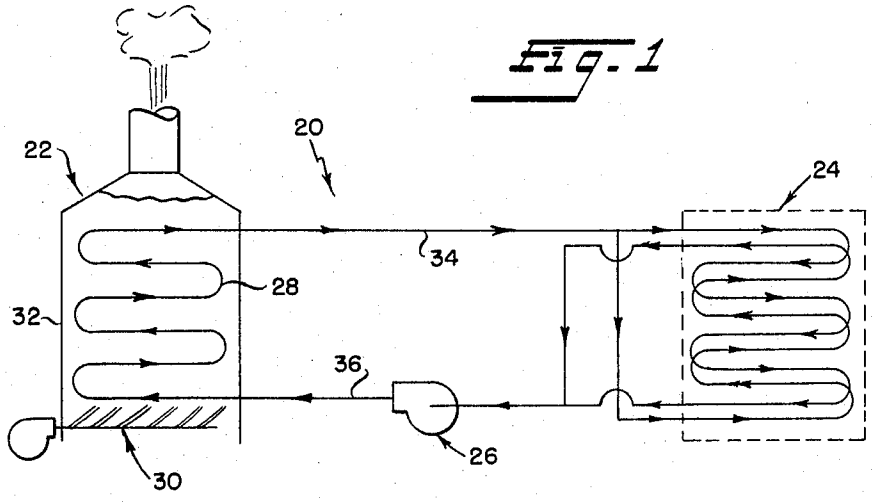
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HEAT EXCHANGERS

Original Filed Nov. 14, 1963 4 Sheets-Sheet 1

Fig. 1



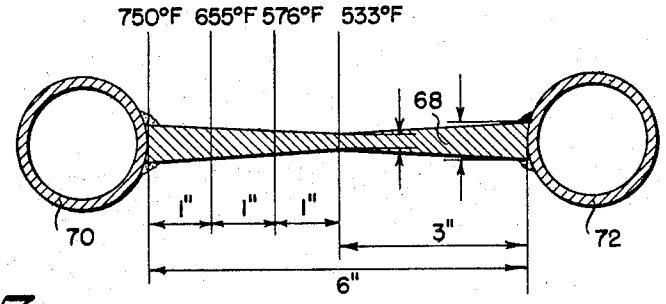
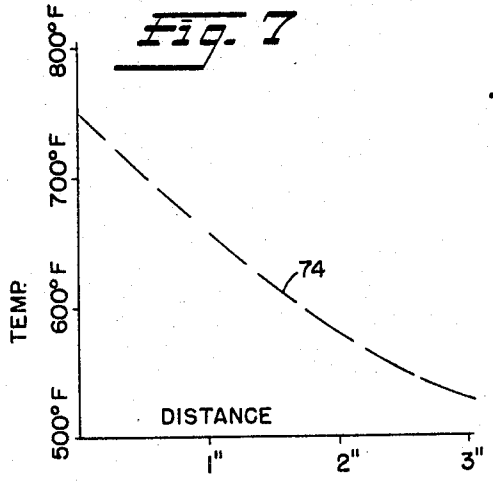


Fig. 6

Fig. 7



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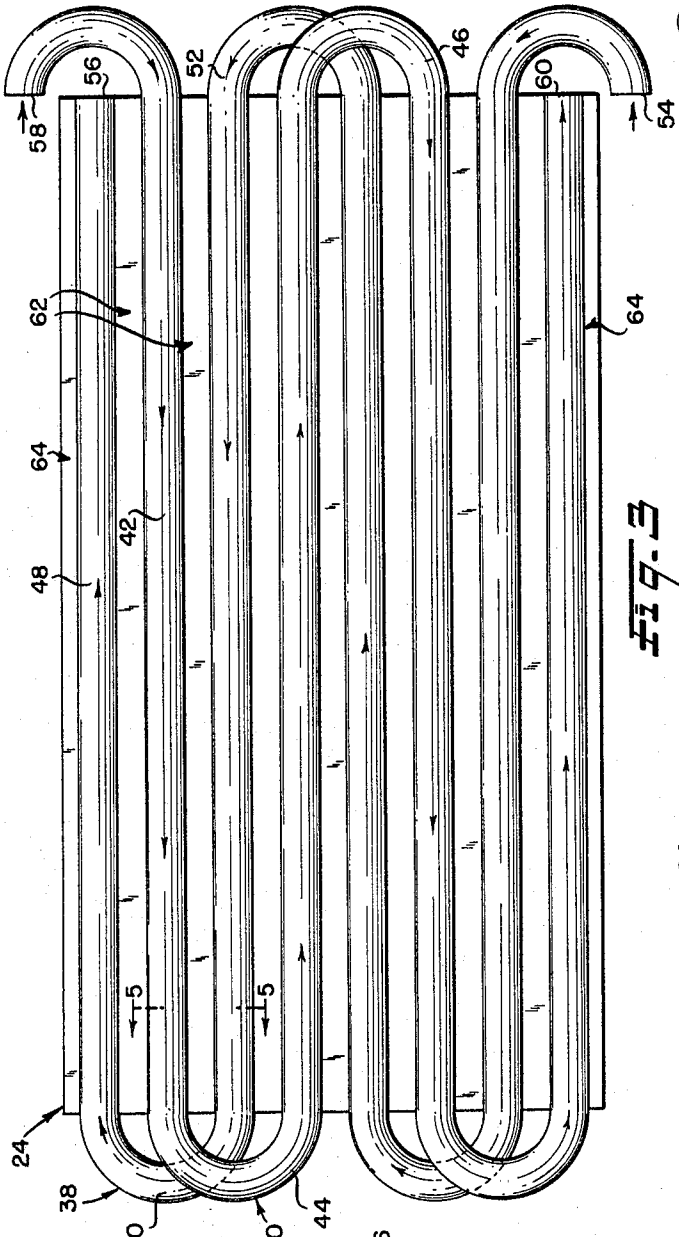


FIG. 3



FIG. 2

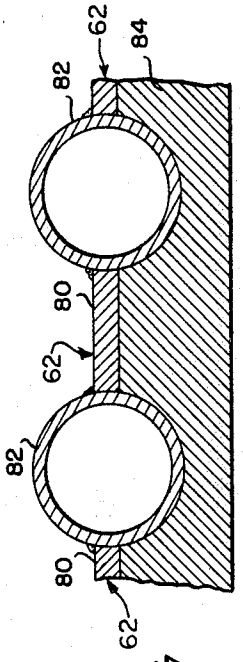


FIG. 5

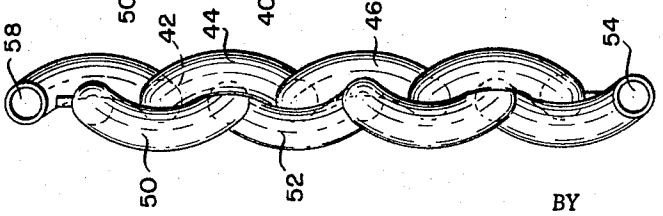


FIG. 4

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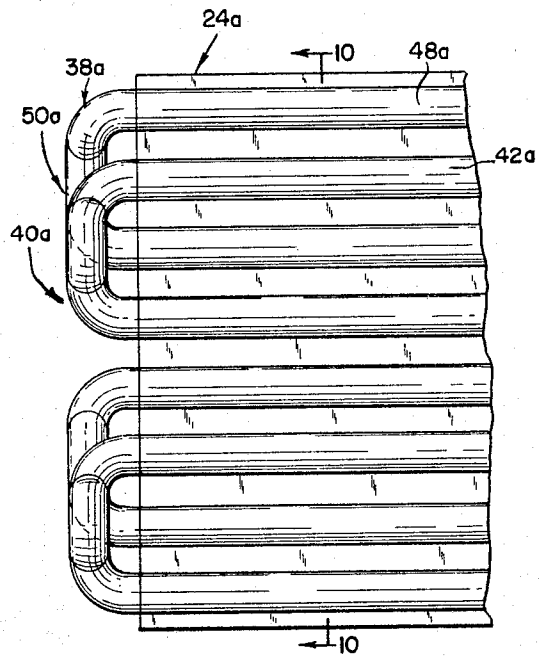


Fig. 8

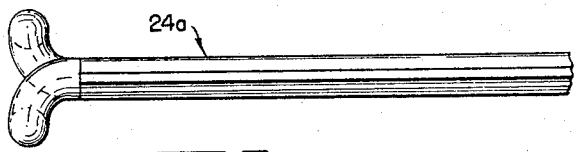


Fig. 9

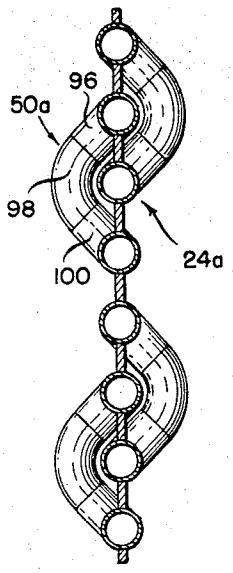


Fig. 10

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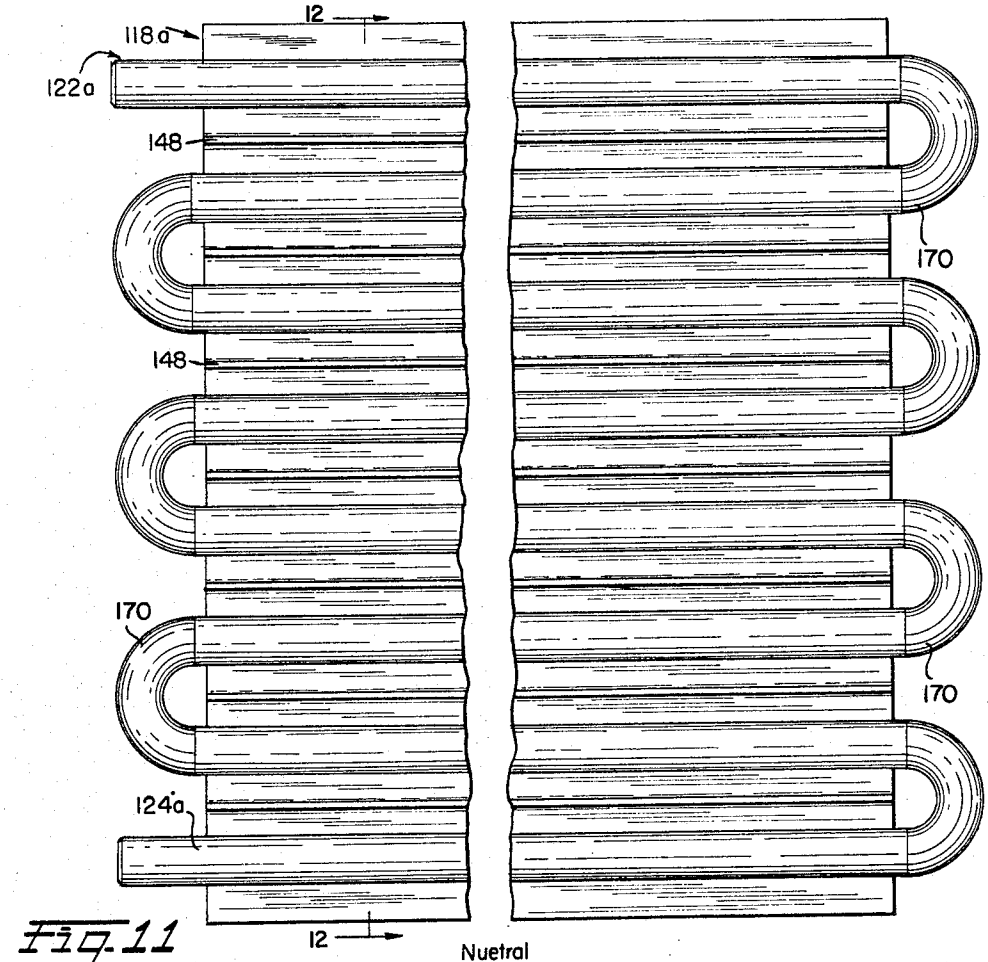


Fig. 11

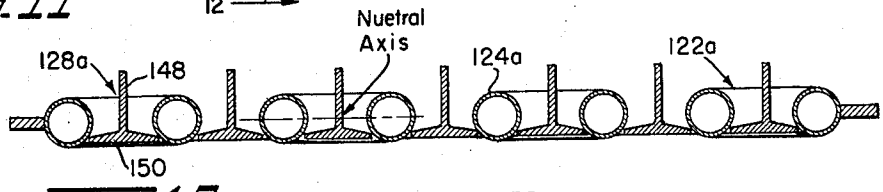


Fig. 12

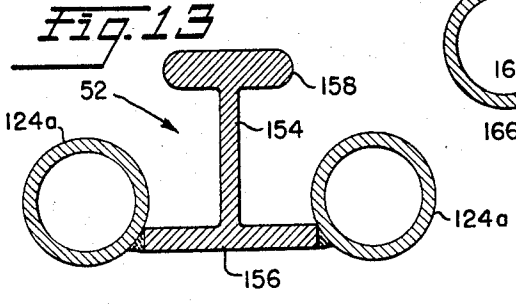


Fig. 13

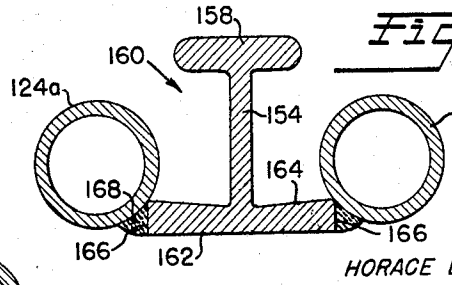


Fig. 14

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3,285,514

HEAT EXCHANGERS

Horace L. Smith, Jr., Richmond, Va., assignor to Hupp Corporation, Cleveland, Ohio, a corporation of Virginia

Original application Nov. 14, 1963, Ser. No. 323,848. Divided and this application Mar. 25, 1966, Ser. No. 537,510

14 Claims. (Cl. 237—63)

This application is a division of United States application Number 323,848, filed November 14, 1963, for Heat Exchangers.

This invention relates to heat exchangers and, more particularly, to heat exchange units of the tubular type and to systems employing such units.

Tubular heat exchangers of various kinds are well known. One kind of tubular heat exchanger (hereinafter referred to by the appellation radiator) consists of a planar array of intercommunicating, parallel flow passages formed, for example, by metal tubes. Hot water or steam is circulated through the tubes, heating them to a temperature at which the tubes will emit substantial quantities of radiant energy.

Such radiators are used for many different purposes such as, for example, to dry continuously moving webs of sheet material. In this and other applications, however, currently available radiators have a number of serious limitations. Because of different physical limitations they can only be made to span relatively short distances; and they are, therefore, not suitable for installations in which heating of a large area is required as in a large paper manufacturing machine, for example.

Another disadvantage of currently available radiators is that the cross-sectional area of the flow passages is relatively small and the volume of liquid that can be circulated through the now available radiators per unit of time is quite limited. Consequently, the radiant energy output of currently available radiators is not sufficient for many applications.

A further drawback of currently available radiators is that the materials of which they are fabricated are relatively inefficient emitters of radiant energy. For example, rolled sheet steel, a common radiator material, has an emissivity coefficient ranging from 0.65 to only 0.82 (a perfect emitter has an emissivity coefficient of 1.0). Because of their inefficiency as emitters of radiant energy, also, currently available radiators are unsuitable for many applications.

Another drawback of currently available radiators is that they emit radiant energy in a non-uniform pattern because there are no emitting surfaces between the radiator tubes. Uneven emission patterns are particularly disadvantageous in many radiator applications. For example, in material drying applications the non-uniform emission pattern may result in streaking of the material.

A further drawback of currently available radiators is that they are suitable only for relatively low temperature applications. Water, the most commonly employed heat transfer fluid, has a boiling point of only 212° F. Steam has also been employed as the circulating heat transfer medium but it too has drawbacks. As the steam temperature is increased above 212° F., its pressure rapidly increases to the point where, for both economic and design considerations, it is not feasible to fabricate a radiator which is sufficiently strong to withstand the pressure of the steam circulated through it. In addition, provision must be made to continuously drain condensate from the radiator. This is often difficult, especially where the radiator has a curved or irregular configuration.

It is one object of the present invention to provide

novel, improved radiators in which the foregoing disadvantages of the prior art are not present.

In general, the novel radiators of the present invention, by which the foregoing object is accomplished, include a novel planar array of plural, internested, sinuous tubes providing independent flow passages through which a fluid heat transfer medium is caused to flow in counterflow relationship. These novel radiators can readily be made in any desired size and can be arranged to accommodate substantially higher volume rates of flow than currently available radiators of comparable size. Consequently, the radiators of the present invention may be made larger and may be designed to produce a greater heat energy output than the radiators theretofore available.

The radiant surfaces of the novel radiators of the present invention are preferably coated with a highly emissive substance, preferably a crystalline, crypto-crystalline or amorphous ceramic such as very thin fused glass frits, preferably of the order of 0.003 to 0.007 inch thick Such coatings inherently have low thermal conductivity, but, in my preferred thickness range, I have discovered that they have negligible temperature gradients through the coatings and emissivity coefficients very close to 1.0 and are therefore virtually perfect radiators. In this manner, the efficiency of the radiators of the present invention can be increased well beyond the maximum efficiencies attainable in presently available radiators.

Another novel feature of the present invention is the provision of conductive webs between and connected to adjacent tube runs in the radiator. These webs are radiation emitters and greatly increase the area of the radiant surfaces of the radiators of the present invention over that of a currently available radiator of the same size.

By properly configuring these webs a substantially uniform temperature can be maintained across the entire radiant face of a radiator constructed in accordance with the principles of the present invention. These radiators, therefore, emit radiant energy in a substantially uniform pattern and at a uniform intensity, eliminating the problems arising from the non-uniform emission of radiant energy by conventional radiators.

These benefits are obtained to a quite appreciable extent by using webs having a unifform cross section. They may be achieved to an even greater extent, however, by using a web with a tapered cross section; i.e., a section which is narrower at its midpoint than at the edges where the web is joined to the tubes. By employing webs of tapered section, the ratio of emitted radiant energy to weight of plate is increased over that obtained from a web of uniform section. Consequently, for a given amount of radiated energy, a radiator utilizing tapered webs may be made lighter than one using uniformly sectioned webs. Conversely, by employing tapered webs, a radiator having a materially greater radiant heat output than a radiator of equal weight with uniformly sectioned webs can be provided. In sum, the use of tapered webs beneficially increases the heat output-radiator weight ratio of the radiators provided by the present invention.

As discussed above one of the advantages of the present invention is that its principles may be employed to fabricate very large radiators. Another novel feature of the present invention resides in the employment, in large radiators of the type described above, of conductive webs having T cross sectional configurations. By using such webs, even very large radiators may be made self-supporting, eliminating the need for intermediate radiator supports and for any stiffeners other than the conductive webs. Simpler and less expensive installation are two extemplary benefits that therefore result from the use of these novel conductive webs.

Another advantage of the present invention is that higher radiator temperatures may be achieved than have heretofore been possible. As a result, heat output is increased and the time required for drying and other heat treating steps may be materially shortened, increasing the speed and thereby lowering the cost of many processes. This highly desirable result is achieved by employing a liquid having an extremely high boiling point as the circulating heat transfer medium rather than water or steam as in present radiator systems. In addition, as the heat transfer medium always remains in the liquid state, none of the problems attending the use of the steam as a heat transfer medium are encountered. Moreover, system components designed to withstand lower pressures and therefore much less expensive than the components employed in the lower temperature prior art steam heated systems may be employed since the system only need be pressurized to the extent necessary to circulate the liquid through the system.

The principles of the present invention may also be utilized to advantage in heat exchangers employed to absorb rather than radiate heat. For example, the principles of the present invention may be efficaciously employed to provide a more efficient tube wall for the radiant sections of steam generating and similar fluid heating units.

As discussed above, the tubular heat exchangers of the present invention, due to the combined use of an emissive coating and conductive webs, are highly efficient emitters of radiant energy. Bodies that are good emitters are equally good absorbers of radiation, and it can readily be shown that their absorptivities are equal to their emissivities. Therefore, heat exchangers employing the novel combination of conductive webs and emissive coating discussed above are highly effective absorbers of radiations and may be advantageously employed in circumstances where absorption of radiant energy is required.

Other objects of the present invention include:

(1) The provision of novel, improved radiators which may be fabricated in sizes suiting them for distributing radiant energy over larger areas than has heretofore been possible;

(2) The provision of novel, improved radiators which are able to accommodate higher volume rates of flow of heat transfer fluid than radiators currently available and which have a greater radiant heat output per unit area of radiant surface than currently available radiators;

(3) The provision of novel, improved radiators having radiant surfaces that are more efficient emitters of radiant energy than the radiant surfaces of the radiators heretofore available;

(4) The provision of novel, improved radiators which may be fabricated in such a manner that they will emit a substantially uniform pattern of radiation over their entire radiant surface;

(5) The provision of novel, improved radiators which have radiant surfaces of substantially greater area than heretofore available radiators of comparable size;

(6) The provision of novel, improved radiators in accordance with the foregoing objects which are inexpensively manufactured and which have a long useful life;

(7) The provision of novel, improved radiant heating installations employing a circulating liquid heat transfer medium and in which the radiators may be heated to higher temperatures than have heretofore been possible in systems of this type;

(8) The provision of novel, improved radiant heating installations having a circulating heat transfer medium which always remains in the liquid state;

(9) The provision of novel improved radiators which are self-supporting, even in very large sizes, thus eliminating any need for stiffeners or intermediate supports.

Other objects and further novel features of the present invention will become more fully apparent from the appended claims and as the ensuing detailed description and discussion proceeds in conjunction with the accompanying drawing, in which:

FIGURE 1 is a diagrammatic illustration of a novel heating system employing radiators of the type provided by the present invention;

FIGURE 2 is a front elevation of a one form of radiator constructed in accordance with the principles of the present invention with the insulation which may be applied to one side of the radiator to reduce heat losses therefrom omitted for the sake of clarity;

FIGURE 3 is a top plan view of the radiator of FIGURE 2;

FIGURE 4 is a left-hand end view of the radiator of FIGURE 2 with the above-mentioned insulation similarly omitted for the sake of clarity;

FIGURE 5 is a section through the radiator of FIGURE 2, taken substantially along line **5—5** of FIGURE 3;

FIGURE 6 is a figure showing temperature distribution across a web having a tapered section;

FIGURE 7 is a chart of the temperature distribution across the web of FIGURE 6;

FIGURE 8 is a partial front elevation of a second form of radiator constructed in accordance with the principles of the present invention;

FIGURE 9 is a top plan view of the radiator of FIGURE 8;

FIGURE 10 is a section through the radiator of FIGURE 8, taken substantially along line **10—10** of the latter figure;

FIGURE 11 is a plan view of another form of the present invention which may be made self-supporting, even in very large sizes;

FIGURE 12 is a section through the radiator of FIGURE 11 taken substantially along line **12—12** of the latter figure;

FIGURE 13 is a view similar to FIGURE 12 of a radiator of the type illustrated in FIGURE 11, but employing a modified form of conductive web; and

FIGURE 14 is a view similar to FIGURE 13 of a radiator of the type shown in FIGURE 11, but employing yet another form of conductive web.

Referring now to FIGURE 1 of the drawing, heating system **20** includes a fluid heating unit **22**, a novel radiator **24** constructed in accordance with the principles of the present invention, a closed system of flow conduits for circulating a heat transfer medium through the system, and a pump **26** for effecting flow of the heat transfer fluid through the system.

One of the novel features of the present invention resides in employing a high boiling point liquid as the circulating medium, permitting the medium to be circulated at extremely high temperatures in liquid form. Consequently, the heat transfer medium may be heated to very high temperatures and yet the heating system components need be designed to withstand only very low pressures.

The preferred heat transfer liquids include chlorinated biphenyls, polyphenyl alkyls, aryloryloxysilanes, and eutectic salt mixtures as described in detail in parent application No. 323,848.

Referring again to FIGURE 1, heating unit **22** is preferably of the shell and tube type. As illustrated, heating unit **22** includes sinuous heating tubes **28** (only one of which is shown) through which the circulating medium flows and over which hot gases generated by combustion units **30** pass. Heating tubes **28** and one or more combustion units **30** are housed in an outer shell **32** which is preferably lined with an appropriate refractory (not shown) to radiate heat to heating tubes **28**. The combustion units **30** may be either gas or oil burners or, if heating unit **22** is of larger capacity, may be coal fired.

The outlets of heating tubes **28** are connected to the main supply conduit **34** through which the heated circulating medium flows to radiator **24**. From radiator **24**, the circulating heat transfer medium is returned to heating unit **22** through main return conduit **36**. In the illus-

trated diagrammatic figure, circulating pump **26** is interposed in return conduit **36**. This location is not critical but is merely exemplary of several possible locations for the circulating pump.

The above-described portion of the heating system is not, in itself, claimed to be novel and an elaborate description of its components is therefore not deemed necessary. One suitable heating and circulating system is that shown in copending application No. 237,817 filed November 15, 1962, by Horace L. Smith, Jr. for High Temperature Heating Apparatus (now Patent No. 3,236,-292) to which reference may be had if deemed necessary for an understanding of the present invention.

The primary novelty of the present invention resides, in one aspect of the invention, in the novel radiator units which it provides and in their employment in heating systems of the general type described above.

Referring next to FIGURES 2–4 of the drawing, radiator **24** includes two sinuous, internested tube assemblies **38** and **40** providing labyrinthine flow paths for the heat transfer medium circulated through heating system **20** by pump **26**. Tube assembly **40** is formed from a single tube bent to form parallel, spaced, side-by-side straight runs **42** connected, alternately, by end bends **44** at the left-hand end of the radiator and end bends **46** at the radiator's right-hand end. Tube assembly **38**, like tube assembly **40**, is formed from a single tube and consists of straight runs **48** interconnected by end bends **50** at the left-hand end of the radiator and end bends **52** at the radiator's right-hand end. As is best shown in FIGURE 4, the end bends **44** and **46** of tube assembly **40** are also bent outwardly to one side of the radiator and the end bends **50** and **52** of tube assembly **38** are similarly displaced toward the other side of the radiator, permitting tube assemblies **38** and **40** to be internested as shown in FIGURE 4 with the centerlines of the straight runs **42** of tube assembly **40** and the straight runs **48** of the tube assembly **38** lying in the same plane.

Tube assembly **38** has an inlet **54** and an outlet **56**. Tube assembly **40** has an inlet **58** and an outlet **60**. As is shown by the arrows in FIGURE 3, the heat transfer medium flows in opposite directions through the two tube assemblies **38** and **40**, providing the most efficient exchange of heat between the heat transfer fluid and the tube assemblies possible.

As is best shown in FIGURES 3 and 5, rectangular webs of conductive material **62**, extending substantially the length of radiator **24**, are interconnected between each straight run **42** of tube assembly **40** and the adjacent straight runs **48** of tube assembly **38**, as by welding. Similar webs **64** are fixed to the top of the uppermost tube run **48** and to the bottom of the lowermost tube run **42**. Conductive webs **62** and **64** increase the radiant surface of radiator **24** and, in addition, help bring about a substantially uniform emission of radiant energy across the entire radiant surface of radiator **24** since the net effect of the internested tube assemblies, conductive webs, and the counterflow circulation of heat transfer fluid described above is to maintain the entire radiant surface of radiator **24** at a substantially uniform temperature as is explained in more detail in parent application No. 323,848.

Turning now to FIGURE 6, the web **68** interposed between tube runs **70** and **72** has a double tapered cross section, i.e., both sides of web **68** have a V-like configuration with the apex of the V at the midpoint of the web. In the illustrated exemplary example, web **68** is 9/16 inch thick at its edges and 3/16 inch thick at its midpoint. The temperature distribution in web **68** is shown in graphical form by the curve **74** of FIGURE 7. There is a substantially more nearly linear distribution of temperature in tapered web **68** than there is in the uniformly sectioned web **62**.

By employing double-tapered webs in the novel radiators of the present invention, the radiant heat output per unit weight of web material is materially increased. As a result, a radiator of a given radiant heat output may be made substantially lighter; or, conversely, for a radiator of given weight, the radiant heat output may be materially increased by employing double-tapered webs.

Another advantage of the double-tapered construction is that, for a web of given cross sectional area, a web having this construction will have a substantially larger area in contact with the tube runs to which it is joined than a uniformly sectioned web of the same cross sectional area. Since the double-tapered construction has a larger area in contact with the tube runs, heat is conducted with greater efficiency from the heat transfer medium flowing through the tube runs into the web, increasing the efficiency of the radiator.

The double-tapered web illustrated in FIGURE 6 and discussed above need not necessarily be employed to obtain the foregoing advantages. These may also be obtained by employing a non-uniformly sectioned web having one flat surface like a rectangularly sectioned web and one V-like surface as is employed in the double-tapered web **68** of FIGURE 6.

The degree to which the beneficial results discussed above may be obtained is dependent upon the degree of taper and upon the web's cross sectional area. For example, a double-tapered web decreasing in width from 3/4 inch at its side to 3/16 of an inch at its midpoint will not only have a more linear temperature distribution than web **68**, but there wil also be a materially smaller decrease in temperature from the edges to the midpoint of the web.

Referring next to FIGURE 5, the efficiency of radiator **24** may be substantially increased by enhancing the emissivity of the radiator's radiant surfaces identified generally by reference characters **80** and **82**. This is accomplished by coating radiant surfaces **80** and **82** with a highly emissive material. The coating may be applied in any suitable manner, as by chemical means such as anodizing, or by brushing, spraying, or rolling followed by subsequent baking or heat treatment, or by electrical deposition. Examples of suitable coatings are the colored silicone varnishes, lamp black applied in an appropriate vehicle, black enamel, lacquer and shellac.

Another highly suitable coating may be applied in accordance with the ebonizing process disclosed in United States Patent No. 2,394,899 which may be utilized to provide a smooth black oxide film or skin about 0.001 inch thick on the radiant surfaces by applying it in the manner described in parent application No. 232,848.

I have also discovered that very thin ceramic coatings such as commercially available glass frit enamels may be fused to metal surfaces to provide emissivity coefficients up to 0.98. Such coatings are highly durable and will withstand relatively high temperatures without substantial impairment of heat transfer through the metal. Such coatings can be separated from their base, if at all, only with great difficulty, and will retain their integrity as highly emissive surface coatings for relatively long periods of time. Glass frit coatings may be applied in the manner described in parent application No. 323,848. For most applications, one coating is all that is necessary to give good service performance. If severe corrosive conditions are to be encountered, one or more additional coats may be applied to the radiator.

The side of the radiator opposite the radiant surfaces is preferably coated with an appropriate insulating material **84** to prevent heat losses. If radiator **24** is employed in an application in which it is disposed between two areas or articles to be heated, insulation **84** is deleted; and a high emissivity coating is applied to both sides of the radiator.

The radiator **24***a* shown in FIGURES 8–10 is in many respects similar to the radiator **24** shown in FIGURES 2–5. Therefore, insofar as components of the two radiators are identical, like reference characters have been em-

ployed to identify these components except that the components of radiator **24***a* are followed by the letter *a*.

The two tube assemblies **38***a* and **40***a* of radiator **24***a* are formed in the same manner so only the fabrication of tube assembly **38***a* will be discussed in detail, it being understood that these remarks apply also to tube assembly **40***a*.

Referring first to FIGURE 8, tube assembly **38***a* consists of straight runs **48***a* and end bends **50***a* which are independent members and are joined as by welding. Each of the end bends **50***a* is made up of three 90° elbows, **96**, **98**, and **100**, joined to each other and to adjacent straight runs **48***a* of the tube assembly as by welding. As is shown in FIGURE 10, end bends **50***a* have substantially the same configuration as the end bends **50** in radiator **24**, permitting the two tube assemblies **38***a* and **40***a* to be assembled in internested relationship with the centerlines of the straight runs **42***a* in tube assembly **40***a* and the straight runs **48***a* in tube assembly **38***a* located in the same plane.

The radiator **118***a* illustrated in FIGURES 11 and 12 is, in most respects, similar to the radiators described previously, differing mainly in the construction of the conductive webs between the adjacent legs of the sinuous tube assembly. In radiator **118***a*, the conductive webs **128***a* have a T cross sectional configuration, providing a rectangularly sectioned stem **148** and a double-tapered arm **150**.

T-section members of this configuration are widely available in a variety of sizes and materials from various producers of structural shapes.

Preferably, the T-sectioned webs **128***a* are so dimensioned that the neutral axes of the webs lie in the same plane as the centerlines of the tube assembly legs **124***a*. Thus arranged, the section modulus of the composite tube-web assembly forming radiator **118***a* is the sum of the section modulus of tube assembly **122***a* plus that of the webs **128***a*.

This provides a substantially higher section modulus than is obtained by using flat conductive webs such as those shown at **62** in the embodiment of FIGURE 2 for two reasons. First, the T-sectioned web **128***a* has a much higher section modulus than a flat conductive web of the same width. Second, as the section modulii of the webs and the tube legs lie in the same plane, they are additive which is not the case when a flat conductive plate is employed.

Because of the substantially increased section modulus, radiators formed in the manner just described are substantially stiffer than those of the preceding embodiments; and, consequently, radiators of very long lengths which are entirely self-supporting may be readily fabricated. This, in turn, eliminates the need for auxiliary stiffening members and intermediate supports, obviating the expense and other disadvantages of such members.

Typically, tube assembly **122***a* may be schedule **40** tubing having an outside diameter of 1.5 inches with legs **124***a* spaced 4.5 inches on center. In this case standard three inch by three inch T-sectioned members (having a section modulus of 0.74) may be employed as conductive webs. The resulting composite tube-web radiator structure will have a composite section modulus of 0.887 and a weight of 25.15 pounds per square foot.

Even greater strength per unit weight of material may be obtained by employing webs having the cross sectional configuration illustrated in FIGURES 13 and 14. The web **152** illustrated in FIGURE 13 is of generally T-shaped cross sectional configuration, having a rectangularly sectioned stem **154** and arm **156**. Web **152** also has, at the edge of stem **154** opposite arm **156**, a generally rectangularly sectioned flange or bulb section **158**. For a radiator of the dimensions discussed above, in which web **152** would have the same stem and arm dimensions as web **128***a*, bulb section **158** would typically be on the order of 2.0 inches wide and 0.5 inch thick. The section modulus of web **152** is 2.46 as compared to the 0.74 section modulus of web **128***a*. The modulus of the composite tube assembly-web structure is 2.67 (as compared to a modulus of 0.887 for the embodiment illustrated in FIGURES 11 and 12); and the radiator weight is 32.5 pounds per square foot.

It will be apparent from the foregoing that, by employing the web **152** of FIGURE 13, a much stiffer web can be provided at very little increase in weight. Conversely, in comparison with the embodiment of FIGURE 11, an equally stiff radiator can be provided at a lower weight by employing webs having the cross sectional configuration of web **152**.

The web **160** illustrated in FIGURE 14 is identical to that illustrated in FIGURE 13 except that the two web arms **162** and **164** extending from the web's stem **154** are substantially wider at the outer edges **166** where they are connected to tube legs **124***a* by welds **168** than at their inner edges where they are integral with stem **154**. This web configuration has approximately the same section modulus as the web **152** illustrated in FIGURE 13. Where maximum efficiency is desired, web **160** is preferred over web **152** since the double-tapered web portion provided by flanges **162** and **164** permits maximum heat flow by conduction for the reasons discussed above and in parent application No. 323,848. However, this section is difficult and expensive to roll and may be deemed inferior to web **152**, which can be readily rolled, in applications where the ultimate in efficiency is not required.

For the sake of simplicity, only a single tube run has been illustrated in FIGURE 11. It will be apparent from the foregoing and is to be understood, however, that the T-sectioned webs illustrated in FIGURES 11–14 may equally well be employed in radiator embodiments such as those described previously in which internested tube assemblies are employed to permit counterflow circulation.

Also, as illustrated, radiator **118***a* has separate end bends **170** joined to tube legs **124***a* as by welding. It will be apparent that tube assembly **122***a* could equally well be formed from a single sinuous tube, if desired. Such modifications are, therefore, to be understood as being within the scope of the present invention.

Many variations in the application of the principles of this invention to tubular heat exchangers utilized to absorb heat may be made without exceeding the scope of the invention. For example, these principles may be applied to water walls composed of straight tubes and upper and lower headers as well as to the illustrated tubular heat exchangers.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

1. A radiant heating installation, comprising:

(a) a radiator having plural sinuous internested tube assemblies providing independent flow circuits, each of said tube assemblies being fabricated of a heat conductive material and having substantially parallel straight runs connected by end bends with the centerlines of the straight runs of the two tube assemblies being substantially coplanar and T-sectioned conductive webs between adjacent ones of said runs, said webs being connected directly to said tube runs and extending therealong to increase the radiant surface of said radiator; and

(b) means for effecting simultaneous counterflow of

a heat transfer fluid through said independent circuits.

2. The radiant heating installation as defined in claim 1, wherein adjacent end bends lie on opposite sides of the plane including the centerlines of the straight runs.

3. The radiant heating installation as defined in claim 1, wherein each of said end bends consists of three elbows.

4. The radiant heating assembly as defined in claim 1, wherein the conductive webs have a tapered cross section, said webs being thinner at their midpoints than at their edges.

5. The radiant heating installation as defined in claim 1, including a coating of high emissivity material on at least one side of said radiator.

6. The radiant heating installation as defined in claim 2, wherein said coating is a ceramic material fused to the radiating surfaces of said radiator.

7. The radiant heating installation as defined in claim 1, including:

(a) a fluid heater;

(b) a supply line connected between said heater and the inlets of said tube assemblies;

(c) a return line communicating between the outlets from said tube assemblies and the heater; and

(d) a pump for forcing the heat transfer liquid seritatim through said heater said tube assemblies.

8. The radiant heating installation as defined in claim 1, wherein each of said tube assemblies is a single tube.

9. In a radiant heating installation:

(a) a plurality of spaced tube runs having substantially uniplanar centerlines; and

(b) T-sectioned conductive webs between and extending substantially the length of adjacent runs.

10. The radiant heating installation as defined in claim 9, wherein the neutral axes of said webs lie substantially in the plane of said centerlines.

11. The radiant heating installation as defined in claim 9, wherein said webs each have a stem and flanges extending normally and in opposite directions from said stem and said flanges have tapered sections and are wider at their free edges than at the flange-stem junctures.

12. The radiant heating installation as defined in claim 9, wherein at least some of said webs have a stem and flanges extending normally and in opposite directions from one edge of the stem and an integral bulb section at the opposite edge of said stem for increasing the section modulus of the web.

13. A radiant heating installation, comprising:

(a) a liquid heating unit;

(b) at least one radiator having plural independent flow circuits provided by plural sinuous internested tube assemblies each having an inlet and an outlet, a plurality of spaced tube runs, T-sectioned conductive webs extending between and substantially the length of adjacent ones of said runs, and a highly emissive and absorptive coating on one side of the assemblage formed by said tube runs and said conductive webs;

(c) a branched supply conduit and a branched return conduit connecting said heating unit and said radiator into a closed circulation system, the branches of said supply conduit being connected in parallel to the inlets of said tube assemblies and the branches of said return conduit being connected in parallel to the outlets of the tube assemblies and the inlet of each of said tube assemblies being adjacent the outlet of another of said tube assemblies to provide counterflow in the radiator circuits; and

(d) a high boiling point liquid heat transfer medium in said closed system.

14. A radiant heating installation, comprising:

(a) a radiator having plural sinuous internested tube assemblies providing independent flow circuits, each of said tube assemblies having substantially parallel straight runs connected by end bends, the centerlines of the straight runs of the two tube assemblies being substantially coplanar and the runs of the two tubes being alternated, the end bends in one of said assemblies all lying to one side of the plane including said centerlines and the end bends in the other of said assemblies all lying to the other side of said plane;

(b) T-sectioned conductive webs between adjacent webs; and

(c) means for effecting simultaneous counterflow of a heat transfer fluid through said independent circuits.

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