July 30, 1968 J. F. PEARSON 3,394,736

INTERNAL FINNED TUBE

Filed Feb. 21, 1966

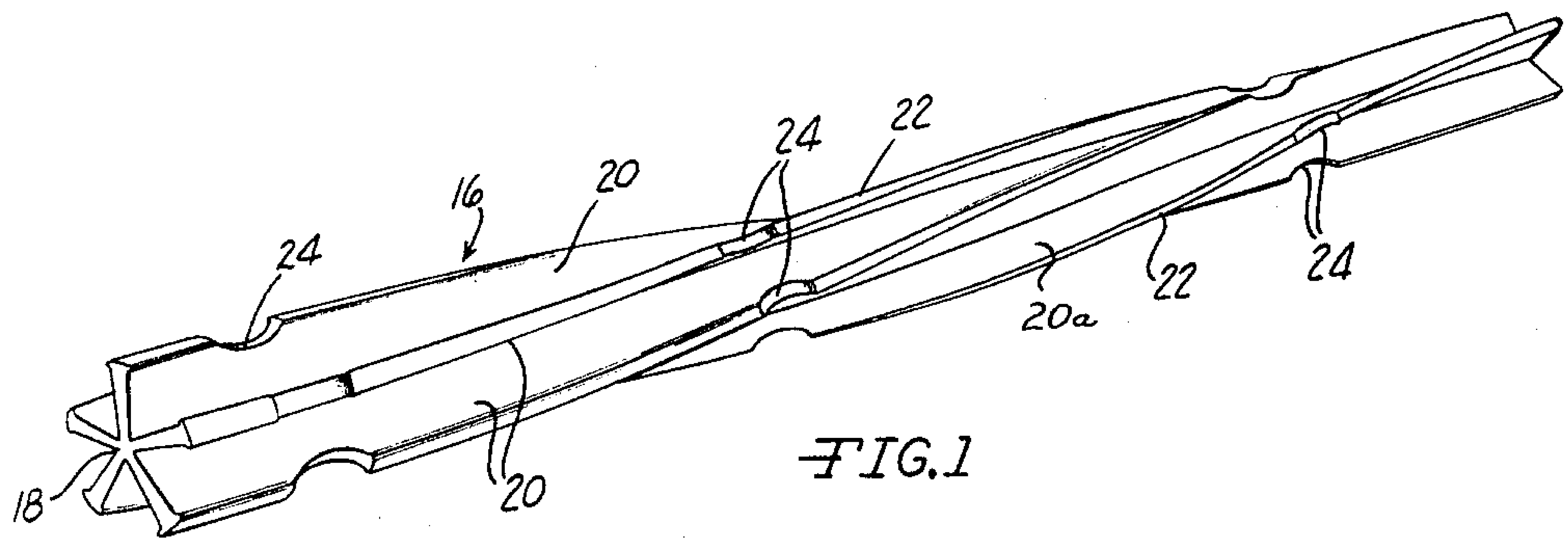

FIG.1

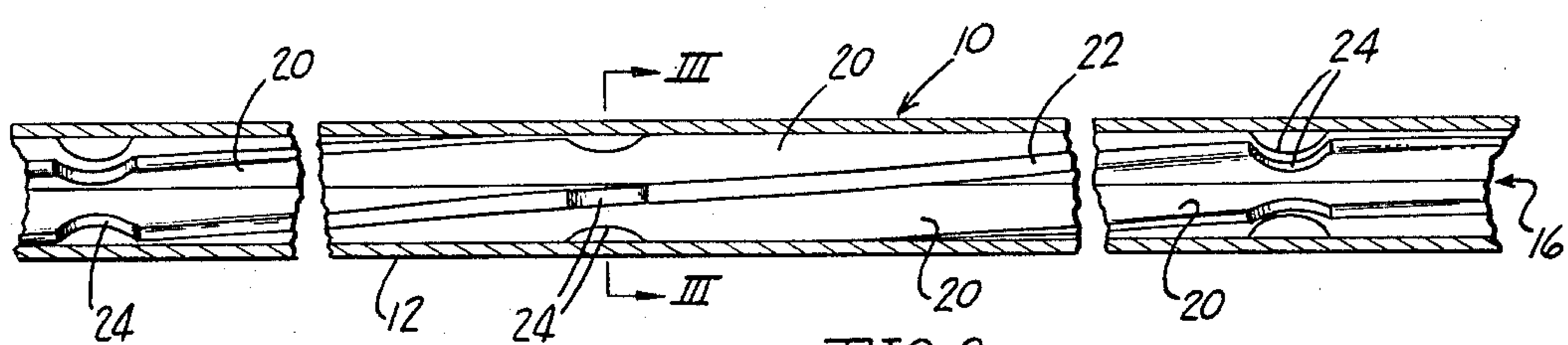

FIG.2

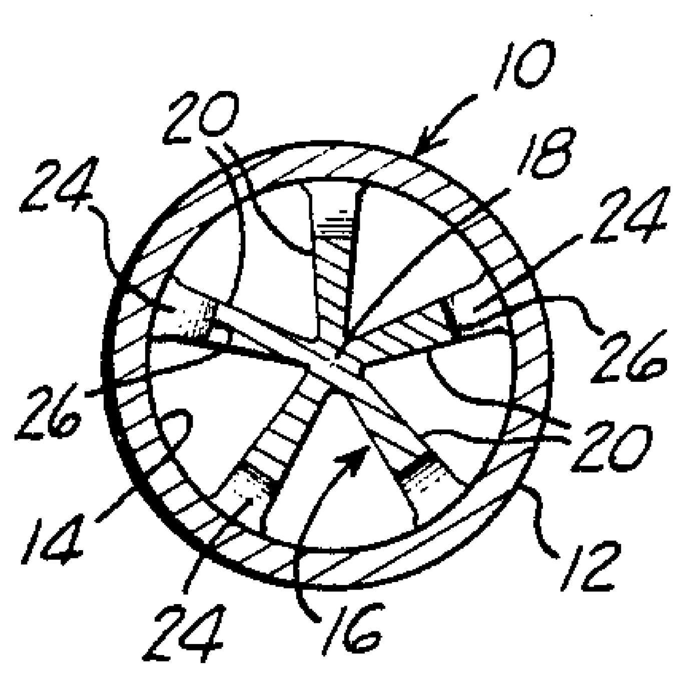

FIG.3

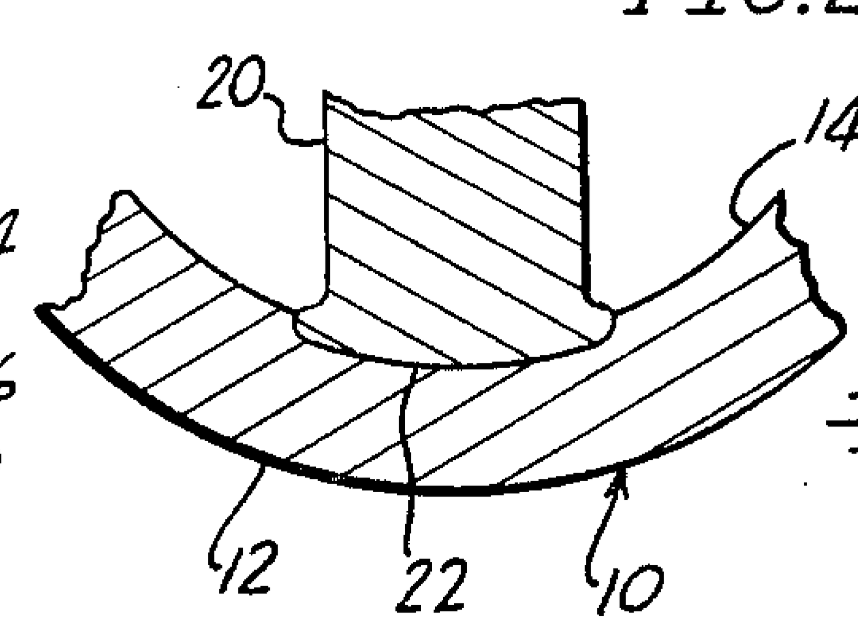

FIG. 4

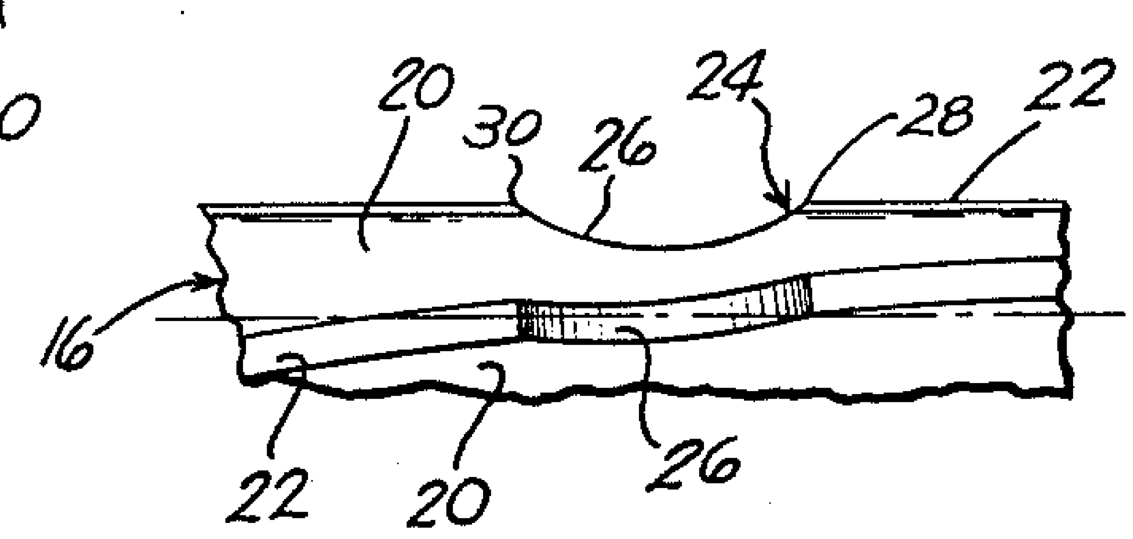

FIG.5

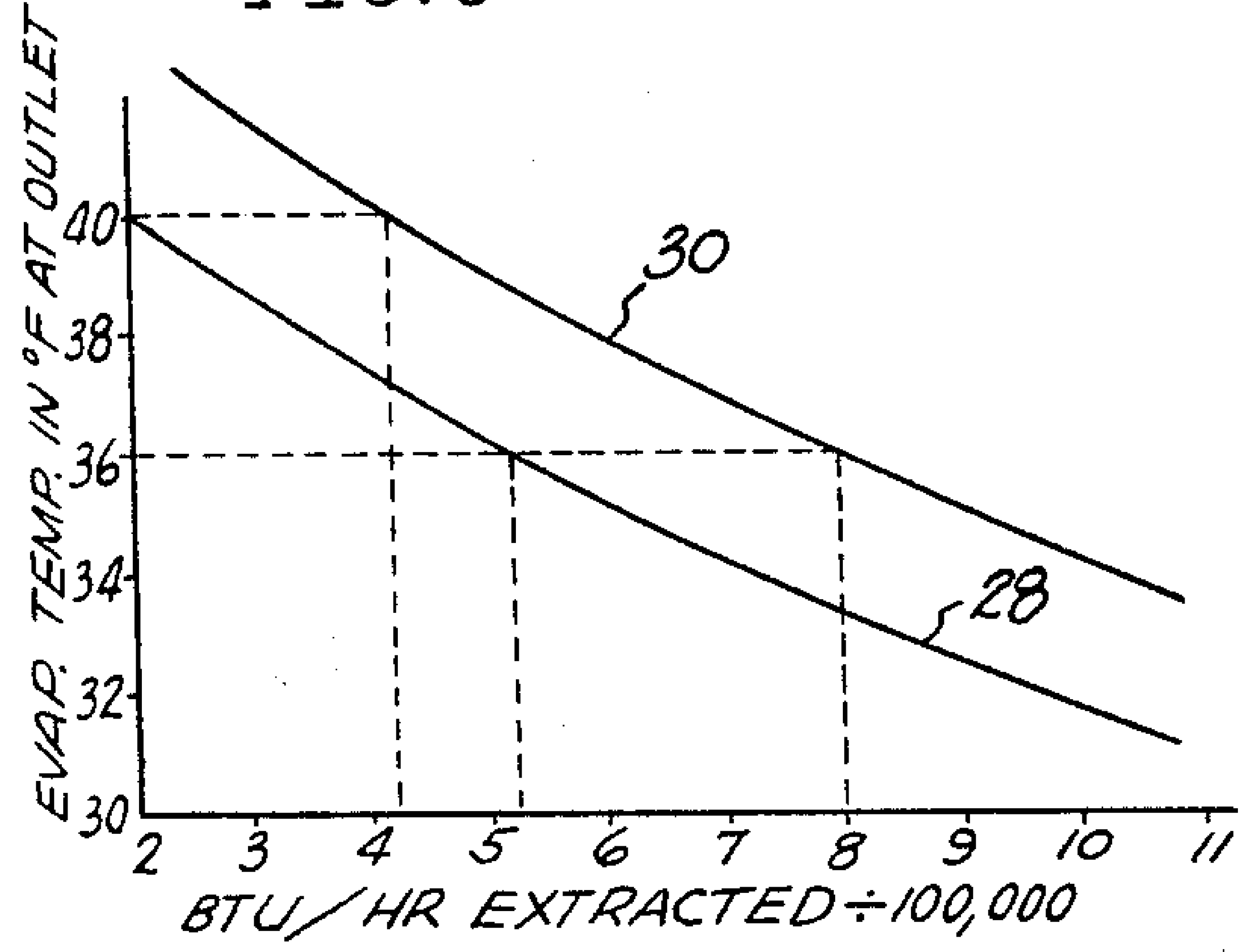

FIG.6

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INTERNAL FINNED TUBE

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ABSTRACT OF THE DISCLOSURE

A tube type heat exchanger wherein internal fins are located within a tube, the fins having a close interference fit with the inner wall of the tube, and improved heat exchanging characteristics being obtained by the spiral configuration of the fins, and the presence of notches in the fins adjacent the tube inner wall to permit heat exchanger medium flow between adjacent chambers within the tube defined by the fins.

The present invention is an improvement in the heat exchanger construction described in the assignee's United States Patent 2,929,408, issued Mar. 22, 1960.

In the aforementioned patent the advantages derived by forming a tubular heat exchanger from a tube and an internal fin member, wherein an interference fit between the internal fin member and the tubular member is produced, are discussed in detail. In the aforementioned patent a fin member having a plurality of radially extending fins is placed within a tubular member and the tubular member is swaged, drawn, or otherwise reduced in diameter to form an intimate interference fit engagement between the ends of the fins and the inner surface of the tubular member. The intimate interconnection between the ends of the fins and the inner surface of the tubular member provides a most effective heat transfer connection between the fins and tubular member substantially increasing the heat transfer ability of this type of heat exchanger over internal fin heat exchangers wherein the fins are connected to the tubular member by mechanical means, brazing or soldering. Tubular heat exchangers of this type are commonly used in refrigeration systems wherein a refrigerant passes through the tubular member through the flow paths defined by the fins, and the medium to be cooled is exposed to the exterior of the tubular members.

One of the problems encountered in any heat exchanger wherein a heat receiving or emitting medium is flowing through a heat exchanger arises from flow patterns occurring within the heat exchanger. Of course, the medium must be in engagement with a heat transfer member of the heat exchanger in order to effectively transfer heat. As the medium flows through a tubular heat exchanger, it tends to "channel" in a flow path having the least resistance to flow, and the mechanical surfaces of the heat exchanger are often not directly exposed to that portion of the heat transfer medium which is most capable of receiving or transmitting heat. To counteract this type of problem, agitators, baffles, and other means are often employed within heat exchangers to agitate the medium so that "new" portions and molecules of the heat transfer medium are continually engaging the mechanical heat transfer surfaces of the heat exchanger.

In a heat exchanger in accord with the invention, wherein a finned member is located within a tubular member, such flow paths of the refrigerant through the passages defined by the fins and the tubular member also develop which decrease the efficiency of the heat exchanging characteristics. Due to surface films existing on the fin surfaces and tube inner surface, it is possible for refrigerant to rapidly flow through the heat exchanger without coming in direct contact with either a fin or the tube

and, thus, portions of the refrigerant flowing through the heat exchanger are not effectively subjected to the mechanical surfaces of the heat exchanger and the efficiency thereof is adversely affected.

The present invention pertains to modifications made to the fin construction disclosed and claimed in United States Patent 2,929,408 wherein improved circulation of the refrigerant within the heat exchanger is provided. The innovations of the present invention have increased the heat exchanging capabilities of the heat exchanger tube of the aforementioned patent as much as one hundred percent under some conditions. In the present invention, the fin member is spiraled relative to its longitudinal axis. Preferably, such spiraling is in the order of approximately a 180° rotation of a fin relative to the fin member axis for each linear foot of the fin member. Such spiraling of the fins imparts a rotational movement to the heat exchange medium, usually a refrigerant, about the axis or core of the finned member, and centrifugal forces acting upon the molecules of the heat exchange medium tend to throw the heavier molecules radially outward into engagement with the inner surface of the tubular member. In a refrigerant such heavier molecules would be the colder molecules and, thus, place such molecules in direct contact with the inner surface of the tubular member. Also, such rotational movement of the heat exchange medium, as caused by the spiraling of the fins, produces an internal movement within the heat exchange medium which "scrubs" the medium against the surfaces of the fins, as well as against the inner surface of the tubular member.

Another feature of the invention which contributes toward improving the heat exchanging characteristics of an internal finned tubular heat exchanger lies in the provision of forming openings at axially spaced locations in the fins immediately adjacent the inner surface of the tubular member. Such openings establish communication between the flow paths defined in the tubular member and the fins and equalize the conditions of the heat exchange medium within the tubular member within the various flow paths thereof. By locating such openings adjacent the inner surface of the tubular member, movement of the heat exchange medium through the opening is encouraged due to the centrifugal forces acting upon the medium. Preferably, such openings constitute notches having a concave, cylindrical segment surface, and the notches have a radial depth defined in a finned member substantially less than the radial dimension of the fin as not to significantly weaken the fin. In that the fin member is subjected to compressive forces as the tubular member is reduced in diameter during the achievement of the interference fit between the tubular member and the fin member, the notches must be so positioned and related to the fin member as to not adversely affect the uniting of the fin member and the tubular member.

As the refrigerant flowing through an internal fin heat exchanger of the type of the invention will often be in both a liquid and gaseous state, the provision of the openings adjacent the inner surface of the tubular member prevents unequal ratios of refrigerant and gas from existing in the various flow paths of the heat exchanger as defined by the fins and, thus, the heat absorbing characteristics of the heat exchanger will remain consistent throughout the circumferential dimension of the tubular member.

It is, therefore, an object of the invention to provide a heat exchanger tube having internal fins wherein improved heat transfer medium flow through the tube is accomplished.

Another object of the invention is to provide a heat exchanger tube of the internal fin type wherein the fins are in an interference fit relationship with a tubular member and wherein the fins are spiraled with respect to the longitudinal axis of the tubular member.

Another object of the invention is to provide a heat exchanger tube of the internal fin type wherein the fins are spiraled with respect to the axis of the tubular member whereby centrifugal forces are imposed upon the heat transfer medium and openings are defined in the fins to permit communication between the flow paths of the tube.

Yet another object of the invention is to provide a heat exchanger tube of the internal fin type wherein the fins are in an interference fit relationship with a tubular member, and wherein spiraling of the fins is provided and communication is established between adjacent flow paths defined in the tube adjacent the inner surface of the tubular member, and wherein such spiraling of the fins and provision of such interfin communication does not adversely affect the interference fit uniting the finned member and the tubular member.

These and other objects of the invention arising from the details and relationships of the components of an embodiment thereof will be apparent from the following description and accompanying drawing wherein:

FIG. 1 is a perspective view of a fin member constructed in accord with the invention,

FIG. 2 is an elevational, diametrical, sectional view of a heat exchanger tube constructed in accord with the invention, the finned member and the tubular member being fully assembled and the finned member being shown in elevation for purposes of illustration,

FIG. 3 is an elevational, sectional view taken along section III—III of FIG. 2,

FIG. 4 is an enlarged, detail, sectional view of the interconnection of a fin member with the inner surface of the tubular member,

FIG. 5 is an enlarged, detail view of one of the notches defined in a fin terminating edge, and

FIG. 6 is a graph illustrating the improvements derived from the incorporation of the inventive concepts of the invention.

In the drawings the tubular member is indicated at **10**. Such tubular member is of a cylindrical configuration having a cylindrical outer surface **12** and an inner cylindrical surface **14**. The tubular member **10** is formed of a relatively soft metal having a high coefficiency of thermal conductivity. Copper or aluminum are usually employed, although copper is preferable and is most widely used.

A finned member **16** is located within the tubular member **10** and, in the illustrated embodiment, comprises a core portion **18**, FIG. 3, defining an axially extending axis, and a plurality of fins **20** are integral with the core portion **18** and radially extend therefrom. The finned member **16** is formed by an extrusion process and is formed of a metal also having a high coefficiency of thermal conductivity. The material of the finned member is of a greater hardness than the material of the tubular member in order to permit the proper interference fit to be accomplished. In practice, the tubular member is normally formed of copper and the finned member is formed of an alloy having a greater hardness than that of copper, such as one of the aluminum alloys 63S–T5, 63S–T6, or 63S–T2, properly aged.

The fins **20** of the finned member are preferably related to the core **18** such that the fins are not in diametrical relation to each other. In the disclosed embodiment, five fins **20** are illustrated. The fins are, preferably, of a reduced cross-sectional thickness adjacent the core **18** as compared to the cross-sectional thickness of the fins adjacent their associated radial terminating edge **22**. This gradual increase in the mass of the fins in accord with the proximity to the tubular member inner surface **14** makes the most effective use of the material of the finned member as the flow of heat through the fins is greatest adjacent the edges **22**. Also, by reducing the thickness of the fins **20** adjacent the core portion **18**, the maximum area of flow path between the fins can be achieved. Increased heat transfer between the fins and tubular member is also obtained by the presence of a T-shaped section on the fins adjacent the edges **22**. The T-shaped cross section increases the circumferential length of the edges **22** over that which would exist if the T configuration were not present and thereby increases the area of contact between the assembled tubular member **10** and finned member **16**.

To provide the improvements mentioned above, with regard to the flow of the heat transfer medium through the heat exchange tube, the finned member **16** is spiraled with respect to its longitudinal axis. Thus, each fin **20** is spiraled in the longitudinal direction about the axis of the core **18**. In practice, it has been found that a spiral between 174° and 180° for each linear foot of the finned member produces advantageous results. In the actual practice of the invention, the finned members are extruded with a 174° spiral, which means that the fin **20***a*, for instance, FIG. 1, will spiral 174° in the counterclockwise direction for each linear foot of the finned member. The spiraling of each of the fins **20** is of an identical nature in a common direction with respect to the axis of the finned member.

The spiraling of the fins **20** of the finned member is of such a nature as not to weaken the structural characteristics of the finned member, which are necessary to withstand the forces imposed thereon by the interference fit between the finned member and the tubular member.

In order to permit communication between the flow paths defined in the heat exchange tube by the fins **20**, the fins are each notched adjacent their terminating edge **22** at axially spaced locations. The spacing of the notches **24** will be apparent from FIGS. 1 and 2. In one embodiment of the invention, the notches nearest an end of the finned member will be placed approximately three and one-half inches from the end and thereafter the notches will be placed at eight inch intervals along the axial length of the finned member. To simplify manufacturing techniques the notches **24** in each fin member are, preferably, located at identical axial locations, and the notches are usually formed by a punching operation. In the preferred embodiment, the notches **24** are defined by a concave, arcuate surface **26** constituting a cylindrical segment surface which intersects the associated terminating edge at spaced axial locations **28** and **30**, FIG. 5. Preferably, the surface **26** is of a three-quarter inch radius and the notches have a radial depth into the associated fin from the terminating edge **22** of one-eighth of an inch. As the aforementioned dimensions of the notches **24** are defined in fins **20** having a radial dimension no less than one-quarter of an inch, it will be appreciated that the notches **24** only extend into the associated fin about half of the radial dimension of the fin on the smaller finned member sizes and, thus, the fins and finned member are not unduly weakened by the presence of the notches. With the preferred dimensional relationship set forth above, the axial dimension separating the locations **28** and **30** of a common notch, wherein the notch intersects the associated fin terminating edge, is more than five or six times the dimension of the radial depth of the notch in the fin. This relationship appears to provide a most advantageous communication between the flow paths of the heat exchanger tube without producing an excessive pressure drop within the heat exchanger tube.

To assemble the heat exchanger tube, the finned member **16** is located within the tubular member **10**. The dimension of the finned member in a transverse cross-sectional form is such that the circumference defined by the fin terminating edges **22** is slightly less than the internal circumference of the tube and the finned member may be readily inserted within the tubular member. Upon the finned member being properly axially located within the tubular member, the tubular member is radially contracted by a drawing operation, whereby the inner surface **14** of the tubular member is brought into an interference fit relationship with the terminating edges **22** of the fins. This relationship is best appreciated from FIG. 4. As will be seen from FIG. 4, the interference fit between the tubular member and the fins causes the material of the tubular member to intimately engage the fin terminating edge and the lateral portion thereof adjacent the terminating edge and forms an effective heat conducting connection between the internal fins and the tubular member. The fact that the fins **20** are not diametrically related permits the interference fit to be accomplished without fracturing the finned member or the tubular member and, as the notches **24** have not unduly weakened the finned member, the aforedescribed interconnection between the finned member and the tubular member can take place without damage to the finned member.

It will be appreciated that the aforedescribed assembly of the finned member **16** and the tubular member **10** will locate the notches **24** immediately adjacent the inner surface of the tubular member, whereby the communication between the flow paths within the tubular member defined by the fins **20** will be immediately adjacent the inner surface **14** of the tubular member.

In practice, a common means for utilizing the heat exchanger tubes of the invention is to place a plurality of these tubes in parallel relationship extending through a casing in which water or brine may be circulated. As refrigerant passes through the tubes, the refrigerant therein absorbs heat from the surrounding water or brine and reduces the temperature thereof. The water or brine is circulated through the casing and is pumped to cooling coils or the like and used for cooling. It is the usual practice that the refrigerant travels through the heat exchanger tubes in such a manner that the tubes are arranged in a plurality of "passes" whereby the refrigerant passes through various series of heat exchange tubes to permit the refrigerant to absorb the maximum amount of heat from the water or brine.

When the refrigerant is initially introduced into the heat exchanger tubes, it is usually in the form of both a liquid and a gas. The refrigerant typically may initially consist of 80% liquid refrigerant and 20% gas, as it leaves the expansion valve and is introduced into the heat exchanger tubes. After several passes through the heat exchanger casing, the refrigerant will consist entirely of a gas. The velocity of the refrigerant flowing through the heat exchanger tubes in a typical heat exchanger installation may lie between seven hundred feet per minute and fifteen hundred or more feet per minute. As the liquid and the gaseous refrigerant rapidly moves through the heat exchanger tubes, the spiral of the fins will rotate the medium and produce centrifugal forces within the medium. Thus, the heavier molecules of refrigerant, such as the colder gaseous molecules and the liquid molecules will tend to be disposed adjacent the inner surface **14** of the tubular member **10** and, thus, be in the best position for absorbing heat from the tubular member wall. In addition to the optimum refrigerant distribution obtained by the spiraling or rotational movement of the refrigerant to the heat exchanger tube, the existence of the notches or openings **24** permits the refrigerant to be uniformly distributed throughout the cross-sectional configuration of the heat exchanger tubes. Thus, no one flow path through the tubes will contain a disproportionate percentage of liquid or gas refrigerant with respect to another flow path. Equalized flow characteristics through the flow paths of a heat exchanger tube are, therefore, produced and the pressure drop characteristics of the tube are maintained at a minimum so as not to adversely affect the saturation temperature.

The graph in FIG. 6 compares the heat-exchanging characteristics of an internal finned heat exchanger tube of the nonspiraled, nonnotched type of United States Patent 2,929,408, but having T-sectioned terminating fin edges with the improved construction in accord with the invention. The curve **28** represents the heat-exchanging results of a tube constructed in accord with Patent 2,929,408 wherein the fins of the finned member are

not spiraled but are of a linear configuration and there is no communication between the flow paths defined in the tube by the fins of the finned member. The curve **30** represents the heat exchange characteristics obtained by a heat exchanger tube in accord with the invention. The vertically disposed numerals on the graph represent the saturation temperature i n degrees Fahrenheit of the refrigerant corresponding to the pressure at the refrigerant outlet as the refrigerant leaves the test cooler casing. The horizontally disposed numerals indicate the amount of heat the refrigerant within the heat exchanger tubes has extracted from the cooler within the test cooler casing and is indicated in B.t.u.'s/hour divided by 100,000. The conditions of temperature of test water to be cooled introduced into the test cooler, rate of water flow, number of tubes and passes, and other conditions necessary to permit comparison of the heat-exchanging characteristics of the two types of internal finned tubes were maintained in deriving curves **28** and **30**.

At an evaporation temperature of 36° F. the B.t.u./hour/100,000 extracted by the unimproved heat exchanger tube is 5.25, while the tube in accord with the invention extracts 8.00, an improvement of 1.52. At higher evaporation temperatures the improvement is even greater. At 40% F. the B.t.u./hour/100,000 of the unimproved tube is 2, while the improved tube extracts 4.2 for an increase of 2.02.

It will, therefore be appreciated from the above that the spiraling and notching of the fins substantially improves the heat-exchanging capacity of this type of internal finned heat exchanger. While the spiraling of the fins does slightly increase the refrigerant pressure drop within the tubular member, the increase in improved heat transfer more than offsets the disadvantages occurring from the increased pressure drop.

It is appreciated that various modifications to the inventive concept may appear to those skilled in the art without departing from the spirit and scope thereof, and it is intended that the invention be defined only by the following claims.

What is claimed is:

1. A heat exchanger tube for conducting a refrigerant comprising, in combination:

(a) an outer tubular member of relatively soft metal having an inner cylindrical surface,

(b) an internal, integral fin member disposed within said tubular member, said fin member having a solid central core portion and being formed by an extrusion process and of a metal having a greater hardness than the material of said tubular member,

(c) a plurality of fins defined on said fin member radially extending from said central portion, said fins being of elongated configuration and each being radially defined by a terminating edge, said fin terminating edges having an interference fit with said tubular member inner surface providing an intimate heat-conductive engagement between said fins and said tubular member, said fins being spirally disposed in a common direction about the longitudinal axis of said fin member, and

(d) a plurality of notches defined in each of said fins, said notches being axially spaced along each of said fins, intersecting the terminating edge of the associated fin and of a radial dimension less than the radial dimension of the associated fin whereby said notches define openings adjacent the tubular member inner surface establishing communication between adjacent refrigerant flow paths defined in said tubular member by said fins.

2. In a heat exchanger tube as in claim **1** wherein:

(a) said fins each have a cross section increasing in thickness from a point adjacent said central core portion outwardly to the associated terminating edge,

(b) said fins being disposed out of diametrical relation to each other, and

(c) a preformed T-shaped transverse cross section defined on each of said fins adjacent the terminating edge thereof, the upright of the T-shaped cross section being defined by the associated fin and the crossed portion thereof defining said terminating edge and the maximum transverse dimension of the associated fin.

3. In a heat exchanger tube as in claim 2 wherein:

(a) said fins of said fin member spiral in a common direction about said fin member longitudinal axis at a rate whereby the pitch of said fins is approximately one complete spiral about said axis for every two linear feet of said fin member.

4. In a heat exchanger tube as in claim 3 wherein:

(a) the axial distance separating said spaced locations defined by the intersection of a notch concave surface with the associated fin terminating edge is at least five times the radial depth of said notch in the associated fin.

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