provided to accommodate steam-jets 12 employed as soot blowers or cleaners. A by-pass flue 14 is connected into the bottom of the casing to provide for diversion of a part of the hot gases as occasion may require, the flow through the by-pass flue being controlled by dampers 16. The water is admitted to the top section and flows downwardly through the twenty sections to be discharged at the bottom into the boiler.

Referring to Figs. 1 and 2, each section comprises a plurality of horizontal tubes 18, preferably of steel to withstand the high pressures employed in modern practice, and connected at their ends into the horizontal headers 20 and 22. As shown in Fig. 2, each section comprises nine tubes. Each tube is provided on its outer surface throughout its length with spaced disks or fins 24 to increase the heat transfer capacity of the apparatus. The disks are preferably secured upon the tube by passing an expanding tool through the tube while the disks are maintained spaced at proper intervals along the tube. Each tube is then coated inside and out with a lead coating to resist both internal and external corrosion.

The sections are supported in the casing by angle irons 26 which are secured to the sides of the casing and on which the ends of the headers rest. An intermediate support for the middle of each section comprises a channel iron 28 secured to all of the tubes of the section by bands 30. The channel iron engages, as shown in Fig. 1, with the tube proper and not with the flue. The ends of the channel rest upon the angle irons 26. A single section may be conveniently inserted or removed by sliding it along its pair of angle iron supports.

As shown in Fig. 2, the tubes are not symmetrically arranged with respect to the ends of the headers. The distance between the ends of the headers and the tube 18^a at one side of the section is greater than the distance from the ends of the headers to the tube 18^b at the other side of the section. These distances are represented at A and B in Fig. 2. The distance B in the preferred form of the invention is approximately equal

to the center line distance between tubes in the same horizontal row, and the distance A is greater than B by one-half the center line separation between tubes. It will therefore be seen that if alternate sections are inverted, that is, turned either end for end or upside down about the longitudinal axis, (but not both ways,) with the ends of their headers in alignment, the tubes will be staggered vertically, as shown in Fig. 3.

In order that the connections between headers may be vertically arranged, the inlet and outlet openings of the headers must be located at equal distances from the ends of the headers. Thus the header 20 has an inlet opening 31 and the header 22 has an outlet opening 32, the centers of both of these openings being arranged at the same distance A from the end of the header. The opening 31 will therefore be disposed directly opposite the tube 18^a but the opening 32 in the opposite header will have its center intermediate to the tube 18^b and the tube adjacent thereto.

The openings 31 and 32 which provide for connections between sections are disposed at diagonally opposite corners of the section, the opening 31 being at one end of the header 20 and the opening 32 being at the opposite end of the header 22. This diagonal arrangement of the inlet and outlet insures that all the water passing through the section will traverse the same length of path, that is to say, assuming the opening 31 to be an inlet and the opening 32 an outlet, the total length of any path of the water from inlet to outlet will be equal to the length of one tube plus the length of one header. The lengths of all possible paths of flow through one section being equal, the resistances of the parallel flow will be substantially equal, and an equal division of water through all the tubes of the section is assured.

In order to afford means for securing the ends of the tubes in the headers, each header is provided opposite the tube openings with tool inserting openings which are subsequently closed by plugs 34. The tool employed is preferably a rotary expander having a flexible shaft to permit the tubes near the inlet and outlet openings 31 and 32 to be operated upon.

Water is admitted to the top section through an inlet pipe 36 and connections between sections are afforded by return bends 38. As shown in Fig. 1, the top section has a front header 20 to which the inlet connection 36 is bolted and a rear header 22 to which the return bend 38 is connected to permit flow of water to the next section below. This next section comprises a rear header 20 and a front header 22 and is similar to the first section except for being turned around, so that the inlet of the second section will be directly under the outlet of the

top sections. The third and fourth sections are respectively identical to the first and second sections. In each case, therefore, the type 20 header comprises an inlet header and the type 22 forms the outlet header for any given section.

The top unit which consists of four sections is connected to the next unit below by a long bend 40. The other sections and units in the economizer are similarly connected and a suitable connection is taken from the rear of the bottom section to conduct the feed water to the boiler.

In some instances where an economizer of considerable horizontal length or vertical height is necessary in order to effect the necessary heat transfer, the apparatus above described will introduce a water resistance too high to be economically overcome by the feed pump. In such event the present invention contemplates arranging the sections for a plurality of parallel paths of flow. This arrangement is shown in Figs. 4 and 5, wherein an economizer of the same number of sections is arranged so that the water divides and flows in two parallel branches or paths.

Considering the upper group or unit of four sections shown in Figs. 4 and 5, the water is admitted from the supply connection 50 which divides the water into two paths flowing to the T's 52 and 54 and thence into the down pipes 56 and 58, respectively. The T connection is employed to afford flanges 59 for mounting of safety valves. The pipe 56 comprises an inlet pipe similar to the inlet 36 of the single path construction previously described. It enters a top section which has a front header 20 and a rear header 22. The section next below is connected with the inlet pipe 58 at the opposite side of the apparatus. This section also comprises a front header 20 and a rear header 22, both being turned upside down, however, with respect to the top section in order that the tubes may be staggered, as clearly shown in Fig. 5.

The third section is exactly similar to the top section and is connected to the top section at the rear by a pipe 60. The second section is connected to the fourth at the rear by a pipe 62. Similarly, connections 64 and 66 lead respectively from the third and fourth sections at the front thereof to the fifth and sixth sections forming a part of the second group.

As shown by the arrows in Fig. 4, the water divides into two branches or paths, the one path comprising the first, third, etc. sections, and the other path comprising the second, fourth, etc. sections of the economizer. The two paths join at the front of the economizer in a common discharge 68 at the bottom. For the same number of tubes and sections and therefore the same heating surface, this economizer has a total resistance only one-fourth

that of the single path or series section economizer of Figs. 1 and 2. These two paths, it will be noted, are alike or symmetrical with respect to each other, and have the same number of sections, tubes, and connections all similarly arranged, so that the capacities and resistances of the two paths are substantially identical, insuring the same flow through each. Furthermore, each path traverses the same portions of the flue or gas stream so that each is subjected to the same heating effect.

Thus, the first and third sections of each group which form part of the path entering through branch 52 and connection 56 extend entirely across the gas stream. In a similar manner, sections 2 and 4 of each group which are included in the second path of flow entering through connections 54 and 58 extend entirely across such stream. Whatever stratification therefore may exist in the gas stream, the sections of each path being equally exposed to it are equally affected, so that both paths are subjected to practically identical heating effects.

The fact that the sections of one path average to be slightly nearer the gas inlet than the sections of the other path does not necessarily result in a greater heating effect on the former path. Not only is this difference in position very slight, but as a matter of fact the temperature of the gas impinging upon the tubes of adjacent sections is substantially the same. This is obvious when it is considered that none of the sections is exposed to the radiant heat of the furnace but only to the hot waste gases, and these gases suffer a reduction in temperature only by contact with the economizer tubes. Since the tubes are staggered, the tubes of the higher of each pair of sections, beginning at the bottom, are swept by gas which has passed between the tubes of the lowest section without loss of temperature. Thus, each pair of adjacent sections, although lying in different paths and at slightly different heights in the economizer, receive substantially the same amounts of heat. As a result, the maximum efficiency in operation will be secured and liability of internal conventional currents due to unequal temperatures in the two paths will be avoided.

It will also be noted that the connection from one header to another is by a single pipe or bend which, while of greater diameter than the individual tubes, is very much smaller in cross-sectional area than the total cross-sectional tube area of the sections, preferably less than one-half. Since all of the water of a section must pass through a single connection, it follows that the velocity of flow through such connection will be correspondingly greater than through the tubes, preferably at least twice as great. Such increased velocity will effectively prevent any tendency in either path to reverse its direction and flow upwardly under convectional action which

necessarily is relatively weak being based upon difference in weight of the water in the two paths, due to difference in temperature. Since the main portions of the paths are composed of the tubes in parallel with correspondingly low resistance and velocity, but little additional work is thrown upon the pump.

It will be seen that the invention affords provision for assuring practically uniform distribution of water at all points where parallel flows occur. Thus, in any section there is assured a substantially equal distribution of water among the tubes, and where the parallel branch flow construction is employed, the water is also forced to divide in practically equal quantities through the separate branches and is subjected to substantially equal heating in each branch. Operation of the economizer with either up or down flow of water and at high efficiency and with maximum heat transfer at all times is consequently attained.

Although the economizer of Figs. 4 and 5 has been illustrated and described as comprising two parallel flow branches, it may obviously consist of a larger number of branches, if it is desired to decrease the total resistance to an even lower value. In such case, the separate branches will each comprise the same number of sections disposed and arranged to subject the water in each branch to substantially the same heating effect.

In the illustrated embodiment of the present invention the tubes are provided with fins on their outer surfaces in order to increase the surface exposed to the gas and thereby facilitate the transfer of heat from the gas to the tube. While this is not an essential feature of the invention, it is of advantage since it enables the same amount of heat to be transferred to a given volume of water in a much shorter period of time, thus not only reducing the size of the economizer for a given output and correspondingly reducing the internal resistance and hence the work required of the pump, but increasing the velocity of flow through the tubes and connections. This increased velocity through the economizer as a whole, supplementing the localized increase in velocity in the connections or bends between the sections due to their relatively smaller cross-sectional area, makes even more remote the possibility of reversal of flow through such connections or bends and still further insures the proper and efficient operation of the economizer with down flow of water.

The present invention has been shown and described as embodied in an economizer comprising a plurality of vertically disposed sections having horizontal tubes located in a vertical gas flue, but it will be apparent to those skilled in this art that many features of the present invention are equally applicable to the familiar and common type of economizer

wherein the series of sections and the flue are horizontally arranged.

Having thus described the invention, what is claimed is:

1. A heat exchange apparatus comprising a plurality of sections each having a front header and a rear header and tubes connecting the headers, the headers having diagonally opposed openings for inlet and outlet whereby the paths through all tubes of the section are of substantially equal length, and a connection between the inlet opening of one section and the outlet opening of another section.

2. A heat exchange apparatus comprising a plurality of sections each having a front header and a rear header and a single row of parallel tubes extending between the headers, the front header having an inlet adjacent one end and the rear header having an outlet adjacent the opposite end whereby a plurality of paths of flow are provided from inlet to outlet each of substantially the same length, and a connection between the inlet of one section and the outlet of another section.

3. A heat exchange apparatus comprising a plurality of sections each having a front header and a rear header and tubes connecting the headers, each header having an inlet and outlet opening, and connections between the inlet and outlet openings of a pair of sections, the connections being of materially less cross-sectional area than the total cross-sectional area of all the tubes of a section.

4. A heat exchange apparatus comprising a plurality of sections each section consisting of a front header and a rear header and a plurality of tubes connecting the headers, the sections being arranged in a plurality of branches for parallel flow through the branches, and means for connecting all of the sections of the separate branches in series, and a common supply and discharge connections for all of the branches.

5. A heat exchange apparatus comprising a plurality of sections, each section consisting of a front header and a rear header and a plurality of tubes connecting the headers, the sections being arranged in a plurality of branches for parallel flow through the branches, and means for connecting in series all of the sections of each separate branch, the connecting means for adjacent sections comprising a single pipe of materially less cross-sectional area than the total cross-sectional area of all of the tubes in one of said sections.

6. A heat exchange apparatus comprising a plurality of parallel flow branches having a common supply at the top and discharge at the bottom, each branch including a vertical series of horizontal sections having headers and connecting tubes, a single vertical pipe connection between each of the adjacent sec-

tions of the separate branches constructed and arranged to cause materially higher velocity of flow through said pipes than through the tubes, and means for passing hot gas upwardly over the sections.

7. A heat exchange apparatus comprising a plurality of parallel flow branches having a common supply at the top and a common discharge at the bottom, each branch including a vertical series of horizontal sections having headers and a plurality of connecting tubes provided with fins to afford increased heat absorbing surface, and a connection between each pair of adjacent sections said connections being of less cross-sectional area than the total cross-sectional area of the tubes of one of the sections.

8. A heat exchange apparatus comprising a plurality of superposed horizontal sections each consisting of a pair of headers and a plurality of parallel connecting tubes, the sections being arranged in a plurality of branches, the separate branches including regularly spaced and non-contiguous sections, means for connecting the regularly spaced sections of the separate branches in series, and a common supply and a common discharge for the branches.

9. A heat exchange apparatus comprising a plurality of superposed horizontal sections each consisting of a pair of headers and a plurality of parallel connecting tubes, the sections being arranged in two branches, the separate branches including alternate sections, means for connecting the sections of the separate branches in series, and a common supply at the top and a common discharge at the bottom for the branches.

10. A heat exchange apparatus comprising a plurality of horizontal sections each having an inlet header and an outlet header and a single row of tubes having extended heating surface and providing a plurality of parallel paths of flow between the headers, the headers having diagonally opposed inlet and outlet openings to make the several paths of flow through the different tubes substantially uniform, the sections being arranged in a plurality of branches, pipes connecting the sections of several branches in series, and supply and discharge connections at the top and bottom of the apparatus for connecting the branches for parallel flow, the connecting pipes between sections being of reduced area relative to the total tube area of a section.

11. A heat exchange apparatus comprising a flue for the hot gas and a series of sections each extending across the flue, and comprising a front and a rear header and a single row of tubes between the headers, the headers having diagonally opposed inlet and outlet openings, and a single pipe connection between the inlet and outlet openings of a pair of sections.

12. A heat exchange apparatus comprising

a flue for the hot gas and a series of sections each extending across the flue, and comprising a front and a rear header and a single row of tubes between the headers, the sections being arranged in a plurality of branches, pipes for connecting together the sections of each branch in series, and a common supply and common discharge for the branches.

13. A heat exchange apparatus comprising a vertical flue for the hot gas, a series of superposed horizontal sections extending across the flue, each section comprising a pair of horizontal headers and a single row of parallel tubes therebetween having fins to provide increased heat absorbing surface, the headers having diagonally opposed inlet and outlet, the sections being arranged in a plurality of branches, a single pipe for connecting together adjacent pairs of sections of the separate branches in series, the sections of each branch being separated from one another by sections of another branch, and the tubes of contiguous sections being staggered, and a common supply and discharge for the branches.

14. A heat exchange apparatus comprising a plurality of vertically superposed horizontal sections arranged in a plurality of branches, each branch including a plurality of sections the adjacent sections of each branch being separated by sections of another branch, means for connecting the sections of the several branches in series, and means for connecting the branches in parallel.

15. A section for heat exchange apparatus comprising two headers each open interiorly throughout its length, and having inner and outer walls, a single row of tubes extending between the inner walls of the headers and provided with fins to increase the heat absorbing surface, the headers having one an inlet and the other an outlet opening in the outer walls at diagonally opposite corners of the section.

16. A section for heat exchange apparatus comprising two headers, a plurality of tubes connecting the headers, the tube at one side of the section being spaced from the ends of the headers a distance greater than the spacing of the tube at the other side of the section by a distance equal to one-half the tube spacing, the headers having inlet and outlet openings at substantially diagonally opposite corners of the section.

17. A section for heat exchange apparatus comprising two headers, a plurality of tubes connecting the headers, the tube at one side of the section being spaced from the ends of the headers a distance greater than the spacing of the tube at the other side of the section by a distance equal to one-half the tube spacing, the headers having inlet and outlet openings at substantially diagonally opposite corners of the section, the openings being

at equal distances from the ends of the headers.

18. The method of operating a heat exchange apparatus which consists in causing
5 the gas to pass upwardly in a stream and the liquid to pass downwardly in a plurality of separate streams and subjecting each liquid stream to substantially the same portions of the gas stream at substantially the same tem-
10 perature whereby each liquid stream receives substantially the same heating effect.

19. The method of operating a heat exchange apparatus which consists in causing
the gas to flow upwardly in a stream and the
15 liquid to flow downwardly in a plurality of streams, and passing the liquid of each stream in a plurality of separate paths through the gas stream, each stream of liquid traversing substantially all portions of the gas stream
20 whereby each stream is subjected to substantially the same heating effect.

20. The method of operating a heat exchange apparatus which consists in causing
the gas to flow upwardly in a stream and the
25 liquid to flow downwardly in a plurality of streams, passing the liquid of each stream in a plurality of parallel paths across substantially the entire gas stream at a plurality of separated points along said gas stream,
30 and passing the liquid of each stream from point to point along the gas stream in a single path.

21. The method of operating a heat exchange apparatus in which the gas flows up-
35 wardly in a stream and the liquid flows downwardly in a plurality of separate streams which consists in passing each liquid stream horizontally across substantially the entire gas stream, and downwardly at a linear ve-
40 locity, greater than the linear velocity of the said liquid stream passing horizontally.

In testimony whereof I have signed my name to this specification.

GARDNER C. DERRY.

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