United States Patent

Tibbetts et al.

[15] 3,672,446

[45] June 27, 1972

[54] AMBIENT AIR VAPORIZER

[72] Inventors: **Alan R. Tibbetts**, Costa Mesa; **Donald R. Tucker**, Lakewood, both of Calif.

[73] Assignee: **Airco, Inc.**

[22] Filed: **Jan. 21, 1969**

[21] Appl. No.: **792,593**

[52] **U.S. Cl.** **165/183**, 285/419

[51] **Int. Cl.** **F28b 1/14**

[58] **Field of Search** 165/179–185, 177–186; 29/202; 285/373, 419; 62/52

[56] **References Cited**

UNITED STATES PATENTS

3,293,871	12/1966	Tyree, Jr.	62/52
3,280,907	10/1966	Hoffman	165/185
2,721,582	10/1955	Hoke	285/419 X
2,743,512	5/1956	Moyer	29/202
3,136,038	6/1964	Huggins	29/202 X
3,330,336	7/1967	Gobel	165/179 X
1,841,380	1/1932	Phelbs et al.	165/183 X
2,405,722	8/1946	Villier	165/183 X
3,231,298	1/1966	Tomb et al.	285/373 X

FOREIGN PATENTS OR APPLICATIONS

38,249	1/1931	France	165/183
716,972	10/1931	France	165/183
881,184	6/1953	Germany	285/419

Primary Examiner—Charles Sukalo
Assistant Examiner—Theophil W. Streule
Attorney—Francis B. Henry, Edmund W. Bopp and H. Hume Mathews

[57] **ABSTRACT**

This invention relates to a finned assembly for a heat exchanger comprising an extended surface portion, an elongated tubular member, said extended surface portion comprising two identical parts, each having an internal cylindrical surface adapted to engage said tubular member and each having radially extending locking members adapted to engage locking members on the other of said parts. The invention further relates to methods and apparatus for attaching said extended surface portion to said member.

11 Claims, 12 Drawing Figures

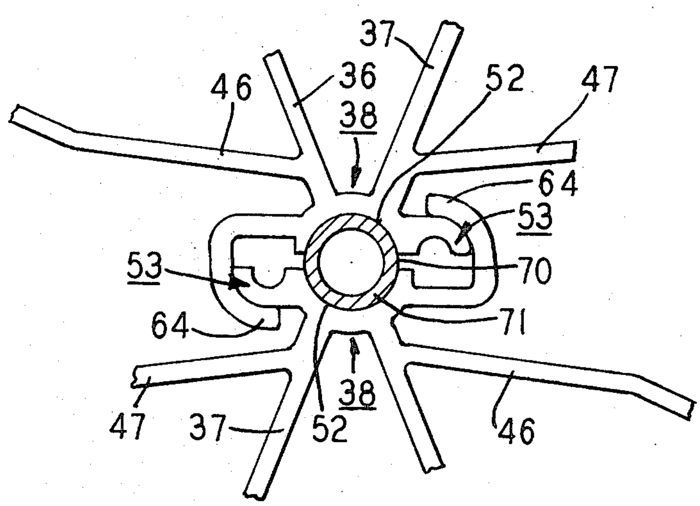


FIG. 1

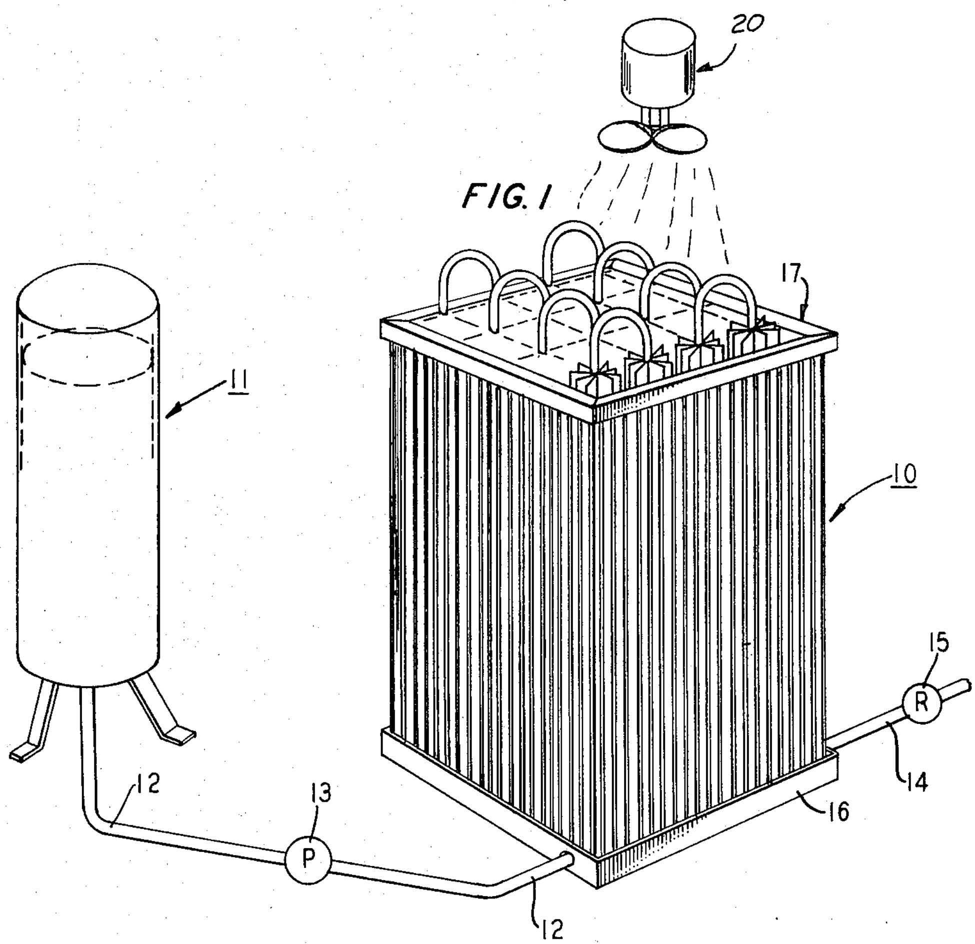
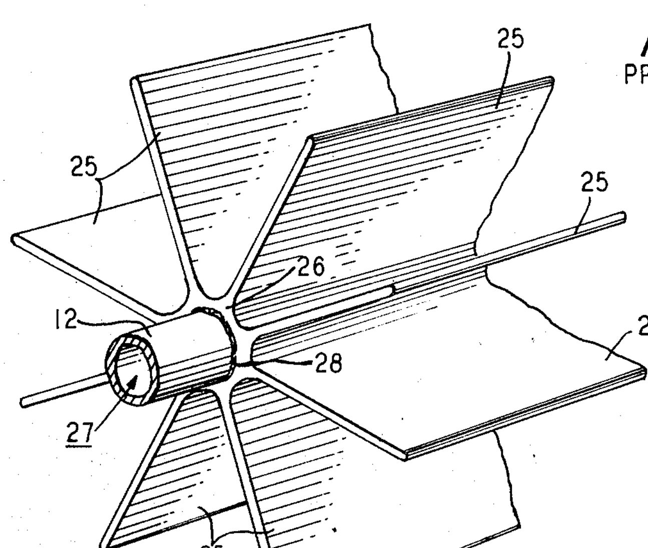


FIG. 2
PRIOR ART



INVENTORS
ALAN R. TIBBETTS
DONALD R. TUCKER
BY
ATTORNEY

FIG. 3

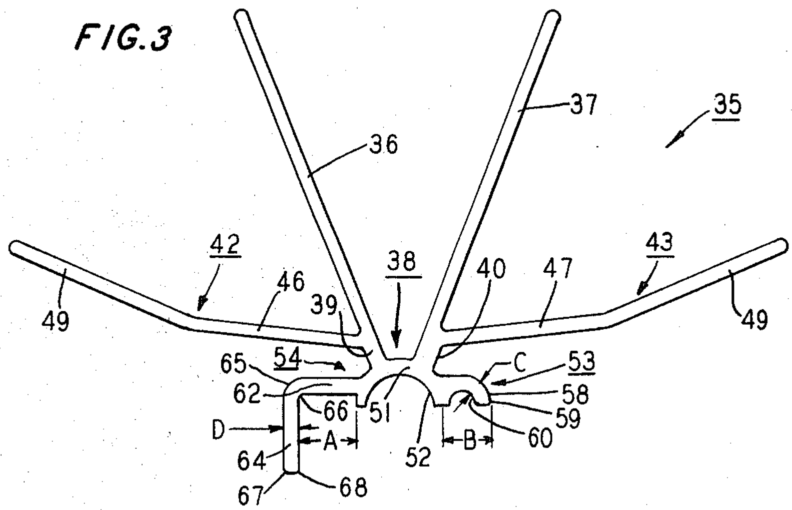


FIG. 6A

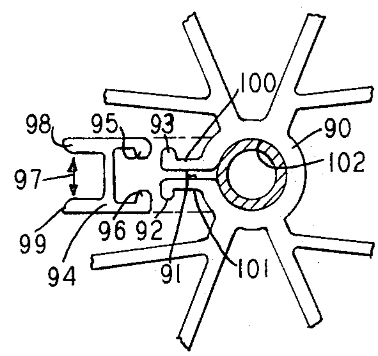


FIG. 4

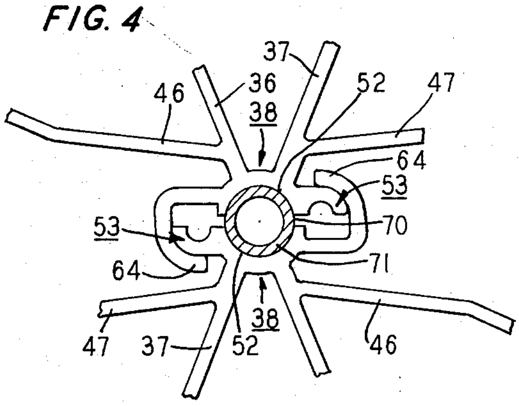


FIG. 6B

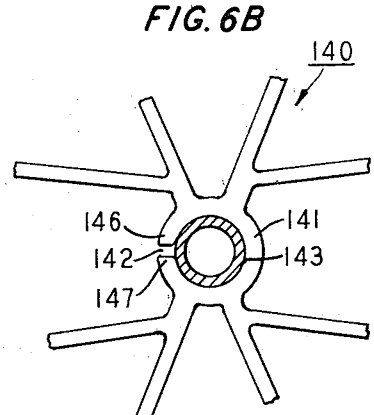


FIG. 5

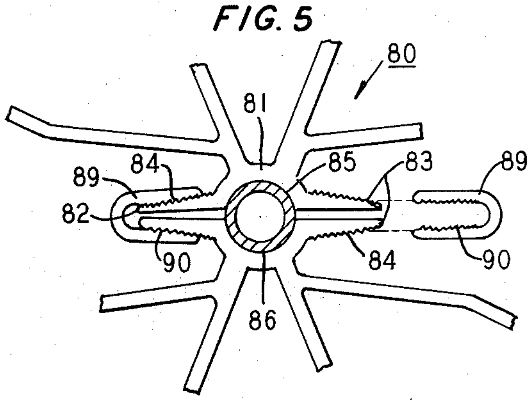
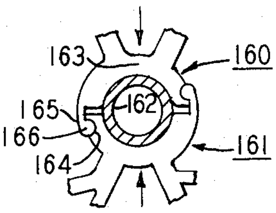
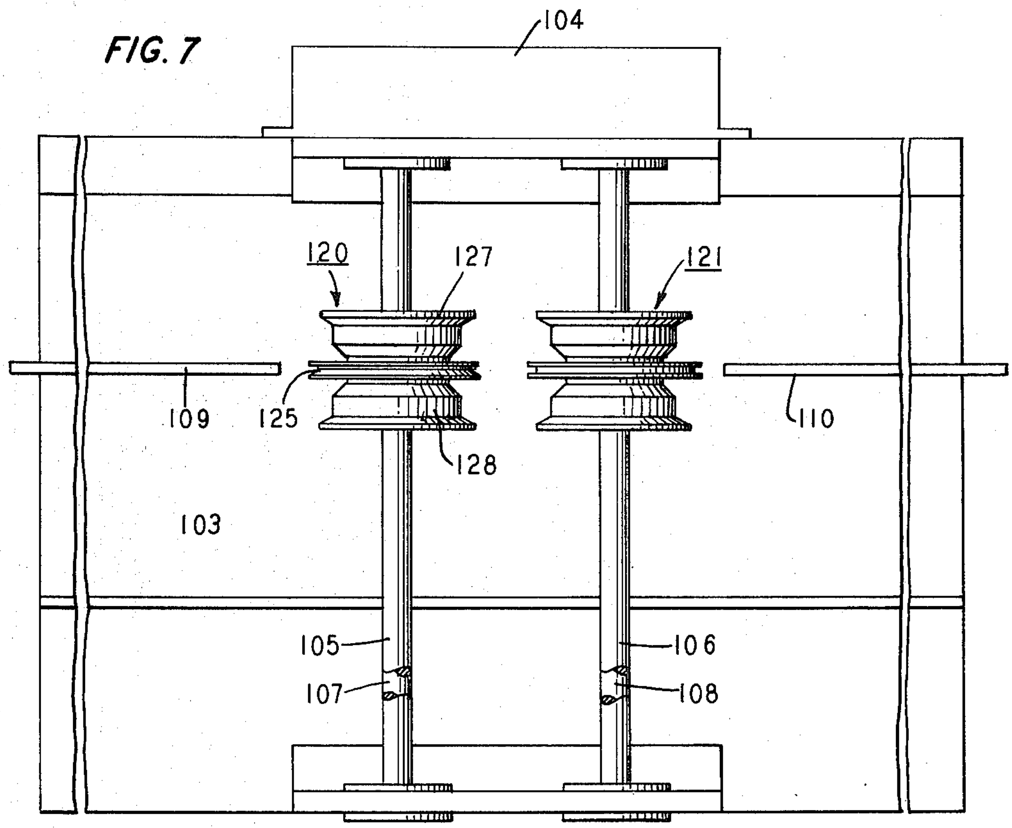


FIG. 11



INVENTORS
ALAN R. TIBBETTS
DONALD R. TUCKER
BY F.B. Henry
ATTORNEY

FIG. 7



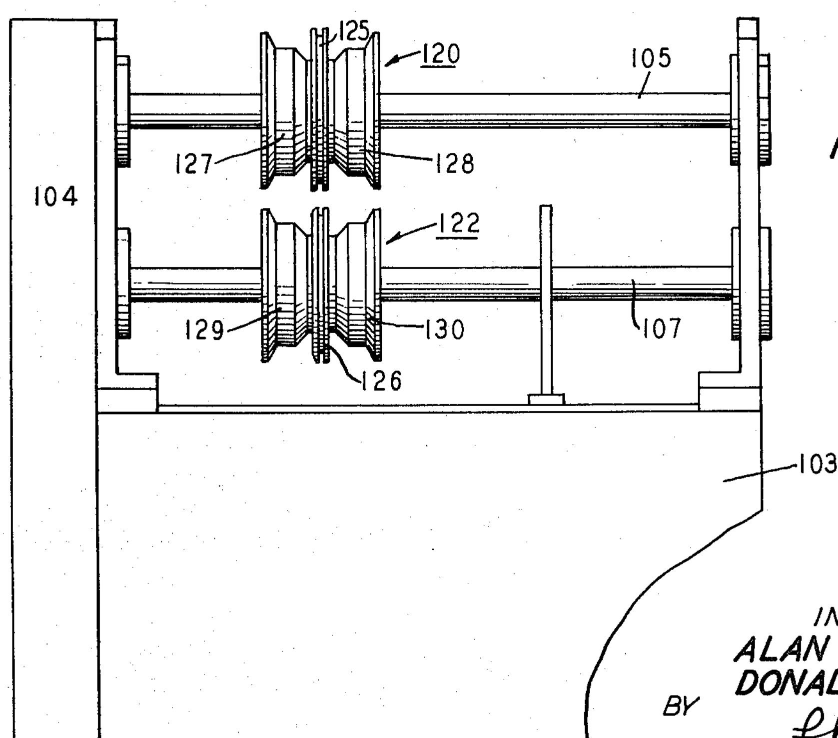


FIG. 8

INVENTORS
ALAN R. TIBBETTS
DONALD R. TUCKER

BY

ATTORNEY

FIG. 9

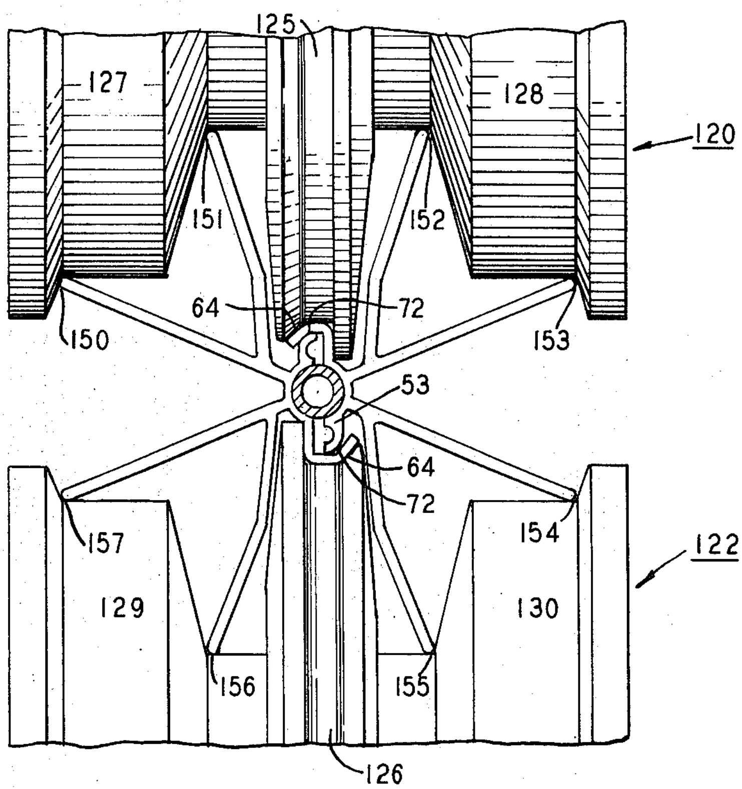
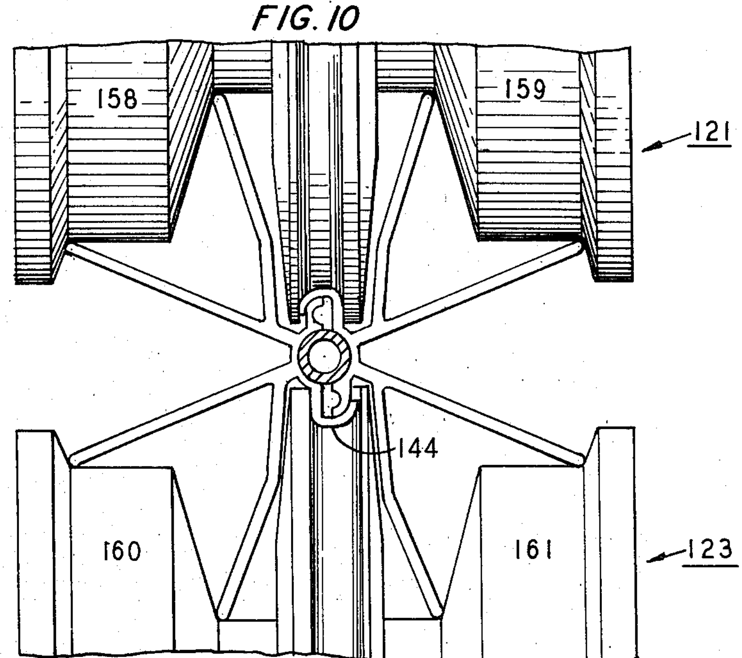


FIG. 10



INVENTORS
ALAN R. TIBBETTS
DONALD R. TUCKER
BY f B Henry
ATTORNEY

AMBIENT AIR VAPORIZER

This invention relates to an improved form of ambient air vaporizer made of dissimilar materials which are joined together without welding. The vaporizer constructed according to the invention is capable of withstanding high vapor pressure and has excellent heat transfer characteristics.

The use of various forms of ambient air vaporizers is well known in the cryogenic industry. The ambient air vaporizers are known to take the form of aluminum castings in the form of blocks which may be interconnected for the passage of the cryogenic fluid being heated. In another well known construction the vaporizer takes the form of elongated sections of extended surface material which are formed from aluminum extrusions. Extrusions are generally star-shaped with a plurality of radially extending fins and with a central opening through which the cryogenic fluid passes. The extrusion is usually made from aluminum alloy 6063–T1 and the extrusion is made in an elongated length which is then cut up into desired lengths. In its most common form the extrusions are placed in a block with four sections on a side and each section is interconnected with the next in a series or parallel or combination thereof (as desired) arrangement by means of bent tubing which is welded to interconnect the central openings of the aluminum extrusions so that fluid may be transmitted into one end of the extrusion and through the opening which passes through the interior of the extrusion and then out the other end through the exit tubing. The exit tubing is serially connected by welding to an adjacent extrusion and the cryogenic liquid is thereby passed from one section to the next until it has passed through all 16 sections. Such ambient air vaporizers are often used with customer stations which include a liquid storage tank in which the liquefied gas is stored, and a high pressure liquid pump which pulls the suction on the liquid storage tank and directs the high pressure liquid output to the ambient air vaporizer. The vaporizer may take the form of any of the vaporizers discussed above and may of course also take the form of the invention as it will be described in more detail hereinbelow. From the vaporizer the gaseous product is directed to a use point such as for example a steel mill, aluminum remelt furnace or perhaps be directed into a gas cylinder filling manifold. In order to assist in the heat transfer process a blower may be placed so that it directs ambient air across the vaporizer. The necessity for such a blower would of course depend upon the rate of vaporization desired and the climactic conditions involved.

In the prior art form of ambient air vaporizer which may be described for purposes of discussion as the star type, it has been found that numerous instances of failure of the critical welds have occurred. The failures occur due to the fact that the tubing which connects the vaporizer sections must be welded to the ends of the vaporizer sections in such a manner so as to withstand thousands of pounds of pressure. In general the tubing interconnecting the vaporizer sections is made of bent aluminum tubing and the vaporizer sections themselves are made of extruded aluminum. The welds joining these two elements must therefore be made with a high degree of skill so as to be entirely fluid tight and so as to be able to withstand high internal vapor pressure. In a conventional customer station a normal anticipated pressure of 3,000 psi or more is reached in the vaporizer. In the most commonly used ambient air vaporizer bank 16 sections are utilized. It is therefore apparent that at least 32 welds are required to join and interconnect the tubing with the extruded sections. As mentioned above each individual weld must be carefully made and must then be closely inspected and hydrotested in order that it be able to withstand the rigors of cryogenic service. It is evident that the degrees of expansion and contraction of dissimilarly shaped metal parts vary. Thus as the low temperature cryogenic liquid which for purposes of example might be liquid nitrogen at −320° F, flows through the tubing and through the extruded sections, the various parts of the ambient air vaporizer will contract at various rates. This will cause the welds which interconnect the various portions to be placed under additional stresses. The ambient air vaporizers are often cyclicly utilized and the stresses and strains which are undergone by the welds interconnecting the portions can often cause failure of the welds. Thus the technique of welding the sections to the interconnecting piping has been found to be an extremely costly method of manufacture and has further been found to produce an unreliable product.

Thus it has been found that although the prior art form of ambient air vaporizer is widely used in the field, it embodies various structural and design concepts which leave much to be desired.

This invention relates to a heat exchanger structure which alleviates all of the above-mentioned defects in the prior art form of ambient air vaporizer. It is an object of the present invention to provide an ambient air vaporizer utilizing extruded aluminum extended fin surfaces coupled to a stainless steel conduit which passes through the extended fin section. It is a further object of the present invention to couple the extruded aluminum sections to the stainless steel tubing without any welds.

It is a further object of the invention to couple the aluminum extrusions to the interior tubing in a manner so as to allow the dissimilar materials to expand and contract without affecting the operation of the vaporizer in any way.

It is a further object of the present invention to provide an improved fin arrangement for an extended surface ambient air vaporizer.

It is a further object of the present invention to provide identical extrusions which may be locked around a conduit adapted to carry cryogenic liquid which is to be vaporized. Each identical extruded section carries a locking device which may be coupled to another identical section in a manner so as to prevent the sections from becoming unlocked.

Other and further objects of this invention will become apparent to those skilled in this art from the following detailed description on the annexed sheets of drawings, which by way of preferred example, illustrate several embodiments of the invention.

In the drawings:

FIG. 1 is a view partly in perspective of an ambient air vaporizer coupled with a schematic showing of a conventional customer station.

FIG. 2 is a perspective view, partly broken away, partly in section of a conventional ambient air vaporizer section made of extruded aluminum.

FIG. 3 is an end view of an extrusion formed in accordance with the preferred form of the invention.

FIG. 4 is an end view, partly in cross section, partly broken away showing a pair of identical extrusions locked to a conduit in accordance with the preferred form of the invention.

FIG. 5 is an end view, partly in section, partly broken away, of a pair of extrusions about to be coupled together in accordance with the principles of another embodiment of the present invention.

FIG. 6A is a cross sectional view of an extruded ambient air vaporizer section about to be coupled to a conduit in accordance with the principles of a still further embodiment of the present invention.

FIG. 6B is an end view, partly in section, partly broken away, of a still further embodiment of the present invention.

FIG. 7 is a plan view, partly broken away, of apparatus for locking together the sections of ambient air vaporizer made in accordance with the present invention.

FIG. 8 is an elevational view, partly broken away, of the apparatus shown in FIG. 7.

FIG. 9 is an end view, partly in section, partly broken away, of the vaporizer sections and conduit being locked together in a first locking operation in a first set of forming rolls.

FIG. 10 is an end view, partly in section, partly broken away, of a second set of forming rolls completing the locking of the extruded aluminum sections to the tubular conduit.

FIG. 11 is an end view, partly in section, partly broken away, of a still further embodiment of the invention.

In FIG. 1 there is illustrated an ambient air vaporizer bank 10 which is connected to a cryogenic storage tank 11 by means of conduit 12. A pump 13 suitable for pumping a cryogenic liquid forces high pressure cryogenic liquid into the ambient air vaporizer bank 10. If the storage tank 11 contains for example liquid nitrogen, the temperature of the nitrogen entering the ambient air vaporizer bank is approximately −320° F. The cryogenic liquid passes serially through the sections of the bank 10 wherein the liquid is vaporized and the resulting vapor exits through conduit 14. The delivery pressure of the cryogenic vapor is normally controlled by a pressure regulator 15 and both the storage tank 11 and the delivery conduits 12 and 14 are normally supplied with conventional relief valves, shut-off valves and coupling connections which are not shown. In a typical nitrogen customer station the pumping system and vaporizer are capable of supplying 5,000 SCFH at 3,000 psi to the use point. The size of the vaporizer 10, pump 13 and storage tank 11 would of course depend upon the amount of vapor that must be delivered to the use point. The illustration in FIG. 1 is not to scale. Persons skilled in the art will recognize that normally the storage tank is considerably larger than the vaporizer structure. The vaporizer bank is normally enclosed in a framework indicated generally by the reference numerals 16 and 17. In the prior art form of ambient air vaporizer, the fins of the vaporizer sections were directly connected to the frameworks 16 and 17 in order to structurally mount the bank in the framework. As will be discussed in greater detail below, the present invention calls for connecting the tubing to the frameworks 16 and 17. This greatly strengthens the entire vaporizer bank 10 in view of the fact that the stainless steel tubes are directly connected to the steel housings 16 and 17.

Depending upon the desired output of the ambient air vaporizer bank 10 it may be necessary to install a blower indicated by the reference number 20 to blow ambient air over the vaporizer bank. By forcing air over the vaporizer bank, additional output of the vaporizer may be obtained.

The details of the storage tank 11, which is normally vacuum insulated, and of the pumping system 13 are not provided in this disclosure in that they form no part of the present invention and in view of the fact that many different types of tanks and pumping systems are available commercially.

In FIG. 2 there is illustrated a perspective view of a conventional ambient air vaporizer section coupled in the conventional fashion to aluminum tubing by a continuous annular weld 28. In the conventional star type vaporizer there are 8 radially extending fins 25 which emanate from a central annular hub 26 having a hollow interior 27. This structure is normally extruded aluminum. The cryogenic liquid passes in the first instance from the conduit 12 into the interior 27 wherein it is warmed up as it passes through the extruded section. Note that the star configuration provides a large surface area per unit of length of the section thus resulting in high heat transfer to the cryogenic liquid. Upon the completion of welding the tubing to the extrusion the weld must be stress-relieved in the conventional manner by a heating process or extremely heavy-walled tubing must be employed. Similarly, a conduit comparable to conduit 12 is connected to the other end of the section and is welded in the same manner as discussed above in connection with weld 28. Thus a weld must be made at each end of the vaporizer section. If the vaporizer bank contains 16 vaporizer sections, at least 32 welds will have to be made to interconnect the sections with suitable tubing. To withstand the high vapor pressure, the wall thickness of the aluminum tubing must be considerably thicker than the wall thickness of stainless steel tubing designed to withstand a comparable pressure.

In FIG. 3 there is illustrated an end view of one part of an ambient air vaporizer section built in accord with the preferred form of the invention. The part which is indicated by the reference numeral 35 is formed of extruded aluminum and is normally used in standard lengths of 6 feet. The part comprises a pair of radially extending fins 36 and 37 which are connected to a central hub 38 by means of fin portions 39 and 40 respectively. The fin portions 39 and 40 are of a greater thickness than the fin portions 36 and 37 in that they support fins 36 and 37 and fins 42 and 43. The extra thickness also provides improved heat transfer characteristics.

The fins 42 and 43 have been formed as an extension of fins 36 and 37 due to the fact that the portion of the hub 38 which would normally support the fins 42 and 43 is now used to support locking members which will now be described.

Each of the fins 42 and 43 is made of two parts, a radial part 48, 49 and an offset part 46, 47. The radial part lies along a radius extending from the longitudinal axis of the vaporizer section and the offset portion diverges from the radius and is interconnected with the adjacent fin 36 or 37. It can be observed from FIG. 3 that the included angle between fins 36 and 37 is 45° and the included angle between fin 37 and the radial part 49 of fin 43 is also 45°. The same may be said for the radial part of fin 42 and the fin 36. The angle between the radial fins 36,37 and offset part 47, 46 is preferably as close to 45° as possible without interfering with the locking members before, during or after the forming process.

It has been found that an angle of 45° between adjacent fins on an ambient air vaporizer is preferred due to the fact that the frost build-up which inevitably occurs on the fin surfaces does not bridge over between adjacent fins when the angle is approximately 45°. If the included angle between the fins is less than about 40°, it has been found that the frost bridges between the two fins starting at the root of the angle and then proceeding radially outwardly. A frost build-up of course substantially reduces the desired heat transfer characteristics of the air vaporizer. If the included angle is greater than approximately 45°, the number of fins and thus the surface area must be reduced.

The hub 38 comprises a substantially annular portion 51 with an interior partly cylindrical surface 52. Projecting from the annular member 51 but formed integral therewith are a pair of locking members 53 and 54. The locking member 53 will be described as the narrow or fixed locking member and the member 54 described as the broad locking member in the interest of defining the invention. The short locking member 53 takes in part the form of a partly cylindrical surface 58. The surface 58 preferably has an approximately 90° arc. The outermost end of the locking member 53 is rounded off at 59 and this somewhat diminishes the said arc, and the purpose for this will be discussed below. The locking member 53 further comprises an interior partially cylindrical surface 60 which is concentric with the cylindrical surface 58. The radius defining the cylindrical surface 60 is preferably one-half the radius defining the cylindrical surface 58. As shown in FIG. 3, the partially cylindrical surface 60 has a 180° arc.

The long locking member 54 is also formed from an extension of the hub 38 and is integral therewith. The last-mentioned locking member includes a base portion 62 which extends in preferably the opposite direction from the extension defined by the locking member 53. The base member 62 is slightly broader than the total extension of the fixed locking member 53 as indicated by the fact that the dimension A shown on FIG. 3 is greater than the comparable dimension B. The reason for this will be discussed below.

The outer portion 64 of the locking member 54 is formed at 90° to the base member 62 during the extrusion process. The interconnection between the outer member 64 and the base member 62 is formed with rounded surfaces 65 and 66 in order that the outer member 64 may be bent inwardly toward the hub 38 without the interconnection fracturing or otherwise failing. In the preferred form of the invention the outer member 64 is formed slightly broader than the base member 62. Note that the outermost extremities of the outer member 64 are also rounded off 67, 68. It has been found that by rounding surfaces of aluminum which is to be bent or otherwise shaped, metal failures are often avoided.

It is to be noted that the interior cylindrical surface 52 of the hub 38 is formed with a cylindrical surface which is less than one-half the full cylindrical surface (less than a 180° arc). The reasons for thus forming the surface 52 will be described below in connection with the assembly of the extruded parts and the conduit tube.

By utilizing two identical vaporizer parts as illustrated in FIG. 3 and by positioning the two parts in the manner which will now be described about a fluid carrying conduit composed of a similar or dissimilar metal and by interlocking the locking members of the two identical parts a unitary ambient air vaporizer section may be formed without the necessity for making any welds The end product is illustrated in FIG. 4. By mating the cylindrical surfaces 52 of the separate parts with the exterior cylindrical surface 70 of the conduit 71 and by bending over the outer members 64 of the broad locking member to engage the fixed locking member 53 of the opposite part, the two identical parts may be affixed in good heat transfer relationship to the conduit 71.

The apparatus for accomplishing this step will be discussed in detail below. The bending or forming actually takes place in the two-stage forming rolls in one operation. In the first stage the outer member 64 is bent at a 45° angle with respect to the base member 62. This brings the inner surface 72 of the outer member 64 of one part in contact with the arcuate surface 58 of the fixed locking member 53 of the other part. In a subsequent forming stage the outer member 64 is forced still further inwardly toward the base member 62. The first-forming step is illustrated clearly in FIG. 9 and the second-forming step is indicated in FIG. 10. By forcing the locking member 64 even further inward in the second step it is caused to conform to the exterior curved surface 58 of the fixed locking member 53. This results in the clamping of the parts together about the tubing or conduit 71 and causes the cylindrical surfaces 52 to conform to the exterior cylindrical surface 70 of the conduit 71. By having these surfaces conform to one another and by causing substantially complete contact between the surfaces 52 and 70 throughout the length of the section optimum heat transfer characteristics are realized.

In forming the interior partly cylindrical surface of the hub 38 a radius is utilized which slightly exceeds the radius of the external cylindrical surface of the tubing or conduit 71. For example, if the radius of the tubing is 0.625 inches the radius of the hub will be approximately 0.65 inches. This is done for a number of reasons. Due to the nature of the extrusion process tolerances on extruded parts are normally greater than on comparable parts made by other processes (machining, etc.). Therefore, we have designed the internal radius to be slightly oversize. Furthermore, it has been found that if the radius of the hub 38 slightly exceeds the radius of the outer cylindrical surface of the tube, the hub will be better able to conform to the surface of the exterior of the tube. In the preferred form of the invention the tubing is stainless steel and therefore the extruded aluminum will conform to the surface of the harder stainless steel.

Thus when the locking members are forced over one another, the cylindrical surface 52 is able to closely conform to the outer cylindrical surface of the tubing so as to minimize the thermal contact resistance between the tubing and the hub. If the radius of the arcuate portion 52 were smaller than the radius of the conduit (or undersized), the hub 38 would not as readily conform to the surface of the conduit. It is therefore preferable to design the hub to be slightly over-sized so that the extrusion tolerances can be taken into consideration and so that the hub will always readily conform to the tubing.

The arcuate portion 58 of the locking member 53 is formed so that the outer member 64 of the adjacent vaporizer part will be able to bend arcuately about the narrow member. This is done in order to reduce sharp bends in the member 64 which would be subject to failure. The dimension A of base member 62 is of course greater than the dimension B of the member 53 in order that the outer member 64 may clear the rounded surface 59 and be formed around the member 53. Arcuate surface 60 of member 53 is formed in order that the thickness indicated by the dimension C is equal to the thickness of the broad locking member 54, indicated by the dimension D. This is done in order that the spring back forces which will result from the forming process will be equal in both the narrow and broad locking members. By causing the spring back forces to be substantially equal, the locking members will play an essentially equal role in generating the clamping force on the tubing. Thus when cryogenic liquid is pumped through the tubing 71 and the stainless steel conduit contracts slightly due to its low temperature, the spring back forces will maintain the cylindrical surfaces 52 in contact with the exterior surface 70 of the conduit. This inherent resiliency in our locking technique therefore allows for variations in tolerances and for variations in dimension caused by cryogenic temperature. The methods and apparatus for forming will be discussed in detail below following the discussion of other embodiments of the invention.

In FIG. 5 there is illustrated a further embodiment of the present invention which utilizes a pair of identical vaporizer parts 80 which are to be locked about a fluid carrying conduit. The hub 81 of each of the parts is formed with substantially oppositely extending locking members 82, 83. On one surface of each of the locking members 82 and 83 there are formed serrations or projections indicated by 84. In the preferred form the inner cylindrical surface 85 is formed with an arc slightly less than 180°. A pair of identical parts 80 are placed around the conduit 86 in such a manner that the locking projections 83 and 84 lie alongside adjacent locking projections on the adjacent part. When this has been done a locking clamp 89 is forced over each pair of adjacent locking members and the locking clamp 89 is driven substantially radially inwardly so that the locking members are clamped together. The clamp 89 is formed with inner serrations or projections 90 which pass over the serrations 84 and which are so angled so as to prevent the removal of the clamp 89 from the locking members 83 and 84 when the clamp is fully seated thereon. In the embodiment shown in FIG. 5 the inner radius of the hub 81 is again made to be slightly larger than the radius of the exterior of the conduit 86 so as to obtain the same result as discussed above in connection with FIG. 4. Thus the clamps 89, which may be forced on by form rolling, exert a resilient clamping force on the hubs 81 so that they conform to the surface of the tubing. The parts 80 may be made from extruded aluminum sections and the locking clamps 89 may also be made from aluminum.

In FIG. 6A there is illustrated a still further embodiment of the present invention in which the hub 90 is formed of one piece and is split as indicated at 91 in a longitudinal direction. The hub 90 has an arc slightly less than 360° (2°–5°). A pair of lugs 92 and 93 are formed integral with the hub and extend substantially radially from the portion which has been split. A clamping mechanism 94 is adapted to engage the radially extending lugs 92 and 93 and by this device the hub is clamped to the tubing 102. The clamping device 94 is preferably as long as the hub section 90 so that a clamping force on the lugs 93 and 92 will be exerted substantially along the entire length of the hub 90. The clamping member 94 has an I beam configuration with projecting lugs 95 and 96 which lock about the lugs 92 and 93 on the hub. By forcing the arms 98, 99 of the I beam apart as indicated by 97, the lugs 95 and 96 can be made to contact seats 100 and 101 to force the lugs 92 and 93 toward one another, thus clamping the hub 90 about the tubing 102. The conduit 102 is actually slid into the hub 90 before the clamping device is applied. The clamping device, which is preferably made from aluminum is also slid into position on the hub prior to clamping. As in the case of FIGS. 4 and 5 the internal radius of the hub is made slightly greater than the radius of the external cylindrical surface of the conduit 102 for the reasons stated above.

In FIG. 6B there is still illustrated a still further embodiment of the present invention. The vaporizer section 140 is formed from a single extrusion, the hub 141 being split longitudinally at 142. In this embodiment the clamping force on the conduit 143 is exerted by the hub 141 itself. The split portion of the hub is forced open slightly to allow the insertion of the conduit 143. When the conduit is fully inserted the hub is allowed to close around the conduit **143**. Portions **146** and **147** constitute locking members which wrap around the conduit. The inherent spring back characteristics of the hub keep it locked to the conduit. In this embodiment the internal radius of the hub **141** is preferably the same as or slightly smaller than the radius of the external surface of the conduit. Due to the hardness of the stainless steel conduit, the softer inner aluminum surface of the hub readily conforms to the conduit to obtain good heat transfer.

In FIG. **7** there is illustrated an apparatus for forming the ambient air vaporizer described in connection with FIG. **4**. The apparatus takes the form of a suitable supporting stand **103** on which is mounted a drive mechanism **104** and a plurality of bearing assemblies which rotatably support 4 shafts, **105** through **108**. Directly beneath the shafts **105** and **106** are shafts **107** and **108**. All of the shafts are drivably connected to a drive means inside drive housing **104**. This housing contains a motor connected to suitable gearing, etc., for rotating the upper shafts **105** and **106** in the same direction and at the same speed. The drive mechanism drives the lowermost shafts **107** and **108** at the same speed and in the same direction but in a direction opposite to that of the upper driveshafts **105** and **106**. Guide plates **109** and **110** are vertically mounted on the supporting stand **103** and are positioned to guide the vaporizer parts and the associated tubular conduit into the forming rollers indicated by the reference numerals **120** and **121**. Two pairs of forming rollers are utilized each having an upper forming roller and a lower forming roller, as illustrated in FIG. **8**. Each of the forming rollers is composed of a plurality of interlocked wheel-like members of varying radius and configuration.

In assembling the ambient air vaporizer described in FIG. **4** the identical parts are positioned around the central conduit tube and the locking members are placed in a substantially vertical position. The assembly is then placed on guide plate **109** in such a manner that one of the outer members **64** rests on the surface of the guide plate **109**. The assembly is then slid along the plate **109** and is passed between the forming rollers **120** and **122**. The locking members are engaged by forming rolls **125** and **126** as indicated in FIG. **9**. The radial tip portions of the vaporizer fins engage portions of the forming rolls **127** through **130** as shown at **150–157**. By contacting the tips of the vaporizer fins with the forming rolls as shown, the vaporizer parts are held in place while the main forming rollers **125** and **126** form the outer member **64** about the fixed locking member **53**. The first set of forming rollers encountered bend the outer members **64** 45° and into contact with the arcuate surface of the fixed locking member. The next set of forming rollers which the vaporizer section encounters is located directly behind the forming rolls indicated in FIG. **8**. This set of forming rolls completes the bending of outer members **64** so that they fully conform to the arcuate surface **72** on the fixed locking member. The shape of the forming rolls for accomplishing this is indicated in FIG. **10**. They have a channel shaped groove **144** which further bends the outer member **64** inwardly. Supporting rolls (**158–161**) similar to those disclosed in FIG. **8** (**127** through **130**) are used with the second set of forming rollers to support the radial tips of the fins.

As the vaporizer section leaves the second set of forming rolls and rides on guide plate **110**, it can be inspected to determine whether or not the forming has been completely accomplished and whether or not the identical parts of extended surface material are completely fixed to the conduit in the manner desired. The drive mechanism **104** is therefore made reversible in order that, if desired, the sections of vaporizer may be run back and forth through the rolling mechanism. The details of the drive mechanism and of the bearing structure supporting the shafting for the roll forming mechanism have not been described in detail in that they are conventional in nature.

A roll-forming mechanism comparable to that disclosed in FIGS. **7** through **10** may be utilized to assemble the embodiment disclosed in FIG. **5** and in FIG. **6A**. That is, forming rollers force clamping devices **89** over the lugs **83**, **84** which extend from the hub section of the vaporizer. In FIG. **6A** a roller may be used to force arms **98** and **99** apart.

In FIG. **11** there is illustrated a still further embodiment of the present invention. Identical parts **160** and **161** are formed from extruded aluminum and are clamped about a tubular conduit **162**. Each part is made up of a hub portion **163** and two locking members, a partially cylindrical recess **164**, and a snap lock **165**. The snap is formed from an extension of the hub and has a rod shaped element **166** which snaps into the recess **164**. The connection between the element **166** and the hub has sufficient flexibility and resiliency to allow the element to snap into the recess and thus the two parts **160** and **161** may be placed around the conduit **162** and snapped in place. The internal radius of the hub **163** is made slightly greater than that of the conduit **162** for the same reasons as stated above in connection with FIGS. **4**, **5**, and **6A**. Thus the parts **160** and **161** are resiliently coupled to the conduit. Forming rollers may be utilized to affect the snap coupling of the embodiment shown in FIG. **11**. By forcing the parts together as shown by the arrows the snap connection may be made.

When the vaporizer sections have been assembled as described above, they may be mounted in a supporting framework so that they may be transported and mounted at a customer station. It is evident that since stainless steel conduit is used and since a steel framework is usually employed to form the supporting structure, the stainless steel conduit may be affixed by means of clamps or struts to the supporting structure of the framework. In the embodiments shown the aluminum extended fin surface expands and contracts at will without affecting the structural mounting between the tubing and the support structure. In all of the embodiments the aluminum fin structure may expand or contract radially or axially at will but will always conform itself to the exterior surface of the stainless steel tube.

It has been found beneficial to coat the entire surface of each of the aluminum parts with a thin layer (0.001 – 0.100 inch) of fluorocarbon material such as for example Teflon, Coracone, Kynar, etc. This coating presents a very good appearance, substantially reduces the frost-up which normally occurs, and has been found to only slightly reduce the anticipated heat transfer rate of the vaporizer. The coating may even be applied to the internal cylindrical surface of the hub in that the layer is so thin that only a temperature drop of 1° or 2° has been encountered across this film. The fluorocarbon film is mechanically strong and tough, resistant to low temperature, and to most chemicals and solvents and as mentioned above, greatly reduces the frost-up encountered in this type of unit.

The present invention may be utilized not only with the manufacture of ambient air vaporizers, but with the manufacture of any other device or structure calling for the attaching of one part to the outside of another part. Thus the invention may be used in the manufacture of many types of heat exchangers. It may be used to couple insulation or decorative material to piping or conduits.

To those skilled in the art to which our invention relates, many changes in construction and widely differing embodiments and applications of the invention may suggest themselves without departing from the spirit and scope of the invention. Our disclosure and the description herein are purely illustrative and are not intended to be in any sense limiting.

We claim:

1. A heat exchanger for warming low temperature fluids comprising a conduit capable of containing high internal pressures, at least one extended surface section coupled to the conduit whereby as fluid passes through said conduit it is progressively warmed, each extended surface section comprising a pair of extrusions of a material having a high thermal conductivity; each extrusion having a hub adapted to closely conform to a substantial portion of the external surface of the conduit, each extrusion having a plurality of fins to provide a large surface area per unit of length of the extrusion, means to resiliently connect said extrusions together about said conduit comprising a deformable locking member on each extrusion extending for substantially the full length of the extrusion, a fixed locking member projecting outward from said hub on each extrusion and extending for substantially the full length of the extrusion, a deformable member on one extrusion lying adjacent to a fixed member on an adjacent extrusion when said extrusions are in assembled relationship about said conduit, a portion of each fixed locking member facing said adjacent extrusion and a proximate portion of each adjacent extrusion defining therebetween a gap,each deformable member having been resiliently deformed about and engaging an other portion of the adjacent fixed locking member to exert a force on said fixed member tending to close said gap, the resilient connections between the deformable members and the fixed members causing said extrusions to conform to the conduit and maintain said conformation during dimensional changes, including expansions and contractions, caused by temperature changes.

2. A heat exchanger for warming low temperature fluids comprising a conduit capable of containing high internal pressures, a plurality of extended surface sections coupled to the conduit in a series relationship whereby as fluid passes through said conduit it is progressively warmed, each extended surface section comprising a pair of extrusions of a material having a high thermal conductivity; each extrusion having a portion adapted to closely conform to a substantial portion of the external surface of the conduit, each extrusion having a plurality of fins to provide a large surface area per unit of length of the extrusion, means to connect said extrusions together about said conduit comprising a deformable locking member on one extrusion extending for substantially the full length of the extrusion, a substantially radially projecting fixed locking member on one extrusion extending for substantially the full length of the extrusion, a deformable member on one extrusion lying adjacent to a fixed member on an adjacent extrusion when said extrusions are in assembled relationship about said conduit, a portion of each fixed locking member facing said adjacent extrusion and a proximate portion of each adjacent extrusion defining therebetween a gap, each deformable member having been resiliently deformed about an other portion of the adjacent fixed locking member to exert a force on said fixed member tending to close said gap, said deformation causing a part of said deformable member to conform to a part of said other portion of the adjacent fixed locking member, the resilient deformation of each deformable member about its adjacent fixed member creating a resilient clamping force which causes the portions of the extrusions to conform to the conduit and maintain said conformation during dimensional changes, including expansions and contractions, caused by temperature changes.

3. The heat exchanger of claim 1 in which each fixed locking member has an arcuate surface about which an adjacent deformable locking member is deformed.

4. The heat exchanger of claim 1 in which the portion of each extrusion which conforms to the conduit comprises a part of a cylindrical surface having an arc of less than 180°.

5. The heat exchanger of claim 1 in which each deformable locking member comprises a base portion formed from an extension of its extrusion and a deformable portion adapted to be bent inwardly toward the conduit.

6. The heat exchanger of claim 5 in which the extremities of the deformable portion are rounded off to prevent failures.

7. The heat exchanger of claim 1 in which the conduit has an external cylindrical surface and the conforming portion of each extrusion comprises a partially cylindrical surface having a radius which slightly exceeds the radius of the said external cylindrical surface of the conduit whereby the extrusions are better able to conform to the conduit upon assembly.

8. The heat exchanger of claim 1 in which the conduit is stainless steel and the extrusions are made of aluminum.

9. A heat exchanger for conveying heat to a fluid comprising a tubular conduit made from material adapted to withstand high internal pressure and temperature variations ranging from cryogenic to ambient, an extended surface means of a material having good heat conducting properties, said extended surface means having a hub portion in close conformity with at least a portion of said tubular conduit, means to resiliently connect the extended surface means to said tubular conduit to allow the hub portion to expand or contract in a radial or axial sense due to temperature variations while allowing the hub to conform itself to the exterior surface of the tubular conduit, said connecting means comprising a broad deformable locking member extending for substantially the full length of the extended surface means, a fixed locking member projecting outward from said hub and extending for substantially the full length of the extended surface means, a deformable member lying adjacent to a fixed member when said extended surface means is in assembled relationship about said conduit, a portion of the fixed locking member and a proximate portion of said adjacent deformable member at least partially defining an air space, said fixed locking member including an arcuate surface, said broad locking member having been resiliently deformed over the arcuate surface of the fixed locking member to apply force to said fixed locking member tending to close said space and thereby cause said hub portion to conform to the exterior of the conduit and maintain said conformity during during dimensional changes caused by said temperature variations.

10. An ambient air vaporizer for vaporizing liquefied gas comprising a stainless steel conduit adapted to convey the gas being heated, at least a portion of said conduit having a substantially cylindrical outer surface, extended surface means assembled about a portion of said conduit to assist in heat transfer to the gas, said extended surface means comprising a pair of identical aluminum extrusions, each of said extrusions having a hub with a partially cylindrical surface adapted to conform to the cylindrical surface of the conduit, the hub of each aluminum extrusion adapted to contact a substantial portion of the cylindrical surface of the conduit when in assembled position, a plurality of fins extending outward from each hub to provide a large surface area per unit of length of the extrusion, means for resiliently connecting the extrusions about the conduit to allow the dissimilar materials to expand and contract due to the extreme temperature changes encountered in the operation of said vaporizer and yet maintain the cylindrical surfaces of the said hubs in close conformity with the cylindrical surface of the conduit, said resilient connecting means including a first locking member on each extrusion extending for substantially the full length of the extrusion, a fixed locking member on each extrusion projecting outward from said hub and extending for substantially the full length of the extrusion, each first locking member including a deformable portion, each fixed locking member lying adjacent to a first locking member on an adjacent extrusion when said extrusions are assembled about said conduit, a portion of each fixed locking member and a proximate portion of the adjacent first locking member at least partially defining an air space, each fixed locking member further including an arcuate surface, the deformable portion of one extrusion having been resiliently arcuately deformed over the arcuate surface on the adjacent fixed locking member on the other extrusion to apply a force to the fixed locking member in the direction of the said one extrusion tending to close said space and thereby cause the softer cylindrical surfaces of the hubs to conform to the exterior of the harder stainless steel conduit and maintain said conformity during dimensional changes caused by said temperature changes.

11. An ambient air vaporizer for vaporizing cryogenic fluids comprising a conduit adapted to convey the fluid being heated, at least a portion of said conduit having a substantially cylindrical outer surface, extended surface means assembled about a portion of said conduit to assist in heat transfer to the fluid, said extended surface means comprising a pair of identi-

cal extrusions, each of said extrusions having a hub with a partially cylindrical surface adapted to conform to the cylindrical surface of the conduit, the cylindrical surfaces of said hubs when taken together including an arc less than 360° whereby the cylindrical surfaces of said hubs do not completely surround the conduit when in assembled position, means for resiliently connecting the extrusions about the conduit to allow the conduit and the extended surface means to expand and contract due to the extreme temperature changes encountered in the operation of said vaporizer and yet maintain the cylindrical surfaces of the said hubs in close conformity with the cylindrical surface of the conduit, said resilient connecting means including a broad locking member on each extrusion extending for substantially the full length of the extrusion, a fixed locking member on each extrusion projecting outward from said hub and extending for substantially the full length of the extrusion, each broad locking member including a deformable portion, each fixed locking member lying adjacent to a broad locking member on an adjacent extrusion when said extrusions are assembled about said conduit, a portion of each fixed locking member and a proximate portion of the adjacent broad locking member at least partially defining an air space,the deformable portion of one extrusion having been resiliently deformed over the adjacent fixed locking member on the other extrusion to apply a force to the fixed locking member in the direction of the said one extrusion tending to close said space and create spring back forces in said broad locking member and in said fixed locking member which oppose one another.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,672,446 Dated June 27, 1972

Inventor(s) Alan R. Tibbetts and Donald R. Tucker

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 40, delete "short"

line 52, delete "long".

Column 9, in claims 3, 4, 5, 7 and 8, the reference to "claim 1" should read --claim 2--.

Signed and sealed this 5th day of March 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334