IMPROVED HEAT PUMP WATER HEATER

BACKGROUND

The present invention relates to water heaters and more particularly relates to an improved heat pump water heater in which a heat exchange coil is located inside a housing disposed inside the heater.

PRIOR ART

There are in existence a wide variety of water heaters including those that employ heating elements and those that use heat pumps for heat exchange. It is the latter variety of heaters to which the present invention is primarily directed.

A heat pump is a system for transferring heat from a low temperature source to high temperature application. In mechanical vapour compression systems, typically, a compressor compresses a phase change fluid (a refrigerant) raising the pressure thus the temperature of the gas refrigerant. Hot and high-pressure refrigerant gas is then passed through a heat exchanger where, in a water heating application, water is heated from the heat rejected by the refrigerant due to condensation. The condensed liquid refrigerant is then expanded to low pressure through an expansion device. At low pressure, the liquid evaporates inside an evaporator where heat of evaporation is absorbed at low temperature from the surrounding environment of the evaporator.

In the more common type of condenser heat exchanger, water is pumped through an external heat exchanger. These devices are typically simple to manufacture and are readily available. However, the cost of the pump and piping as well as their maintenance places limitations on these devices. Moreover, additional protection is

required to protect the compressor in the event of any failure of water flow which could occur due to pump breakage, blocking of water flow due to fouling etc. Potential fouling and blockage also reduces heat transfer performance.

An immersion type heat exchanger eliminates the need for pumping, but suffers from a drop in performance due to waterside scaling and corrosion. If not electrically isolated they require cathodic protection (such as is used in steel tanks) to prevent corrosion.

The immersion type exchangers are required to be manufactured in double wall configuration. In this type of heat exchanger free convection heat transfer occurs at the water side. They also need a large heat transfer surface area compared to a single wall type. Furthermore, a bulky heat exchanger must be fitted before the storage tank is completed or the completed tank must be modified to insert the heat exchanger. In case of a failure, removal of the heat exchanger may not be possible. The immersion heat exchanger requires special machine tools to achieve double wall configuration.

An alternative water heater is disclosed in Australian patent 603510 and includes a tube wrapped around an outside wall of a water storage tank. This heat pump water heater eliminates demerits of a pumped system, provides double wall construction, has reduced corrosion and fouling, and do not cause any damage to an anode.

It is desirable in heat exchange design to provide a low cost competitively priced product, manufactured with a minimum capital investment and with readily available and/or produced materials. It is a further manufacturing objective that the heat exchanger has minimum maintenance and suffers no degradation of

performance over its working life, does not cause any environmental damage and is double wall construction to ensure that the heat transfer fluid does not come in contact with potable water contained in the water tank in the event of mechanical failure of the heat exchanger.

Heat exchanger design and construction are dictated by suitable material selection from available materials, materials costs, efficient production. The aim is to minimize capital investment in production and to produce a high efficiency low maintenance product and with no reduction in performance over the life of the product.

INVENTION

The present invention seeks to provide an alternative to the known heat pumps by providing an improved energy efficient and economic heat pump and more particularly a condenser heat exchanger suitable for the mass production of heat pump type water storage heaters.

More particularly the present invention provides an improved heat exchanger wherein a heating coil is contained within a housing contained in a water heater tank. This design offers all the benefits of the prior art exchangers and more particularly those that employ a tube wrapped outside the storage tank wall. The invention further provides a heat exchanger in which heat transfer takes place via a wall of said housing and where a heat exchange surface area is provided by the surface area of the housing.

In view of the limitation of the heat exchange surface area to the surface area of the housing, to compensate for loss of heat transfer surface area, alternative housing configurations are proposed. According to one embodiment, there is provided an aluminium extruded gallery tube which provides sufficient heat transfer as determined by theoretical calculation to accommodate a heat pump size suitable to get a recovery of 275 Litres of hot water in 4-5 hours in typical 20°C climate.

It is one object of the invention to reduce the cost of a heat pump heater without compromise to its effectiveness, thereby increasing its market appeal and which is cost effective but employing existing facilities and materials. This objective enables the heater to be produced within existing infrastructure. It is a further object of the invention to provide a heat exchanger by fitting a coil having a high coefficient of thermal expansion inside a housing tube so that the coil applies a positive contact against an inner surface of the housing tube. The coil is made from a hollow tube having higher thermal expansion coefficient than a housing tube. This will improve thermal contact during heating due to higher thermal expansion of the hotter tube

In its broadest form the present invention comprises:

a heat exchanger for a water heater of the type including a water tank having an inlet for water to be heated and an outlet for discharging heated water, the heat exchanger comprising;

a housing which receives and retains therein a coil in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from the heat pump circuit;

wherein the heat exchanger is disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing.

Preferably the heat exchanger comprises a housing tube which receives axially disposed therein the heat exchange coil. The housing tube is disposed within said tank, wherein an outer surface of said housing tube is in contact with said water. Heat exchange occurs by means of thermal contact between said coil and an inner surface of the housing tube.

Preferably, the housing tube is a cylindrical tube and the coil disposed therein forms a wound helix. The helical coil communicates with a vapour compression assembly comprising, a compressor for compressing a phase change fluid (a refrigerant), a heat exchanger (evaporator). The coil is preferably made with tube material having a thermal expansion coefficient higher than the housing tube material example copper tubing. But as an alternative may comprises aluminium gallery tube. The housing tube and water tank are preferably concentric.

In another broad form the present invention comprises:

a water heater of the type including a water tank having an inlet for water to be heated and an outlet for discharging heated water;

wherein the tank includes a heat exchanger comprising;

a housing which receives and retains therein a coil in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from the heat pump circuit;

wherein the heat exchanger is disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing. The water heater includes a housing tube disposed within said tank which receives axially disposed therein the heat exchange coil so that the outer surface of said housing tube is in contact with said water allowing heat exchange to occur by means of thermal contact between the coil and an inner surface of said housing tube.

When used, the aluminium extruded gallery tube provides sufficient heat transfer as determined by theoretical calculation to accommodate a heat pump size suitable to obtain a recovery of 275 Litres of hot water in 4-5 hours in typical 20°C climate.

In another broad form the present invention comprises:

a water heater comprising;

a tank having an inlet for receiving and holding water to be heated and means for discharge of heated water,

a heat pump circuit in communication with said tank and including a source of heat exchange fluid, an evaporator, a compressor for compressing said heat exchange fluid and further including an outlet from said compressor allowing said heat exchange fluid to communicate with a coil,

a heat exchanger comprising a housing tube which receives and retains therein said coil which circulates said heat exchange fluid delivered from said outlet to said

compressor;

wherein said heat exchanger includes a housing tube disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said coil is imparted to said water via the wall of said housing.

In another broad form the present invention comprises;

a water heater comprising:

a tank including an inlet for water to be heated and an outlet for heated water,

wherein water is heated in said tank via a coil connected to a heat exchange circuit;

wherein the coil is located in a housing tube located in said tank, wherein heat exchange between said coil and water in said tank takes place via physical contact between the coil and a wall of the housing.

In another broad form the present invention comprises:

a water heater comprising:

a tank including an inlet for water to be heated and an outlet for heated water,

wherein water is heated in said tank via a coil connected to a heat exchange circuit wherein the coil is contained within a housing located in said tank, wherein heat exchange in said tank is enabled by contact between said coil and said water via the wall of said housing; the heater further comprising a phase change material which circulates through a vapour assembly in communication with said coil.

In another broad form according to a method aspect the present invention comprises;

a method of construction of a water heater of the heat pump variety, the method

comprising the steps of ;

a) taking a tank comprising a wall defining a reservoir for holding water.

b) preparing a housing having a wall and an internal cavity;

c) inserting in said cavity of said housing a heat exchange coil, wherein the coil and housing provide a heat exchange assembly;

d) inserting said heat exchange assembly into said tank so that an outer wall of said housing and an inner wall of said tank define a space in said reservoir which receives said water for heating;

wherein said heat exchange coil is in communication with a heat exchange circuit and wherein said heat exchange assembly contacts water in said tank to effect heating of said water.

In another broad form according to a method aspect the present invention comprises

a method of construction of a heat exchange assembly for a water heater wherein the method comprises the steps of ;

a) taking a water tank having a wall defining a reservoir;

b) preparing a housing tube having a wall defining an internal cavity;

c) inserting in said internal cavity a heat exchange coil so that the coil and housing tube together form a heat exchange assembly;

d) attaching said coil to an inner surface of said housing tube;

inserting said heat exchange assembly into said water heater in a location such that the heat exchanger will sit in contact with water in said tank; wherein said heat exchange coil is in communication with a heat exchange circuit and wherein said

heat exchange assembly contacts said water in said tank to effect heating of said water.

In an alternative form the present invention comprises:

a coil capable of use in a heat exchanger for use in a water heater of the type including a water tank having an inlet for water to be heated and an outlet for heated water, the exchanger comprising;

a housing which receives and retains therein the coil;

wherein the coil is formed as a wound helix from a tubular member of indefinite length.

The coil is preferably formed from a tubular material such as copper or extruded aluminium the material having an elastic memory. Where copper is employed this is formed in cross section which maximizes physical contact area between the coil and an inner surface of the housing. The coil is in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from a heat pump circuit. Heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing. The coil is preferably in contact with an inner surface of said housing along the full length of the coil.

In a further broad form the present invention comprises;

a method of production of a coil for use in a heat exchanger for a water tank; the method comprising the steps of :

a) taking a quantity of tubular material of indefinite length and which is capable of cold deformation;

b) passing said tubular material through cold forming rollers;

c) winding said material over a mandrel to form a coil of said tubular material.

Preferably, the mandrel is tapered so that the coil formed on the mandrel is tapered from a middle region of the mandrel to end regions either side of the middle region of said mandrel. Prior to winding on the mandrel, cold forming rollers flatten the tubular material. The tubular material is preferably annealed copper capable of plastic deformation. The coil is preferably wound around the mandrel for a predetermined length to form a helical spiral. The mandrel preferably includes a coil pitch control to enable adjustment of the length of the coil. The coil is wide in a middle region and tapers to narrower regions at either end.

In another broad form the present invention comprises;

a mandrel for forming a coil for use in a heat exchanger in which the coil is inserted in and in contact with a housing within a water tank; the mandrel comprising ;

a generally annular body which receives tubular material for formation of the coil ; wherein the tubular body is tapered from a middle region to at least one end region so that the coil formed on the mandrel is wider at a middle region tapering to a narrow region at least one of its ends. Preferably the mandrel tapers from the middle region to narrow regions at either side of the middle region.

Water is heated in said tank via the coil which is connected to a heat exchange circuit and contained within a housing located in said tank, wherein heat exchange

between said coil and water in said tank takes place via the wall of the housing; the heat exchange circuit further comprising a phase change material. Preferably, the phase change material is activated after the water is heated to ensure that the phase change material does not take the heat from the heating water. The phase change material will relieve load on the compressor and thus helps the compressor to run efficiently

According to a preferred embodiment, the coil is fixed to an inner surface of said housing tube by means of soldering, gluing or with heat flux. The completed water heater with housing tube and coil will be enameled on an outer surface of the housing tube.

DETAILED DESCRIPTION

The present invention will now be described in more detail according to a preferred embodiment and with reference to the accompanying illustrations, wherein;

Figure 1 shows a section through a heat exchanger according to one embodiment; connected to a heat pump circuit including a condenser .

Figure 1a shows an enlarged view of a welded connection between a housing tube and tank base.

Figures 2 shows a coil isolated from the heat exchanger;

Figure 2a shows a typical coil cross section.

Figure 3 shows a cross sectional view of an aluminium gallery tube according to an alternative embodiment of the coil; and

Figure 3a shows a section of aluminium gallery tube of figure 3.

Figure 4 shows an enlarged cross section of an engagement between a deformed copper tube and steel housing tube with hatching to show temperature.

Figure 5 shows an enlarged cross section of an engagement between an aluminium gallery tubing and a steel housing.

Figure 6 shows a plan view of an assembly for forming a coil according to one embodiment including a winding mandrel and nip feed rollers.

Figure 6a shows a side view of the assembly of figure 6.

Referring to figure 1 there is shown a typical heat pump circuit including a water heater tank connected to a condenser heat exchanger according to one embodiment. The heat pump circuit 1 comprises a reservoir 2 of heat exchange fluid (which may be a refrigerant) and expansion device 3 which allows for expansion of said fluid, an evaporator 4 and a compressor 5. Each of these devices is in fluid communication via fluid line 6. Intermediate compressor 5 and expansion device 3, a coil 7 is provided which is housed inside a housing tube 8 axially disposed inside tank 9. Coil 7 is preferably copper tube but may be extruded aluminium tube or other tube made with material having higher thermal expansion coefficient than housing tube 8. Housing tube 8 is preferably a cylindrical tube which may be formed from sheet metal.

The heat exchange (HX) coil 7 is connected to the heat pump circuit 1 to provide heat for heating water in tank 17. The top end 19 of HX coil 7 comprises an inlet 16 for hot refrigerant gas which is compressed by compressor 5 and which is

connected to compressor delivery outlet 10. HX coil 7 further comprises an outlet tube 11 for condensed liquid refrigerant returning to expansion device 3. During the condensation process heat is released from refrigerant and transferred to water held in reservoir space 12 though wall 13. On the refrigerant side (inside housing tube 8) heat is transferred to the HX coil 7 by forced convection. On the water side in reservoir space 12, the heat is transferred from the surface of housing tube wall 13 to water in space 12 by natural convection. In the storage tank, the natural stratification is maintained by the upward convective current of hot water to the top of the storage. The heat exchanger is constructed with top down hot to cold flow. The stratification in the storage tank is maintained and an efficient heat exchange is achieved. An upper region 19 of HX coil 7 performs as a de-superheater which provides hottest water at the top of the tank and a bottom region 18 of HX coil 7 performs as a condenser and sub-cooler providing a low temperature condensation which increases the efficiency of the heat pump compressor 5.

Figure 1a shows an enlarged view of a welded connection between housing tubehousing tube 8 and bottom dome base 14 for a typical standard gas water heater cylinder assembly. Typically these will be connected by a fillet weld 15. The housing tube 8 is welded to a bottom dome 14 whereupon the so formed assembly is enameled on the outer surface which will come into contact with water held in space 12. During the enameling process, some scale, which needs to be removed builds up on the inner surface. HX coil 7 is fitted against the inside surface of housing tube 8 for heat transfer.

Figures 2 shows a coil 20 isolated from hot water storage shell and housing tube

assembly of the type described in figure 1. Figure 2a shows a coil cross section of the coil 20 of figure 2. From the cross sectional view it can be seen that coil 20 is preferably a copper tube which undergoes cold deformation to maximize potential contact area between coil 20 and an inner surface of a housing tube in which the coil is placed. Coil 20 preferably is distorted to form substantially straight wall 21 which maximizes potential surface engagement of the coil with an inner wall of a housing tube. As shown in figure 2a the outer face 21 of coil 20 is deformed to a flat tube which will provide optimal thermal contact area with the inner surface of a housing tube for efficient heat transfer. The outside diameter of the coil 20 needs to be larger than the inside diameter of the finished housing tube therefore when inserted under pressure the heat transfer surfaces are in good thermal contact and remain under contact all the time. At higher temperature the coil will expand more than the housing tube ensuring positive contact for thermal transmission. The coil OD must be uniform over the coil height.

Preferably, approximately 25% of coil 20 near the upper reaches 22 can be higher spacing between coils than lower reaches 23 comprising 75% of the coil, thereby providing improved heat distribution. Similar to the arrangement as described in figure 1, coil 20 includes inlet pipe 24 receiving gas formed by refrigerant compression and outlet pipe 25 for delivery of condensate back to an expansion device.

According to one embodiment, a free standing coil will ideally have an outside diameter at one end less than the outside diameter at the middle of the coil. Thus

the coil is tapered inwards from the center to its ends: (see description with reference to figure 6). Where the coil has a free standing height of 1.25 meters there will be 56 turns for a 22 millimeter pitch. It will be appreciated by persons skilled in the art that these parameters for the coil may be altered to suit particular job applications. A standard copper coil would have a tube thickness of 6.9mm and a width of 16.5mm, but these may vary.

According to one embodiment, the heat exchanger typically employs a copper housing tube and heat exchange coil. According to an alternative embodiment, the heat exchanger employs extruded aluminium gallery tube HX coil.

Figure 3 shows an abbreviated cross sectional view of an aluminium gallery tube 30 fixed to an inner surface 31 of housing tube 32. The aluminium gallery tube is formed by extrusion and is configured to maximize contact area between surface 33 of gallery tube 30 and inner surface 31. A heat transfer paste or thermal epoxy glue is disposed between opposing surfaces 31 and 33. Other suitable HX tube material can also be used. Copper and aluminium tubes provide good heat transfer properties at the same time they are also mechanically flexible to achieve various surface profiles and shape to obtain good heat transfer. Preferably, the coil has a higher thermal expansion coefficient than the housing tube. This ensures that the contact is positive between the housing tube and coil when the coil expands due to temperature rise during heating. In heat pump applications, the coil, carrying high pressure refrigerant will also tend to expand due to pressure rise when operating. This will also assist in improvement of thermal contact. During manufacturing of the heater and after the coil is attached inside the housing tube, the coil can be

pressurized with hydraulic pressure to ensure conformity of the coil to the housing tube. This will accommodate any out of roundness condition of the housing tube or coil. Preferably, the pressure is sufficient to exceed its elastic deformation limit to ensure that when the pressure is released the desired conformity between the coil and the inner surface of the housing tube is retained. The coil will preferably exceed its elastic deformation limit to ensure that when pressure is released the desired conformity between the coil and the inner surface of the housing tube is retained. Where the housing tube is out of round, and there is a mismatch between the coil and housing tube, heat transfer is compromised. Heat from the coil is transferred to the housing tube and then to water in contact with the outer surface of the housing tube. Preferably, each coil of the helix spiral is not in abutting relationship with an adjacent coil therefore ensuring that heat is not transferred between tubes of the coil.

According to one embodiment there is provided a double wall housing tube configuration required for heat exchangers used in heat pump heaters for heating potable water. The present invention offers a change to standard storage type gas water heater cylinders reducing the manufacturing cost. The double wall separates the water from the gas in the coils so that in the event of a wall failure there will be no mixing of the fluids as the refrigerant will be safely retained in the coil.

Preferably, coils 7 and 20 described in figures 1 and 2 respectively are made from a material having higher coefficient of expansion than the material of housing tube tube 8 and provides an expansion force which helps improve thermal contact to the

housing tube

tube inner surface at elevated temperature during heating. This arrangement may provide an alternative to soldering or glue type bonding between the coil and inner housing tube wall. .

After the HX coil 7 is attached to the housing tube 8, the space 12 (see figure 1) inside the coil 7 may be filled with insulating material (not shown) to stop heat loss to the atmosphere. With a copper tube used for HX coil 7 an overall heat transfer coefficient of about 350-370W/m2/°C is expected if the wall thicknesses are 3mm and 0.91 mm respectively for housing tube and HX coil tubes.

An aluminium gallery tube as shown in figure 3 enhances heat transfer due to a multi hole gallery 34. With a multi-hole gallery tube 30 as seen in figure 3, made from an aluminium extrusion, the heat transfer is increased greatly due to the fact that the inner webs 35 work as a funnel to the refrigerant gas as well as conducting heat from the hotter outer wall 36 to a colder inner wall 37. Given that aluminium has about 40% less thermal conductivity than copper, a HX coil arrangement with aluminium gallery tube in full 100% contact with a housing tube surface will result in an overall heat transfer expected to be about 10% more than a standard copper tube HX flattened to the same width. The gallery tube offers strength due to the bridging fins between passages. Aluminium has a higher coefficient of thermal expansion than steel.

In a heat pump water heater where heat is extracted from a source with variation of temperature, the condenser heat output may vary depending upon the condition at the source. At a design condensing temperature and acceptable mean temperature

difference across the refrigerant and heated water, higher energy output at the condenser may potentially increase the condensing temperature thus pressure. This increased condensing temperature and pressure eventually may reduce the system performance. High efficiency can be achieved without loosing additional heat available, by a secondary storage of the excess energy.

According to one embodiment, after the HX is attached, space 12 (see figure 1) in the housing tube 8 , can alternatively be filled with a sealed bag filled with phase change material, which melts at a predetermined melting temperature. A phase change material is a substance, which typically melts at a particular temperature and can absorb heat as a latent heat of melting. Typically, the temperature of melting is dependent upon the composition of phase change material. Typically compared to sensible heating of water, phase change material can store 4-6 times more energy per unit volume. Melting at a predetermined temperature allows absorption of additional heat when the condensing temperature is at or above the melting point. During water draw, the phase change material will release heat to water before the compressor will cut in. A thermostat controlling the compressor should be set to a return temperature, which is below the melting point of phase change material. This will allow the phase change material to release heat to water before compressor start. Addition of phase change material will increase overall performance, including heat pump efficiency and hot water delivery of the system. The additional store of energy provided by the phase change material increases the coefficient of performance. A phase change material has not previously been used in a domestic water heater nor inside a heat exchanger.

In the case where the housing tube and the HX tube are made from different material, the presence of moisture may cause electrolytic corrosion to the less noble (more corrosive) metal. It is preferred that an inner cavity of the housing tube 8 must be sealed from moisture ingress after insulation. With a soldered or glued arrangement where relative movement is restricted, a conformal coating may be applied to keep moisture away.

The heat exchanger according to the invention may be manufactured according to one embodiment by application of the following method steps. Firstly, the housing tube is prepared by blasting the clean inner surface following which the inner surface is polished to remove roughness as required prior to insertion of the coil. This ensures optimum coil /surface contact.

Extruded Aluminum gallery tube HX coil as shown in cross section in figure 3 is suitable for an housing tube. The tube can be produced in a continuous roll. The ends of the gallery tube must be fitted with an aluminum adaptor, which will allow connecting standard round tube.

Figure 3a shows an exploded view of an end assembly 40 including a gallery tube 41 and end adaptor 42 which receives aluminum tube 43 to complete the assembly.

Once the gallery tube 41 is connected the so formed coil may be bonded to a housing tube by a number of different methods. Those methods are as follows:

1. Soldering

To provide mechanical and thermal bonding, the HX coil can be soldered to the housing tube with high metal content soldering material. A solder paste may be

sprayed (or wetted by brush) on the inner surface of the housing tube. Some solder paste can also be painted to the HX coil outer face to make it wet before inserting inside the housing tube. After inserting the coil, clamps must be attached at the end of the coil tube to secure to the housing tube wall. The assembly is then baked in an oven at an appropriate temperature. Advantages of soldered HX include, a firm and uniform heat transfer contact is possible, the assembly is not affected by physical movement and insulation can be injected without concern of insulation material running between the tube and housing tube wall. Also, the tube outer wall does not have to be perfectly flat eliminating tight tolerance in production. Metallic solder will fill dents and voids providing good heat transfer.

2. Heat transfer glue.

To eliminate the high temperature oven curing process required for metal soldering, synthetic resin based heat transfer compounds can be used to bond the HX coil to the housing tube. The heat transfer flux may be sprayed on the housing tube surface before inserting the HX coils. HX coil tube ends must be secured to the housing tube. Heat transfer glue reduces contact thermal resistance compared to a system without any heat transfer flux as well as providing mechanical strength to hold the HX in place.

3. Heat transfer flux.

When HX coil is made from material of a higher thermal expansion coefficient than the housing tube material and assembled at low or room temperature, the expansion force the HX will exert on the housing tube at elevated hot water temperature will offer automatic mechanical bonding of the HX coil to the tube. In

this configuration the need for soldering or glue can be avoided. However, to reduce contact thermal resistance a heat transfer flux must be applied between the HX coil and housing tube surface. An advantage of using heat transfer flux is that the HX may be removed in case of failure. The arrangement may also eliminate stress concentration that can arise in a soldered system. But the outer wall of the tube must be made flat therefore a tighter production process is required. Heat transfer glue or flux is almost 40-50 times more heat conductive than air but 300 times of 200 times less conductive compared to copper or aluminium respectively. Therefore, the purpose of the heat transfer compound is only taken to fill unavoidable air void spaces and not to increase heat transfer as compared to perfect metallic contact.

Inserting the HX coil inside the housing tube:

One simple method can be twist, insert, position and release. About half a turn twist will reduce the coil diameter by about 2mm based on an 8" housing tube. A simple tool may be required to assist in insertion. For example, two concentric tubes both fitted with arms to hold coil ends. For instance an inner tube holds the bottom end and an outer tube holds the top end of the coil. Handles are attached to each tube to allow twisting into position. It assumed that the force required to twist a turn could be applied manually without any machine drive.

The Housing tube HX may have alternative applications in domestic environments. Both the aluminum and copper tube HX coil in the housing tube could be used in domestic or small commercial heat recovery from air conditioner or refrigerator condensers by de-superheating or condensing.

Copper tube HX coil in the housing tube can further be used in heat recovery from other heat sources, waste hot water, waste steam, in indirect frost free solar water heater using anti freeze secondary heat transfer fluid etc. For higher heating capacity in a commercial size heater, the fine tube can be finned externally (water side) to enhance heat transfer. Preferably the heat exchange arrangement will result in the water being hot at the top and cooler at the bottom but it will be appreciated that this arrangement could be reversed.

Figure 4 shows an enlarged cross section of an engagement between a section of deformed copper tube 50 abutted against and steel housing tube wall 51 and an enamel layer 52. The section of copper tube 50, adjacent wall 52 and enamel layer are shaded with hatching to show contours of static temperature gradients (° k). Tube 50 has flattened walls 53 and 54 which maximizes surface area contact between opposing surfaces 54a and 51a.

Figure 5 shows an enlarged cross section of an engagement between an aluminium gallery tubing 55 abutted against and steel housing tube wall 56 and an enamel layer 57. The section of gallery tube 55, adjacent wall 56 and enamel layer 57 are shaded with hatching to show contours of static temperature gradients (° k). Aluminum gallery tube 55 has flattened walls 58 and 59 which maximizes surface area contact between opposing surfaces 59a and 56a.

It will be seen on comparison between the condensate rates of refrigerant in copper and aluminium gallery tube that the condensate rate is slower when gallery tube is used. For copper tube the rate is h = 1000 W/m ^{2} °k and for aluminium gallery tube the rate is h = 1000 W/m ^{2} °k. An aluminium gallery tube as shown in figure

5 enhances heat transfer due to a multi hole gallery . With a multi-hole gallery tube 55 as seen in figure 5, made from an aluminium extrusion, the heat transfer is increased greatly due to the fact that the inner webs 55b work as a funnel to the refrigerant gas as well as conducting heat from the hotter outer wall 58 to a colder inner wall 59. Given that aluminium has about 40% less thermal conductivity than copper, a HX coil arrangement with aluminium gallery tube in full 100% contact with a housing tube surface will result in an overall heat transfer expected to be about 10% more than a standard copper tube HX flattened to the same width. The gallery tube offers strength due to the bridging webs 55b between passages 55a.

A method of construction of the coil according to one embodiment will be described below with reference to figures 6 and 6a.

According to one embodiment a coil is inserted inside the housing tube whilst taking advantage of an elastic memory induced in the coil. This may be effected by twisting the preformed coil during insertion into the housing tube. The twisting temporarily reduces the diameter of the coil to allow sufficient clearance for insertion. The twisting is limited to the elastic limit of the coil tube. When the coil is inserted in the tube, unwinding occurs due to release of the elastic energy which causes engagement between the coil and inner surface of the housing tube. A friction force occurs between the coil and inner surface of the housing tube. The amount of friction will depend upon the surface friction coefficients as well as the normal force created by the coil on the housing tube wall. The friction force may cause retention of unwinding process if the tension in the coil is less than the total friction force. There is a relation between the unwinding tension force and friction

force. Thus there is an optimum size diameter of the helical coil to provide a predetermined friction force where the normal force and friction force is in balance. Use of a lubricant reduces the friction force and helps unwind the coil and bring the coil into maximum physical contact with the inner surface of the housing tube wall. Solder paste or heat transfer paste or other form of binder may provide this lubrication action during this insertion process. The coil is prone to start unwinding from the ends first and the portion middle last. The end diameters increase before the middle section during unwinding. This can result in the end coils becoming in tight contact with the housing tube wall while the middle section is still progressing to unwind. If the middle section does not come in contact with the inner wall because of the fact the coil is locked tight by the friction at the ends, this will compromise the heat transfer efficiency. When the coil is the same diameter along the full length of the coil, there is a risk that not all the coil will contact the inner surface of the housing tube. To overcome this potential problem of incomplete contact, the coil may be prepared with a taper forming a wide region at the middle section to a narrow end regions. The process to be described below discloses a coil with a middle region wider than the end regions, wherein the end regions unwind after the middle region. .

Referring to figure 6 there is shown a plan view of an assembly 60 for forming a coil according to one embodiment.

Figure 6a shows a side view of the assembly of figure 6.

Assembly 60 comprises a length of copper tube 61 which will typically be supplied on a roll 62 wherein the coil is formed from a tubular member of indefinite length

which is wound as a helix. The copper tube 61 is unfurled from roll 62 and fed through tube straighteners 63, followed by feeding through guiding roller 64 and feeding roller 65. The copper tube then tracks onto mandrel 66. Mandrel 66 is powered for rolling tube 61 about tapered mandrel 67 . Mandrel 67 has narrow end regions 68 and 69 and intermediate therebetween a wide portion 70. The tubular material of copper 61 has an elastic memory and is formed in cross section so as to maximize physical contact area between the coil and an inner surface of a housing tube.

The method of production of a helical coil for use in a heat exchanger involves taking the tubular material 61 capable of cold deformation by passing said tubular material through cold forming rollers 64 and 65 and then winding the material over mandrel 67 to form a coil of said tubular material. The mandrel is tapered from a middle region of the mandrel to end regions either side of the middle region of said mandrel so that the coil formed on the mandrel is tapered. The coil is wide in a middle region and tapers to narrower regions at either end. The cold forming rollers 65 flatten said tubular material prior to winding onto said mandrel 67 for a predetermined length. Mandrel 67 has a coil pitch control so as to adjust the length of the coil which forms a helical spiral.

It will be recognized by persons skilled in the art that numerous variations and modifications may be made to the invention as broadly described herein such as but not limited to alternative material choice, without departing from the overall spirit and scope of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1 A heat exchanger for a water heater of the type including a water tank having an inlet for water to be heated and an outlet for discharging heated water, the heat exchanger comprising;

a housing which receives and retains therein a coil in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from the heat pump circuit;

wherein the heat exchanger is disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing.

2 A heat exchanger according to claim 1, wherein the housing comprises a housing tube which receives axially disposed therein said heat exchange coil.

3 A heat exchanger according to claim 2 wherein the housing tube is disposed within said tank.

4 A heat exchanger according to claim 3 wherein an outer surface of said housing tube is in contact with said water.

5 A heat exchanger according to claim 4 wherein heat exchange occurs by means of thermal contact between said coil and an inner surface of said housing tube.

6 A heat exchanger according to claim 5 wherein the housing tube is a cylindrical tube.

7 A heat exchanger according to claim 6 wherein the coil forms a wound helix.

8 A heat exchanger according to claim 8 wherein the helical coil communicates with a vapour compression assembly comprising, a compressor for compressing a phase change fluid (a refrigerant), a heat exchanger (evaporator).

9 A heat exchanger according to claim 9 wherein the coil comprises copper tubing .

10 A heat exchanger according to claim 8 wherein the coil comprises aluminium gallery tube.

11 A heat exchanger according to claim 10 wherein the housing tube and water tank are concentric.

12 A water heater of the type including a water tank having an inlet for water to be heated and an outlet for discharging heated water;

wherein the tank includes a heat exchanger comprising;

a housing which receives and retains therein a coil in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from the heat pump circuit;

wherein the heat exchanger is disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing.

13 A water heater according to claim 12 wherein, the housing comprises a housing tube which receives axially disposed therein said heat exchange coil.

14 A water heater according to claim 13 wherein the housing tube is disposed within said tank.

15 A water heater according to claim 14 wherein an outer surface of said housing tube is in contact with said water.

16 A water heater according to claim 15 wherein heat exchange occurs by means of thermal contact between said coil and an inner surface of said housing tube.

17 A water heater according to claim 16 wherein the housing tube is a cylindrical tube.

18 A water heater according to claim 17 wherein the coil forms a wound helix.

19 A water heater according to claim 18 wherein the helical coil communicates with a vapour compression assembly comprising, a compressor for compressing a phase change fluid (a refrigerant), a heat exchanger (evaporator).

20 A water heater according to claim 19 wherein the coil comprises copper tubing

21 A water heater according to claim 20 wherein the coil comprises aluminium gallery tube.

22 A water heater according to claim 20 wherein the aluminium extruded gallery tube provides sufficient heat transfer as determined by theoretical calculation to accommodate a heat pump size suitable to obtain a recovery of 275 Litres of hot water in 4-5 hours in typical 20°C climate.

23 A water heater according to claim 22 wherein the housing tube and water tank are concentric.

24 A water heater comprising;

a tank having an inlet for receiving and holding water to be heated and means for discharge of heated water,

a heat pump circuit in communication with said tank and including a source of heat exchange fluid, an evaporator, a compressor for compressing said heat exchange fluid and further including an outlet from said compressor allowing said heat exchange fluid to communicate with a coil,

a heat exchanger comprising a housing tube which receives and retains therein said coil which circulates said heat exchange fluid delivered from said outlet to said compressor;

wherein said heat exchanger includes a housing tube disposed inside said tank such that water to be heated is disposed around said housing, wherein heat generated in said coil is imparted to said water via the wall of said housing.

25 A water heater comprising:

a tank including an inlet for water to be heated and an outlet for heated water,

wherein water is heated in said tank via a coil connected to a heat exchange circuit;

wherein the coil is located in a housing tube located in said tank, wherein heat exchange between said coil and water in said tank takes place via physical contact between the coil and a wall of the housing.

26 A heater according to claim 24 wherein the housing in which said coil is retained is a cylindrical housing tube disposed concentrically within said tank.

27 A method of construction of a water heater of the heat pump variety, the method comprising the steps of ;

a) taking a tank comprising a wall defining a reservoir for holding water.

b) preparing a housing having a wall and an internal cavity;

c) inserting in said cavity of said housing a heat exchange coil, wherein the coil

and housing provide a heat exchange assembly;

d) inserting said heat exchange assembly into said tank so that an outer wall of said housing and an inner wall of said tank define a space in said reservoir which receives said water for heating;

wherein said heat exchange coil is in communication with a heat exchange circuit and wherein said heat exchange assembly contacts water in said tank to effect heating of said water.

28 A method of construction of a heat exchange assembly for a water heater wherein the method comprises the steps of ;

a) taking a water tank having a wall defining a reservoir;

b) preparing a housing tube having a wall defining an internal cavity;

c) inserting in said internal cavity a heat exchange coil so that the coil and housing tube together form a heat exchange assembly;

d) attaching said coil to an inner surface of said housing tube;

inserting said heat exchange assembly into said water heater in a location such that the heat exchanger will sit in contact with water in said tank; wherein said heat exchange coil is in communication with a heat exchange circuit and wherein said heat exchange assembly contacts said water in said tank to effect heating of said water.

29 A method according to claim 28 comprising the further step of preparing said housing tube prior to insertion of said coil by blasting an inner surface following which the inner surface is polished to remove roughness prior to insertion of the coil.

30 A water heater comprising:

a tank including an inlet for water to be heated and an outlet for heated water,

wherein water is heated in said tank via a coil connected to a heat exchange circuit wherein the coil is contained within a housing located in said tank, wherein heat exchange in said tank is enabled by contact between said coil and said water via the wall of said housing; the heater further comprising a phase change material which circulates through a vapour assembly in communication with said coil.

31 A water heater according to claim 30 wherein the coil is formed from aluminium extruded gallery tube which provides sufficient heat transfer as determined by theoretical calculation to accommodate a heat pump size suitable to get a recovery of 275 Litres of hot water in 4-5 hours in typical 20°C climate.

32 A water heater according to claim 29 wherein the coil is formed from copper.

33 A coil capable of use in a heat exchanger for use in a water heater of the type including a water tank having an inlet for water to be heated and an outlet for heated water, the exchanger comprising;

a housing which receives and retains therein the coil;

wherein the coil is formed as a wound helix from a tubular member of indefinite length.

34 A coil according to claim 33 wherein the tubular material has an elastic memory .

35 A coil according to claim 34 wherein the tubular material is formed in cross section so as to maximize physical contact area between the coil and an inner

surface of said housing.

36 A coil according to claim wherein, the coil is in fluid communication with a heat pump circuit which circulates a heat exchange fluid provided from a heat pump circuit.

37 A coil according to claim wherein, heat generated in said housing is imparted to said water via a wall of said housing, through thermal contact between said coil and said housing.

38 A coil according to claim 37 wherein the coil is in contact with said inner surface of said housing along the full length of the coil.

39 A coil according to claim 38 wherein the tubular material is copper and allows a refrigerant condensation rate of $h = 1000\ W/m^2\ ^\circ k$.

40 A coil according to claim 39 wherein a heat transfer coefficient for copper tube is about 350-370W/m2/°C if the wall thicknesses of said tube are 3mm and 0.91 mm respectively for the housing tube and coil tubes.

41 A coil according to claim 38 wherein the tubular material is Aluminium gallery tube and allows a condensation rate of $h = 1000\ W/m^2\ ^\circ k$.

42 A coil according to claim 41 wherein ends of the gallery tube are fitted with an aluminium adaptor, which allows connection to a round tube.

43 A method of production of a coil for use in a heat exchanger for a water tank; the method comprising the steps of :

a) taking a quantity of tubular material of indefinite length and which is capable of cold deformation;

b) passing said tubular material through cold forming rollers;

c) winding said material over a mandrel to form a coil of said tubular material.

44 A method according to claim 43 wherein the mandrel is tapered so that the coil formed on the mandrel is tapered.

45 A method according to claim 44 wherein the mandrel is tapered from a middle region of the mandrel to end regions either side of the middle region of said mandrel.

46 A method according to claim 45 wherein the cold forming rollers flatten said tubular material prior to winding onto said mandrel .

47 A method according to claim 46 wherein the tubular material is annealed copper capable of plastic deformation.

48 A method according to claim 47 wherein the coil is wound around said mandrel for a predetermined length.

49 A method according to claim 48 wherein the mandrel has a coil pitch control so as to adjust the length of the coil.

50 A method according to claim 49 wherein the coil is a helical spiral.

51 A method according to claim 50 wherein the coil is wide in a middle region and tapers to narrower regions at either end.

52 A method according to claim 51 wherein the coil is inserted in a housing tube by inducing an elastic memory into the coil prior to insertion thereby allowing the coil to spring back against an inner wall of the housing tube.

53 A mandrel for forming a coil for use in a heat exchanger in which the coil is inserted in and in contact with a housing within a water tank; the mandrel comprising ;

a generally annular body which receives tubular material for formation of the coil ; wherein the tubular body is tapered from a middle region to at least one end region so that the coil formed on the mandrel is wider at a middle region tapering to a narrow region at least one of its ends.

54 A mandrel according to claim 53 wherein the mandrel tapers from the middle region to narrow regions at either side of the middle region.

55 A mandrel according to claim 54 wherein the coil produced on said mandrel is wide at its middle region taken tapering longitudinally along an axis of the mandrel to narrow regions at ends of the coil .

56 A mandrel according to claim 55 wherein the coil is deformed to a generally oval cross section prior to winding on said mandrel.