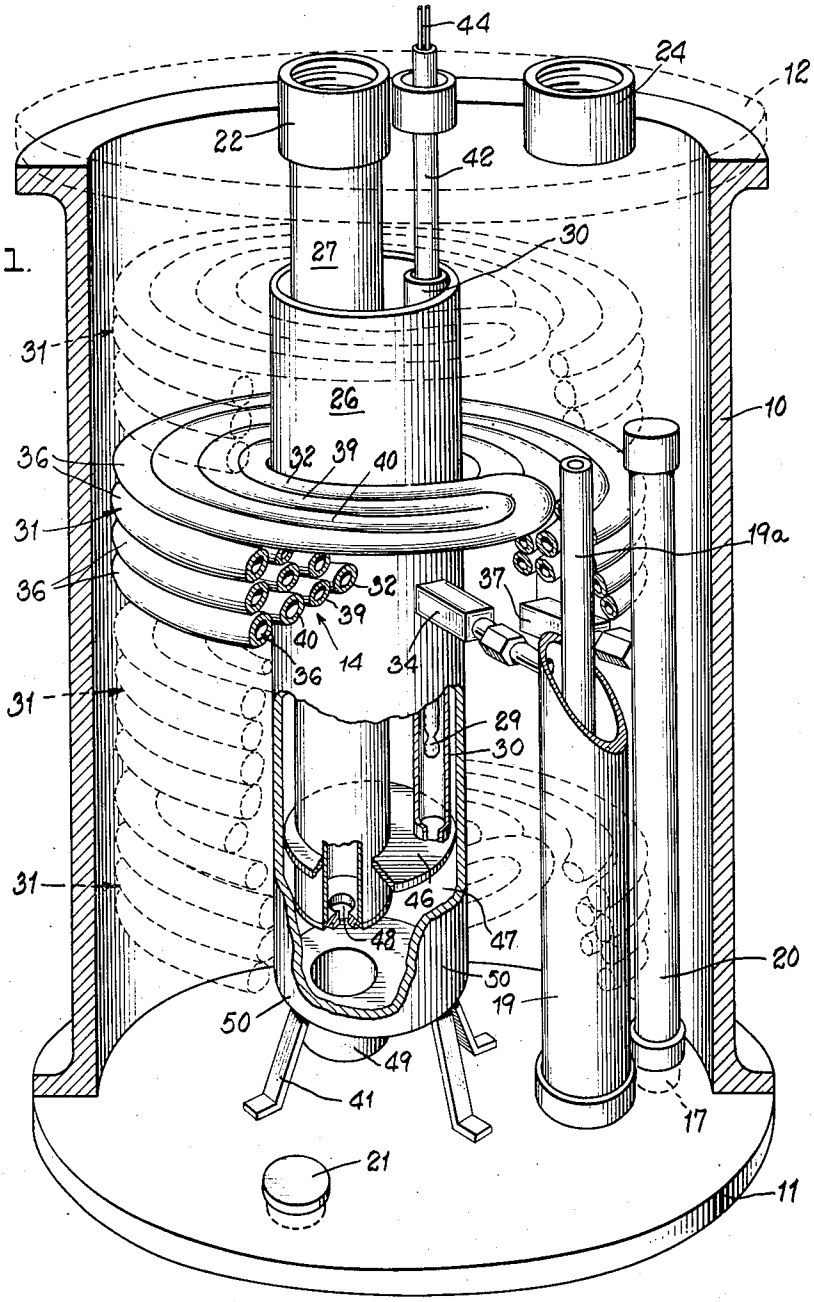
Sept. 3, 1957 H. W. ANGELERY 2,805,048

COIL STRUCTURE FOR HEAT EXCHANGER

Filed Jan. 12, 1954 2 Sheets-Sheet 1

Fig. 1.



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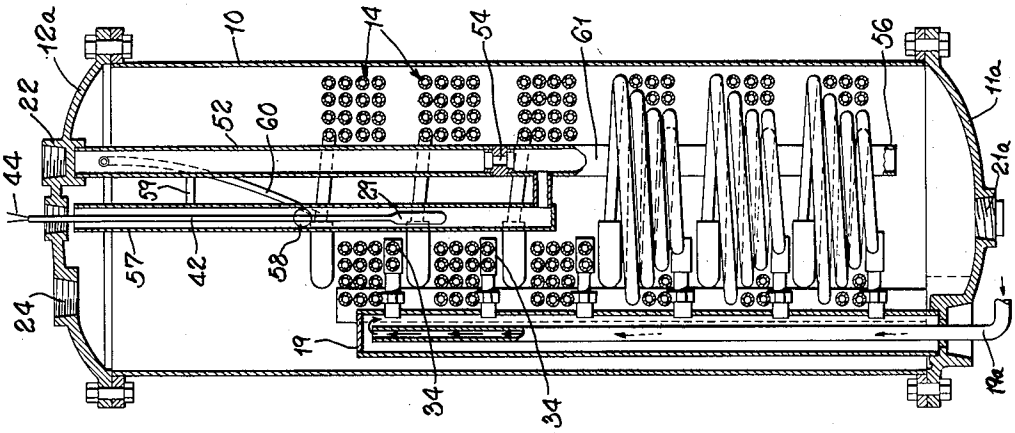


Fig. 3.

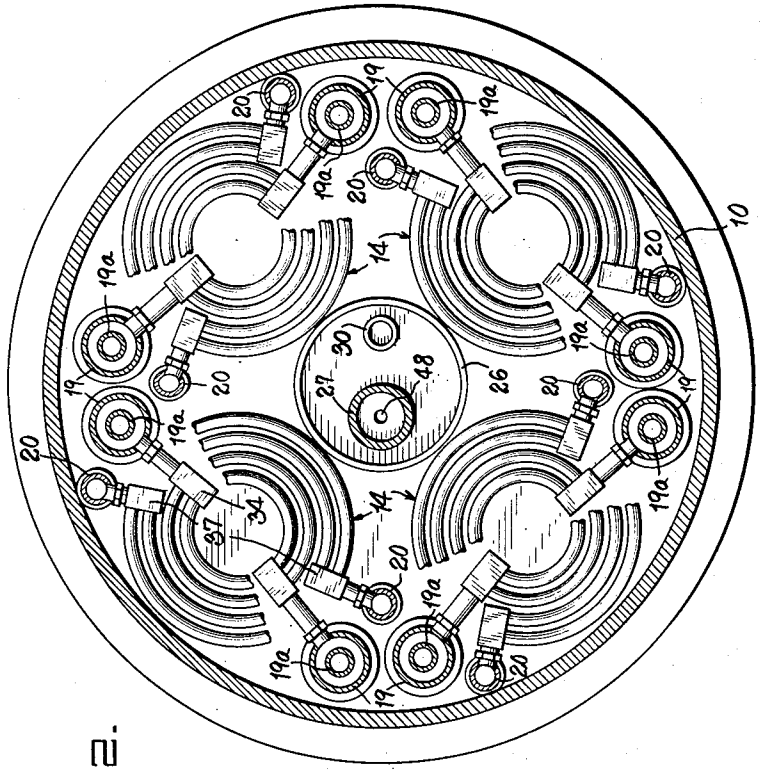


Fig. 2.

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COIL STRUCTURE FOR HEAT EXCHANGER

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Application January 12, 1954, Serial No. 403,610

5 Claims. (Cl. 257—229)

This application is a continuation-in-part of my earlier copending application, Serial No. 159,695, filed May 3, 1950, now Patent No. 2,713,994, dated July 26, 1955, which in turn is a continuation-in-part of my abandoned application, Serial No. 40,959, filed July 27, 1948.

The present invention relates to improvements in heat exchangers designed to effect a transfer of heat between two fluids, to a system for maintaining a mass of fluid at a predetermined temperature, and more particularly to improvements in controlling the rate of heat transfer between two fluids when the flow of the subject fluid varies or becomes intermittent.

The term "subject fluid" as used herein, is applied to the fluid whose final temperature and, if desired, state is to be controlled. The term "regnant fluid" as used herein, is applied to the fluid used to control the temperature or state or both, of the subject fluid.

In order to promote a most thorough and complete understanding of the principles of this invention, the following description is directed primarily to the application of the invention to the transfer of heat from steam to water, wherein steam is the regnant fluid and water is the subject fluid. It is to be understood, however, that it is not intended to limit the application of the invention solely to such use.

In conventional out of contact heat exchangers, the rate of flow and heat content of the regnant fluid and the effective heat transfer area remain substantially constant although the heat requirements of the subject fluid may vary considerably. The only variations in the amount of heat transferred to or from the subject fluid are, therefore, due to changes in the mean temperature differential between the subject and regnant fluids. This is fairly satisfactory when the subject fluid is withdrawn at a more or less constant rate. It is unsatisfactory, however, when the rate of withdrawal of the subject fluid varies appreciably or is intermittent.

Thus, for example, when conventional heat exchangers are used to heat water with steam, difficulties arise due to the overheating of the water when its rate of flow is reduced to a minimum or stopped completely. This is usually due to the simple fact that the amount of heat available from the steam greatly exceeds the amount of heat required by the water at small or zero rates of flow. When, on the other hand, the rate of flow of the water is increased to above average, the amount of heat that can be absorbed by a given volume of water is too small to raise its temperature to the desired point for the simple reason that the amount of heat made available by the steam is not sufficient to satisfy the heat requirements of the water.

The present invention is applicable to a heat exchanger of the type described in my aforementioned patent applications wherein the flow of the regnant fluid is controlled in such a way that it both anticipates and satisfies the heat requirements of the subject fluid to the end that the final temperature of the subject fluid will remain substantially constant at widely varying rates of flow.

In the preferred form of the heat exchanger the water or other subject fluid is introduced through a tubular conduit into the lower end of a shell or tank containing an aspirator, and as the fluid is introduced into the lower end of the shell or tank through the aspirator, the aspirator creates a zone of reduced pressure which circulates the subject fluid within the shell past a thermostat to regulate the flow of regnant fluid into heating coils within the shell.

The heating coils within the shell are disposed at different levels therein and the coils are connected in parallel relationship between inlet and outlet headers within the shell, and the connections between the inlet header and the heating coils are at different levels in the same order that the coils are arranged in the shell. The regnant fluid is introduced into the inlet header through a riser so that the regnant fluid is free to enter the uppermost bank of coils first and then successive banks of coils at lower levels to permit the heat transfer action to take place within the shell in counter-flow fashion.

These and other features of the present invention will be more fully understood from the detailed description which follows, and by reference to the accompanying drawings wherein:

Fig. 1 is a sectionalized view in perspective, illustrating one preferred embodiment of the apparatus of this invention;

Fig. 2 is a plan view in cross-section of a heat exchanger designed for relatively large capacities; and

Fig. 3 is a cross-section view in elevation illustrating another preferred embodiment of the apparatus of this invention.

The embodiment illustrated in Fig. 1 includes a shell **10** having a bottom **11** and a top **12**, inlet and outlet connections **22**, **24**, respectively, to permit the water or other subject fluid to be introduced into the shell and withdrawn from within the shell, a vertical conduit **27** connected at its upper end to the inlet connection **22**, a circulating tube **30** containing a temperature-responsive element **29**, such as a thermostat, a cylindrical member **26** encircling the conduit **27** and the circulating tube **30**, a vapor inlet riser **19***a* which leads the steam or other regnant fluid into a vertical vapor feed header **19**, a vapor or condensate return header **20**, a condensate return port **17**, a bank of concentric spiral tubular elements **14** to conduct the steam or other regnant fluid from the header **19** to the vapor or condensate return header **20**, and finally a drain port **21** in the base **11** of the shell.

The bank of tubular elements **14** consists of a plurality of units **31**, each unit including two pairs of spiral coil members substantially as shown. The innermost spiral coil member **32** begins at a unit vapor feed header **34** connected to the vapor feed header **19** and, after making four turns in an upward direction, reverses its direction and becomes the outermost spiral coil member **36**. After again making four turns in a downward direction, spiral coil member **36** ends at a unit vapor or condensate return header **37** connected to the vertical vapor or condensate return header **20**. The spiral coil member **39** next to the innermost spiral coil member **32** begins at the unit vapor feed header **34**, makes four turns upwardly adjacent the first spiral coil member **32** and then reverses its direction to become the next to the outermost downward spiral coil member **40** terminating in the unit vapor or condensate return header **37** adjacent the outermost spiral coil member **36**.

The diameters of the loops described by each of the four coil members shown in Fig. 1 are different, but the tubes forming them are preferably of the same diameter. The sum of the coil diameters of spiral coil members **32** and **36** is equal to the sum of the coil diameters of coil members **39** and **40** with the result that the length

of the path through one pair of coils, connected in series as shown, is equal to that of the other pair. Inasmuch as the tube diameters and the number of turns of each coil member are the same, it follows that the pressure drop through one pair of coils must be equal to that through the other.

It is to be understood, of course, that the unit **31** of spiral tubular elements **14** is representative only of a plurality of such units that are connected in parallel between the vertical vapor feed header **19** and the vertical vapor or condensate return header **20**. If the pressure drop of the vapor flowing through the pairs of spiral coil members and the design capacity of the heat exchanger permit, it is, of course, within the contemplation of this invention to use only one unit of one or more pairs of spiral coil members.

By the same token, it is within the contemplation of this invention to have three, four or more pairs of spiral coil members in each of one or more coil units, so long as the sums of the diameters of the coil members in the various pairs are equal.

It is also to be understood that while the members in the various coil units are most advantageously arranged concentrically to utilize to a maximum the space available within the shell, the invention is not limited to such an arrangement but is intended to include any arrangement wherein the heat transfer elements are connected in parallel and offer the same resistance to the flow of fluid.

The tubular member **26** is supported from the bottom **11** by a number of feet **41**. The upper end of the tubular member **26** is open for the passage thereinto of the conduit **27** and a tube **42** enclosing the thermostat leads **44**, as well as fluid from the upper zone of the tank **10**. A partition **46** is provided in the lower portion of the tubular member **26** to form a closed well for the fluid to be heated entering the tube at the open upper end and to support the circulating tube **30** which encloses the thermostat **29** and the thermostat lead enclosing tube **42**. The circulating tube **30** is open at the top to receive fluid from the upper zone of the tank **10** and opens into an aspirating chamber **47** to permit circulation of at least part of the fluid in the shell through the tube. The conduit **27**, after passing through the partition **46**, terminates in a nozzle **48** that is in line with a diffuser **49** in the otherwise closed end **50** of the tubular member **26**, said diffuser terminating above the level of the bottom **11**.

In operation, when it is desired to utilize the heat exchanger for heating a liquid to be heated with a vapor, the liquid enters the shell through the conduit **27** whenever liquid is withdrawn from the outlet connection **24** and, by reason of its passage through the aspirator, consisting of the chamber **47**, the nozzle **48**, and the diffuser **49**, induces a circulation of at least part of the liquid in the shell through the circulating tube **30** and past the thermostat **29**. The flow of cold liquid through the conduit **27** withdraws heat from the liquid in the well formed by the tubular member **26** and the partition **46**. This, in turn, withdraws heat from and thereby lowers the temperature of the liquid flowing through the circulating tube **30**. The thermostat **29** thereupon operates to control the rate of flow and pressure of vapor into the vertical feed header **19**.

The steam or other regnant fluid is introduced into the upper portion of the header **19** through the vertical riser **19*a*** located within the header, and the steam is then permitted to flow toward the lower portion of the header and thence into the unit feed headers **34**. This arrangement insures a flow of steam first to the uppermost coil of bank **14** of coils, and then progressively to the next lower coils in sequence to their relative vertical location on the header **19**, i. e., a supply of steam flows to the uppermost coil first then to that immediate below it, then to the next coil directly below until finally a supply of steam is fed to the lowest coil connected to the header **19** by feed headers **34**.

This arrangement permits heat transfer to be conducted in counterflow instead of parallel and/or cross flow. By having counterflow heat transfer, the temperature of the water nearest the temperature-responsive element **29** is immediately affected, thereby decreasing the time lag of impulse to the temperature-responsive element **29** with changes in load.

The details of the control unit are more fully explained in my above-identified copending application. For the present it suffices to say that if the temperature drop at the thermostat is slight, the pressure of the vapor admitted to the tubular elements will be sufficient to fill only a portion thereof with the vapor, with the result that the effective area of the heating surface will be small. If, on the other hand, the temperature drop is appreciable and therefore reflects a high heat demand, the pressure of the vapor admitted into the header will be sufficient to overcome the pressure drop through the coils with the result that the effective area of the heating surface will be increased to the maximum.

When the flow of liquid withdrawn from the heat exchanger ceases or is brought to a minimum, the flow of liquid through conduit **27** decreases correspondingly. This results in a decrease in the amount of heat withdrawn from the liquid trapped in the well and brings about a rise in the temperature of the liquid in circulating tube **30** that surrounds the thermostat **29**. The thermostat **29** thereupon operates to decrease the pressure of the vapor feed supplied to the header. This, in turn, as shown in the above-mentioned copending application, results in the condensation of a portion of the vapor within the coils, and, due to the action of check valves in the vapor supply and condensate return lines, operates to decrease the effective surface area of the tubular elements that is available for transfer of heat from the vapor to the liquid.

If no heated liquid is withdrawn for a period of time sufficient to result in the cooling thereof due to radiation losses from the shell, the liquid will circulate due to thermal action through the circulating tube **30** and any appreciable temperature drop will be sensed by the thermostat **29** and be reflected in a resumption or increase in flow of vapor through the tubular elements **14**.

The embodiment illustrated in Fig. 2 is intended to show how a heat exchanger constructed in accordance with the principle of this invention may have its capacity increased to any desired degree. Any one bank of coils **14** can be increased practically without limit but, in order to avoid too great a pressure drop in the fluid flowing therethrough, it has been found to be desirable to utilize two or more sets of vertical headers **19** and **20** for the feed and return of vapor and vapor condensate. In this event the top unit will be connected to one set of headers **19** and **20**, the next unit to the other set of headers, and so on. Each of the headers **19** contains a riser **19*a*** for admitting the heat thereinto. Still more capacity may be obtained by utilizing two or more banks of coils **14**. The modification illustrated in Fig. 2 shows how four banks of coils may be placed in a single heat exchanger, each bank having two sets of feed and return headers. In this event, it is not necessary to have a well and thermostat within each bank of coils. It is sufficient to have one such control means in only one of the coil banks and it is preferred, as shown in the drawing, to position the control means, including a tubular member **26**, conduit **27** and circulating tube **30**, centrally among the various banks of coils. The essential details of the control means are the same as described with reference to Fig. 1.

The operation of this modification is likewise essentially the same as that of the embodiment illustrated in Fig. 1. If desired, the heat exchanger of this type may be provided with any suitable arrangement of vertical and horizontal baffles to secure maximum contact of the fluids in the shell with the surfaces of the reverse spiral coils.

The embodiment illustrated in Fig. 3 is a modification of that illustrated in Fig. 1 and is designed to reduce to an absolute minimum the "hunting" of the temperature control system and to increase to a maximum the sensitivity of the thermostat to changes in the temperature and/or flow conditions of the subject fluid in the heat exchanger.

The heat exchanger illustrated in Fig. 3 includes a shell **10** having a bottom **11***a* and a top **12***a*, a drain **21***a*, several banks of concentric spiral tubular elements **14**, a vapor inlet riser **19***a* leading into a vapor feed header **19**, a vapor or condensate return header **20** which leads to an outlet port, liquid inlet and outlet connections **22** and **24** and a thermostat **29**. The bank of tubular elements **14** of Fig. 3 is substantiallly identical with the bank of tubular elements **14** illustrated in Fig. 1 of the drawing. The unit vapor feed headers **34** and unit vapor or condensate return headers (behind headers **34** in Fig. 3) are likewise similar to those illustrated and described with reference to Fig. 1.

An inlet conduit **52** is secured to the inlet connection **22** and is provided with a constriction or nozzle **54** at a point spaced from its lower end **56**. The thermostat leads **44** are enclosed in a cable or tube **42** which is, in turn, enclosed in a circulating tube **57** that is substantially parallel to the conduit **52**. The upper end of the tube **57** is spaced from the top **12***a* of the shell or suitably provided with one or more openings **58** to permit the entry into the tube of at least a part of the liquid from within the shell. A support bracket **59** may be provided between conduit **52** and tube **57** to support the latter. A by-pass **60** is provided between the conduit **52** and the tube **57**, the connection of the by-pass with conduit **52** being upstream of the nozzle **54** and the connection of the by-pass to the tube **57** being upstream of the location of the thermostat **29** therein. It will be understood that additional by-pass or sensing tubes may be connected to the tube **57**, these additional tubes taking fluid from one or more points at lower levels than the by-pass **60**. The lower end of the tube **57** communicates with the aspirating chamber and diffuser **61**.

It will be apparent from this description that the thermostat **29** will sense immediately the introduction of fresh water due to the admixture thereof, at a point upstream from the thermostat, with the heated water in the interior of the shell and in the upper portion of the tube **57**, so that the operation of the thermostat does not depend solely upon the withdrawal of heat from the water in tube **57**. Consequently, the thermostat **29**, in effect, anticipates the heat transfer requirements within the shell **10** prior to an actual change in the temperature of the water within the body of the shell.

When the discharge of water by way of the outlet connection **24** is suddenly stopped, the flow of fresh water through the by-pass **60** also ceases immediately. If the water entering through inlet connection **22** is colder than the water within the shell, as it will be when the heat exchanger is utilized as a water heater, and the movement of water through the heat exchanger is stopped, the water surrounding the thermostat **29** quickly reaches the average temperature of the water in the shell and is thus able to control effectively the further entry of steam into the tubular elements **14**.

While the circulating means illustrated in Figs. 1–3 and described in detail herein are preferred as being the most simple in construction and dependable in performance, it is to be understood that it is within the contemplation of the invention to place the thermostat and recirculating tubes in a separate vessel connected with the shell for circulation of the water.

When the heat exchanger of the present invention is to be used as a hot-water heater, the water inlet **22** is connected to a suitable source of water, the water outlet **24** connected to the system to be heated, and the riser **19***a* to a source of pre-heated fluid, such as steam. The thermostat **29** will control a valve (not shown) in the steam line, so that if the temperature sensed by the thermostat goes below the pre-selected temperature, the valve will be opened to admit steam to the header **19** and thence to the tubular elements **14** under a pre-selected pressure until sufficient heat is absorbed by the liquid to raise the temperature to the pre-selected value at which the thermostat will operate to close the valve.

The invention has been shown and described in the preferred forms and by way of example only, and many modifications and variations may be made therein and in its mode of application without departing from the spirit of the invention. For example, although the heat exchanger of the present invention is described primarily as a hot-water heater, the heat exchanger may be employed to cool or condense vapor with a liquid, or to cool a fluid with another fluid or with a vapor. These variations are described in the above-identified copending application. It is to be understood, therefore, that the present invention is not to be limited to any specified form or embodiment, except insofar as such limitations are specified in the appended claims.

I claim:

1. A heating element for a heat exchanger comprising a tubular unit of heat conductive material for conducting a fluid therethrough, said tubular unit including four mutually concentric coils each having a number of turns, the coils being telescoped, the innermost coil member being connected in series to the outermost coil member by a first reversely bent portion to form a first coil unit, and the two intermediate coil members likewise being connected in series by a second reversely bent portion substantially concentric with and adjacent to said first reversely bent portion to form a second coil unit, said coil units being of substantially equal length to provide two paths of substantially equal length in parallel arrangement between a source of fluid and a discharge line.

2. A heat exchanger comprising a feed header, a return header, a plurality of banks of heating elements connecting the feed header and the return header, each bank including four mutually concentric, helical coil elements, each coil element having a plurality of turns, the innermost coil member having one end connected to one of said headers and its opposite end connected in series by a reversely bent portion to an end of the outermost coil member, the opposite end of the outermost coil member being connected to the other header to form a first coil unit, the two intermediate coil members each having an end connected to a different header and their opposite ends connected in series by a reversely bent portion to form a second coil unit, the arrangement being such that fluid in the feed header is directed to the return header through said banks of heating elements, the fluid in each unit being transmitted through two paths in parallel, each path being substantially equal in length and winding helically about the common axis first in one direction and then reversing and winding about the common axis in the opposite direction, said headers supporting said coils in space with the ends of said coils connected by said reversely bent portions free to move relative to said manifolds to enable said coil units to expand and contract relative to each other and to said manifolds.

3. A heating element for heat exchangers and the like comprising two coil members of substantially equal length, one of said coil members having an inner substantially helical coil portion and an outer substantially concentric, helical coil portion, said coil portions being in spaced relation to provide a curved space therebetween, said inner and outer coil portions being joined at one end by a reversely bent portion, the other coil member having parallel substantially helical coil portions disposed in said space between said inner and outer coil portions of said one coil member and being joined at one end by another reversely bent portion, a supply manifold element connected to one end of each of said coil members to supply fluid thereto, and a return manifold element connected to the opposite end of each of said coil mem-

bers to receive the fluid therefrom, said manifold elements supporting said coils freely in space with the reversely bent portions of said coil free to move relative to the manifold elements in response to change of temperature of the fluid in the coils.

4. A heating element for heat exchangers comprising a pair of heating coils formed of equal lengths of tubular material, each coil including an inner helical coil portion wound in one direction and an outer helical coil portion wound in the opposite direction, one coil having its coil portions adjacent to each other and the other coil having its coil portions on opposite sides of the coil portions of said one coil, said inner and outer coil portions of each of said heating coils being joined by substantially concentric, reversely bent portions in side by side relation.

5. The heating element set forth in claim 4 comprising an inlet manifold member connected to one end of each coil and a discharge manifold connected to the other end of each coil.

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