Aug. 3, 1965 C. BOLING 3,197,975

REFRIGERATION SYSTEM AND HEAT EXCHANGERS

Original Filed Feb. 8, 1960

FIG. 1

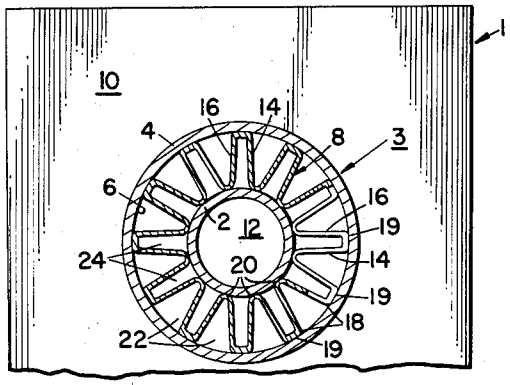


FIG. 2

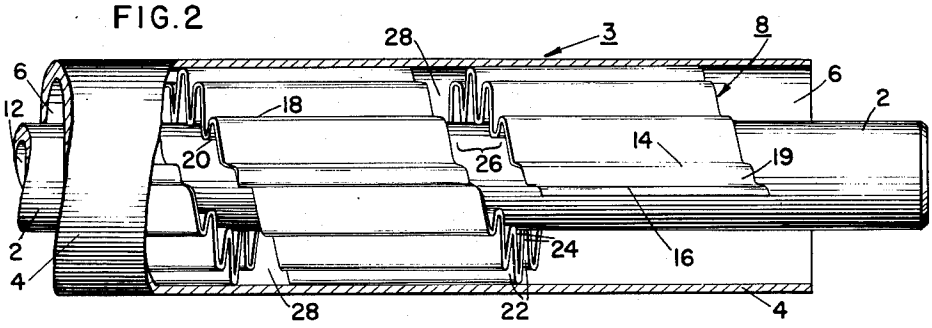


FIG. 3

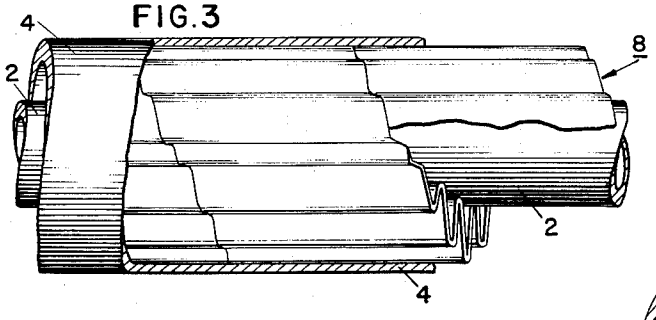


FIG. 4

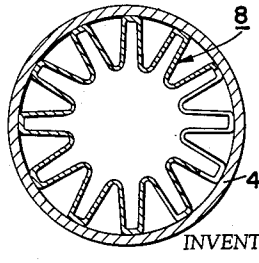
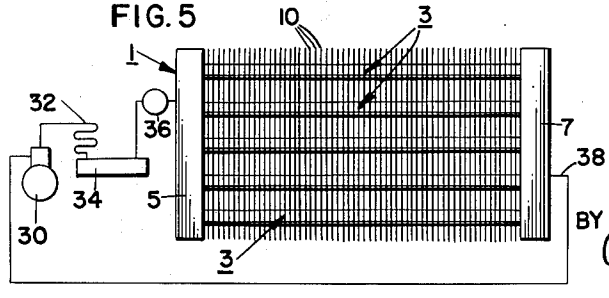


FIG. 5



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3,197,975
REFRIGERATION SYSTEM AND HEAT EXCHANGERS

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1 Claim. (Cl. 62—498)

This invention relates to refrigeration systems and heat interchange equipment forming parts thereof, and more in particular to refrigeration systems having evaporators which are adapted to cool fluids by direct evaporation of refrigerant, for example in air conditioning systems. The present application is a continuation of my copending application, Serial No. 7,223, filed February 8, 1960, and now abandoned, which was a continuation of Serial No. 310,820, filed September 22, 1952, and now abandoned. The invention of the present application is related to those disclosed in the following applications which were copending with the above-identified application Serial No. 310,820: Serial No. 17,899, filed March 30, 1948, and issued September 23, 1952, as Patent No. 2,611,585; application Serial No. 176,128, filed July 27, 1950, and issued September 23, 1952, as Patent No. 2,611,587; and, application Serial No. 256,204, filed November 14, 1951, and now Patent No. 2,658,358.

In Patent Nos. 2,611,585 and 2,611,587 there are disclosed novel fin constructions wherein a sheet metal fin is positioned within an annular passageway between two walls with each of the fin portions extending transversely of the passageway substantially radially. The fin portions are under radial compression so that their edges tightly engage the inner and outer annular surfaces defining the passageway. This insures good heat transfer relationships between the fin portions and each of the walls which present the annular surfaces.

In Patent No. 2,611,587, heat transfer unit constructions are disclosed incorporating an improved form of said fin construction which are used to give high heat transfer relationships between fluids in two or more separate streams of fluid. These heat transfer unit constructions may be used, for example, as air and water-cooled condenser; for such use, the cooling water flows through the inner tube, and the refrigerant flows through the annular passageway between the inner tube and an outer tube and is condensed. This annular passageway contains the improved fin construction which has been referred to, and for air cooling the outer tube carries external fins. Thus, the heat from the refrigerant is carried radially either inwardly to the water within the inner tube or outwardly to the air which is blown over the external fins.

The heat transfer unit construction just referred to has other uses wherein it has the exact form just described or it may be of a different form. For example, when no air transfer operation is involved, the external fins are omitted; and, when desirable, the unit may be used as an evaporator with heat being taken from the air through the external fins, or from liquid flowing through the inside tube or along the external surface of the outside tube. Additional details of construction and use of heat transfer units of this character will be obtained by referring to the patents identified above which are hereby incorporated into the present application to the extent that such is desirable.

It is an object of the present invention to provide an improved refrigeration system incorporating improved heat interchange units of the above character, but of improved construction. It is a further object to provide

improved refrigeration systems characterized by improved evaporators. It is a further object to provide an improved fin construction of the character referred to above which will give improved results in a refrigeration system under various conditions of operations and use. It is a further object to provide for the manufacture of fin constructions of elements of a refrigeration system in an improved manner and in such a way as to make the manufacturing operation as nearly automatic as possible. It is a further object to provide a fin construction which is highly versatile in the sense that a single size and type or construction of fin may be so applied as to provide varying amounts of heat transfer surface for a given length of tubing.

A further object is to provide elements of a refrigeration system with an improved fin construction where the resistance to flow is at a minimum and yet the heat transfer rate is high. A further object is to provide a fin assembly of the above character which may be used with or without a coating or dipping operation to produce a soldered or adhesive bond between the elements. These and other objects will be in part obvious and in part pointed out below.

In the drawings:

FIGURE 1 is a sectional view of one embodiment of the invention;

FIGURE 2 is a side elevation with parts broken away of a portion of the unit of FIGURE 1;

FIGURE 3 is a view similar to FIGURE 2 but showing another embodiment of the invention;

FIGURE 4 is a view similar to FIGURE 1 but showing another embodiment of the invention; and,

FIGURE 5 is a schematic representation of a refrigeration system having an evaporator incorporating the fin construction of FIGURES 1 and 2.

Referring to FIGURE 5 of the drawings, a refrigeration system has an evaporator 1 shown in side elevation, and the following components represented schematically: a compressor 30; a condenser 32; a receiver 34; an expansion valve 36; and a return line 38 for the refrigerant gas. Evaporator 2 is formed by five tube assemblies 3 mounted in parallel relationship between a pair of headers 5 and 7. Each of the tube assemblies 3 is of the type shown in FIGURES 1 and 2, and this construction will now be described in detail.

Referring to FIGURE 1, an inner tube 2 is concentrically positioned within an outer tube 4 so as to form an annular passageway 6 within which a fin assembly 8 is arranged as shown. The outer tube 4 carries a plurality of sheet metal fins 10 so as to provide for the ready transfer of heat between the surrounding air and fluids flowing through passageway 6 and the passageway 12 within the inner tube 2. During manufacture each fin 10 is formed onto and placed onto tube 4. The tube is then expanded slightly so as to tighten the fins on the tube, thus insuring a good mechanical and heat transfer relationship. The fin assembly 8 and tube 2 are then assembled within tube 4 and tube 2 is expanded so as to compress the fin assembly radially between the inner surface of tube 4 and the outer surface of tube 2. The compressive forces are sufficient to insure good heat transfer relationships between each of the tubes and the fin assembly; and, the individual fin elements 14 and 16 have sufficient rigidity and strength to withstand the compressive forces.

The fin elements are interconnected by trough-like portions 18 adjacent tube 4 and by trough-like portions 20 adjacent tube 2. Portions 18 are substantially wider than portions 20. Each portion 18 has a substantially flat portion 19 which mates with the tube surface so as to give a substantial surface contact, and each portion 20

has a similar but narrower tube-contacting portion. This produces passageways 22 each of which is defined by a pair of the fin elements and a portion of the outer tube 14, and passageways 24 each of which is defined by a pair of fin elements and a portion of the inner tube 2. Passageways 22 are slightly greater in cross-section than passageways 24, but all of the passageways are of sufficient cross-sectional dimensions to permit the free flow of fluids longitudinally of the passageways 6. Furthermore, the construction and relationship of parts gives optimum heat transfer characteristics between the various elements.

The fin assembly 3 is formed of a relatively narrow strip of sheet metal which is initially corrugated in a special manner from its original flat condition, and the corrugated strip is then wound spirally and inserted within tube 4. The corrugations are formed by inter-acting dies to which the strip of sheet metal is fed at an angle. That is, in the completed heat transfer unit the fin elements extend parallel to the axis of the tubes, and the strip of sheet metal is corrugated at such an angle that this fin element and tube relationship is obtained.

The spiral winding of the corrugated strip to form the fin assembly is such that an open spiral is formed, thus leaving a strip 26 (see FIGURE 2) of bare tube between adjacent turns of the spiral. Thus, there is an open spiral passageway 28 into which the ends of each longitudinal passageway 22 and 24 opens and each of these longitudinal passageways extends for only a short length of the tube. Therefore, when the refrigerant is being evaporated in the annular passageway 6, the refrigerant flows freely through passageways 22 and 24. The liquid tends to fill certain of the passageways 22 and 24, but this tendency is overcome by the fact that the longitudinal passageways 22 and 24 are broken frequently by the spiral passageway 28. This insures minimum resistance to the flow of the refrigerant through the passageway 6 and yet there is a very efficient transfer of heat from the refrigerant.

The gas and liquid refrigerant both flow freely through the various passageways, and the gas does not become superheated but is resaturated constantly by the flowing liquid refrigerant because the gas and liquid both repeatedly enter the spiral passageway 28. Thus, each of the longitudinal passageways 22 and 24 acts as an efficient heat transfer zone, and the liquid refrigerant is supplied to it in an efficient manner at all times. Furthermore, the objectionable factors are avoided such as excessive resistance to the flow and the flow of unevaporated refrigerant beyond the evaporator zone. Oil which tends to accumulate will also tend to separate from the refrigerant and will flow from the evaporator without difficulty.

With the fin construction of the present invention, the spiral fin construction insures that a high rate of heat transfer is maintained between the fin surfaces and the gas or vapor flowing through passageway 6 (FIGURE 2). When a gas or vapor is flowing through passageway 6 there is a tendency for a stagnant film to build up upon the fin surfaces, downstream with respect to the gas or vapor flow. Assuming that refrigerant is flowing from right to left through passageway 6 there is no stagnant film on the fin surfaces at the right-hand edges of the fin portions, e.g., adjacent the numerals 19, 22 and 24. However, a stagnant film builds up progressively to the left from this right-hand edge of each fin surface, and this stagnant film is progressively thicker toward and to a maximum at the left-hand edge of each of the fin surfaces. This film upon each fin surface remains stationary or stagnant and acts as heat insulation in that it causes resistance to heat transfer.

In this embodiment, the longitudinal dimension of each fin surface is sufficiently small to prevent the formation of a stagnant film sufficient to interfere materially with the proper transfer of heat between the fin portions and the refrigerant. As indicated above, the spiral passageway 28 provides interconnections between the passageways formed by the fin structure, and it also "breaks" the fin structure into "lengths" of fin portions. This feature prevents the building up of a sufficient stagnant film of sufficient thickness to interfere with the desired heat transfer relationship. That is, the dimension of each fin surface in the direction of refrigerant flow is not great enough to permit the stagnant film to build up to an objectionable thickness. Illustratively, the fin elements 14 and 16 extend one inch longitudinally of passageway 6 and passageway 28 is one-quarter inch wide longitudinally of passageway 6. Under some circumstances this dimension of the fin structure may be varied between three-fourths inch and one and one-half inches, and this dimension of passageway 28 may be varied between one-sixteenth to three-sixteenths inch.

Referring again to FIGURE 5, compressor 30 withdraws the refrigerant gas from evaporator 1, compresses it and delivers it to condenser 32 where it is condensed. The liquid refrigerant is collected in receiver 34, from which it flows through a refrigerant line and an expansion valve 36 to header 5 of evaporator 1. In this embodiment, the evaporator 1 has been identified as a coil where air is cooled by the direct expansion of the refrigerant. As indicated above, the evaporator may be of a type for the chilling of water or other liquid where the liquid to be chilled flows in direct contact with tube assembly 3. It should be noted that condenser 32 is preferably of the construction of evaporator 1, in which case the refrigerant is cooled by air contacting fins 10, or by water flowing through tubes 2 in the fin assemblies 3.

The heat transfer construction which has been described may also be used for various other heat transfer operations and it has been indicated that this may be with or without external fins 10. Furthermore, the inner tube 2 may provide a passageway for the same or a different fluid from that which flows through passageway 6. Under some circumstances the tube 2 has its ends closed so as to prevent the flow of fluid therethrough.

In the tube and fin construction described above the heat transfer relationships between the fin assembly and the tubes are solely by virtue of the fin assembly being under radial compression so that a mechanical compression holds each fin portion 18 and 20 tightly against its respective tube surface. Under some circumstances, it is desirable to "dip" or coat the fin assembly and the tube surfaces with solder or the like. This may be to improve the physical and heat transfer characteristics for some conditions of operation, or it may merely adapt the unit for the flow of a fluid which would tend to corrode the fin or tube metal. When such dipping is desirable the melted solder or the like may be poured through the heated assembly, and the solder will flow through each of the passageways 22 and 24 and 28 and complete coverage of all of the surfaces is insured.

In the embodiment of FIGURE 3 the fin assembly is wound in a closed spiral so that adjacent turns of the spiral have their edges in abutting or near-abutting relationship, and there is no open spiral passageway 28 as in FIGURE 2. However, the joint between the ends or edges of adjacent turns of the spiral fin permit leakage to release pressure and resistance to flow in particular passages 22 and 24. Here the corrugations which form the fin elements extend more nearly transversely of the strip than in FIGURES 1 and 2. This increases the amount of heat transfer surface for a given length. The spiral passageway may be narrower or wider than that shown in FIGURE 2 to adapt the heat transfer construction to various conditions of use.

In FIGURES 1 and 2 and also in FIGURE 3, the respective passageways 22 and 24 in successive spiral turns of the fin assembly are in exact alignment so that a straightforward fluid flow is provided. However, the fin assembly may be so constructed that each of the passageways 22 and 24 is out of alignment with the respective passageway of the next adjacent spiral turns.

In this way a broken flow path is provided which gives a turbulent flow and increases the heat transfer relationship for some conditions of operation.

In the embodiment of FIGURE 4 the spiral fin assembly 8 is positioned within tube 3 as in FIGURE 3, but there is no inner tube 2. The fin assembly is soldered to the surface of tube 4 in the manner disclosed above. Under some circumstances the resiliency of the fin assembly is sufficient to give the desired heat transfer characteristics, and the soldering operation is omitted.

It is thus seen that a highly versatile fin assembly is provided wherein a single set of dies may be used to produce fins for a variety of different heat transfer units. That is, the corrugations may be so placed with respect to the longitudinal dimension of the strip of sheet metal that various fin arrangements are produced as desired. This includes variations in the spacing of the spiral turns and variations in the mean radius of the annular passageway where the fin assembly is positioned.

It has been indicated above that the assembly operation can be substantially automatic in that the fin assembly is produced in a continuous operation from a strip of metal drawn from a roll. The strip is then cut each time that the desired length of the spiral fin assembly has been provided to give the total tube length. The fin assembly has its radial fin elements interconnected by trough-like portions which may be semi-cylindrical when the overall width or effective diameter is small. However, when this width is relatively great with respect to the thickness of the metal, there is a substantially flat portion such as at 19 in FIGURE 1. When the fin assembly has been placed under compression, these portions 19 take on the arcuate curvature of the inner tube surface and this curvature of the fin is produced by the die when desirable. Under some circumstances, the width of the trough portions at the inner periphery of the fin assembly may be sufficient to make it desirable to form a tube contacting portion with a somewhat arcuate or cylindrical surface configuration to mate the strip of the tube surface which is contacted.

The manufacturing process which has been referred to above involves the winding of each fin assembly onto a mandrel and the inserting of the fin assembly into the outer tube and the use of the mandrel for inserting the fin assembly into the outer tube. Under some circumstances, it is expedient to wind the fin assembly directly onto the inner tube and to insert the inner tube and the fin assembly into the outer tube simultaneously.

In the illustrative embodiment, the heat transfer unit has headers 5 and 7. For operations where the inner tube 2 does not carry a fluid different from tube 4, the headers may be replaced by U-bends interconnecting the ends of tubes 4. Where the heat transfer unit comprises a sufficient number of tube assemblies to warrant it or where the operation makes it desirable, the tube assemblies are connected in parallel-series relationship with a combination of headers and U-bends.

As many possible embodiments may be made of the

mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth, or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

A refrigeration system including two heat interchange units respectively forming a condenser and an evaporator connected in a refrigerant circuit and means for withdrawing refrigerant vapor from the evaporator at a low pressure and temperature and delivering refrigeration vapor to the condenser at a high pressure and temperature, one of said heat interchange units comprising a plurality of substantially horizontal tube assemblies each being formed by a pair of concentrically positioned tubes defining a substantially annular chamber therebetween which is substantially horizontal and is connected at its opposite ends in the refrigerant circuit for the flow of refrigerant therethrough, and an internal metallic fin assembly within said chamber comprising a strip of corrugated sheet metal extending spirally within said annular chamber with each of the corrugations being substantially straight and non-distortable and extending longitudinally of said chamber and bridging the space between said tubes thereby to divide said annular chamber into a plurality of substantially parallel longitudinal passageways each extending between the side edges of said strip of corrugated sheet metal, the adjacent turns of the spirally formed strip of corrugated sheet metal being spaced from each other to provide a spiral passageway between the side edges of the adjacent turns thereby to reduce the effective length of each of said longitudinal passageways to that of a single corrugation of the strip and to permit arcuate fluid flow of the refrigerant between the serially-related longitudinal passageways along said annular chamber, and the distance between said tubes being such that the inner and outer peripheries of said fin assembly have radial compression forces exerted upon them whereby the corrugations are placed under radial compression and are subjected to sufficient force to insure a good heat transfer relationship between each of said tubes and said internal fin assembly.

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