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(54) METHOD FOR MANUFACTURING A HEAT-EXCHANGER AND A SYSTEM FOR PERFORMING THE METHOD

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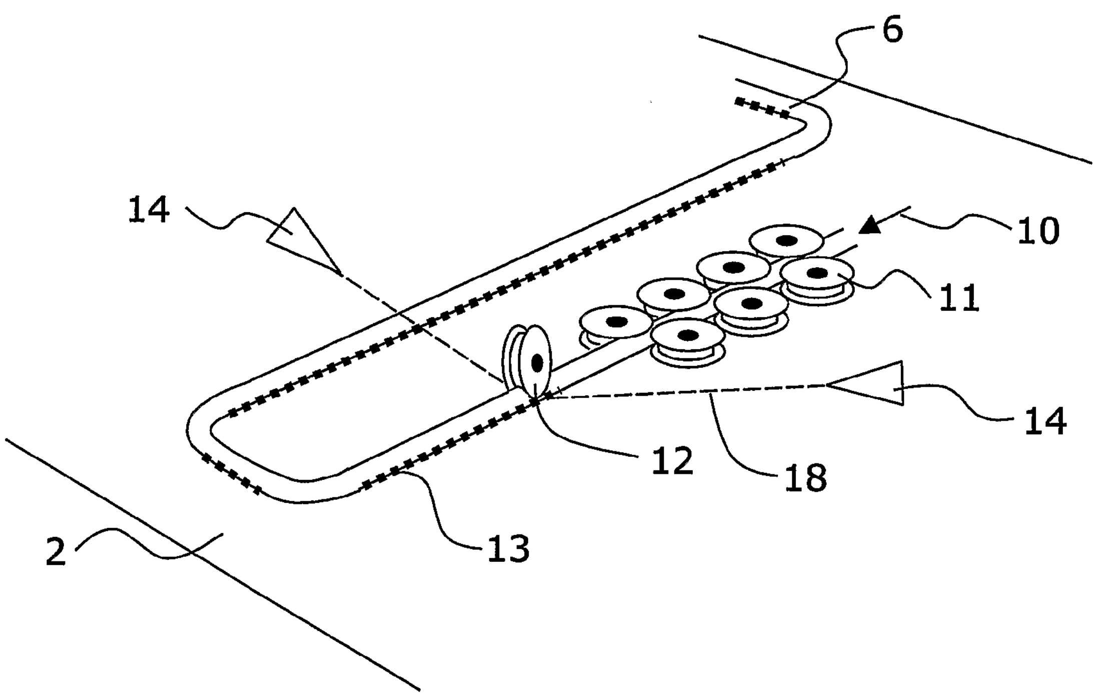
(57) ABSTRACT

A method for manufacturing a heat-exchanger and in particular a heat-exchanger suitable for energy transfer between a plate and a fluid circuit. A sheet metal plate and a predetermined length of continuous metal tubing are prepared. The length of metal tubing is successively applied to the sheet metal plate. The successive application includes bringing the metal tubing into close contact with the sheet metal plate and affixing the metal tubing to the sheet metal plate.



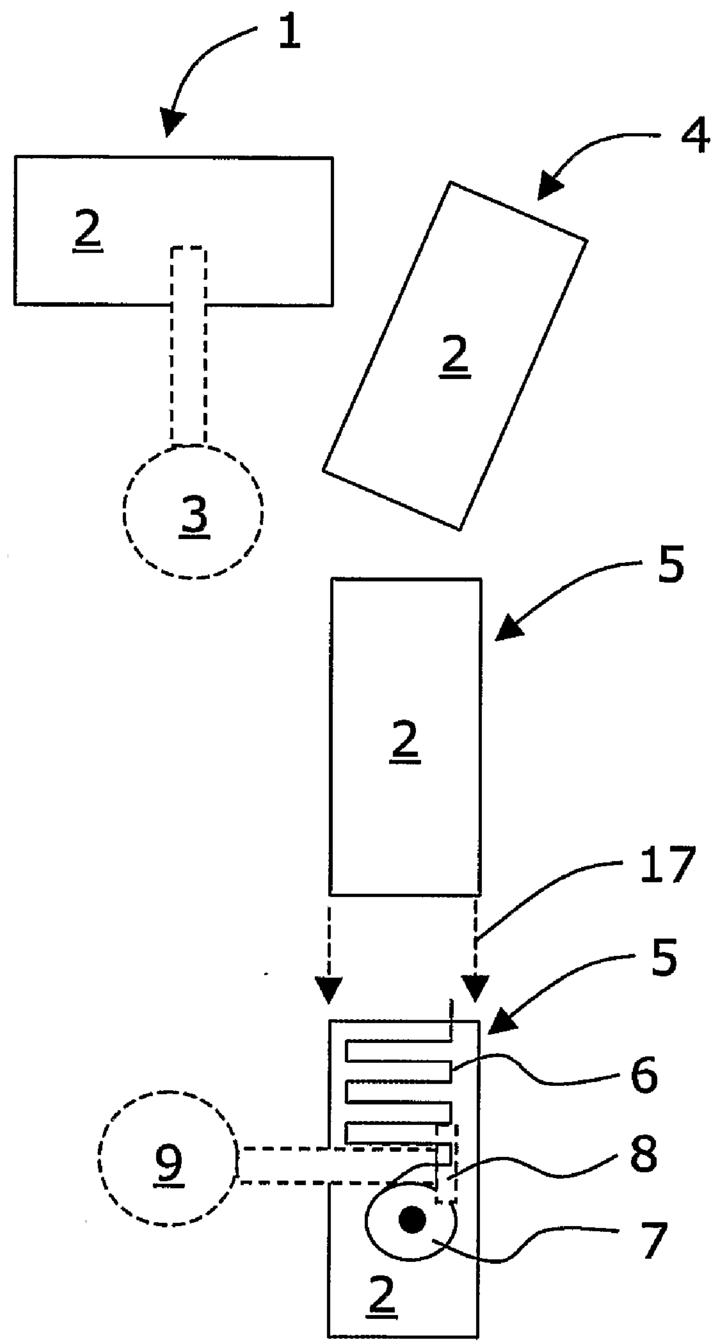


Fig. 1

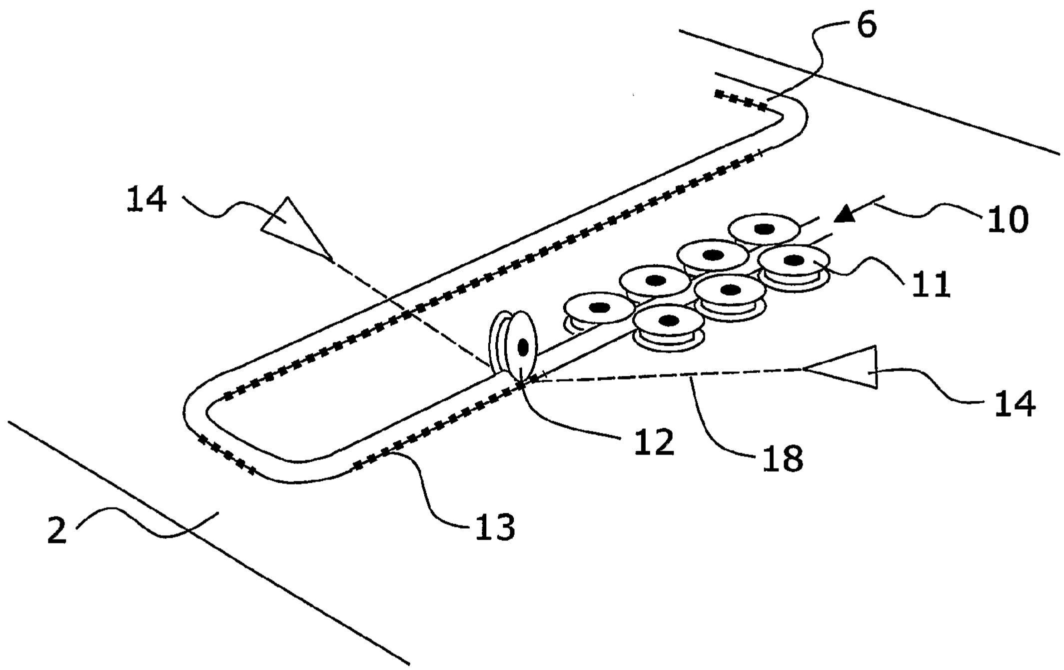


Fig. 2

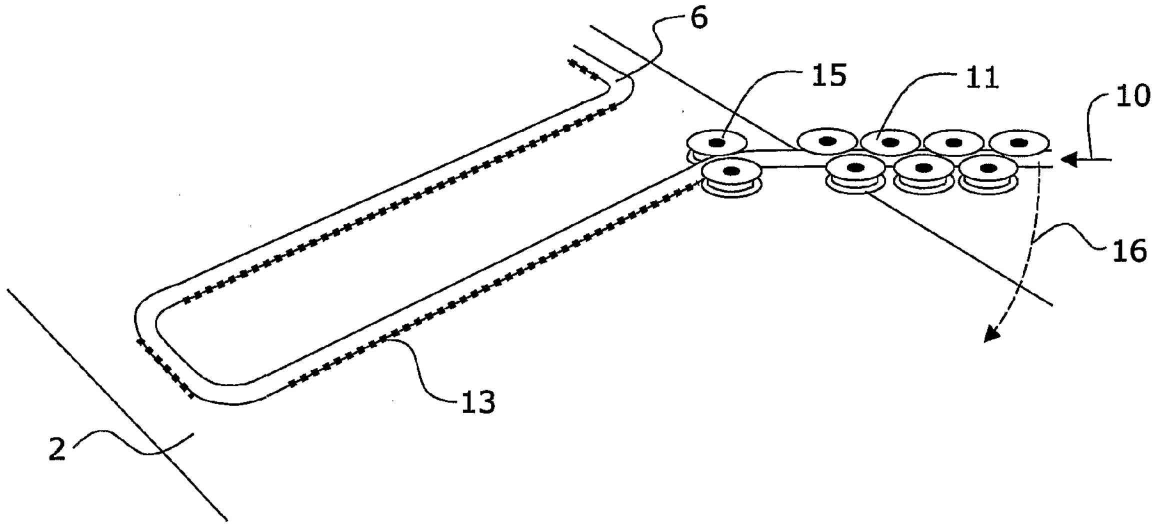


Fig. 3

METHOD FOR MANUFACTURING A HEAT-EXCHANGER AND A SYSTEM FOR PERFORMING THE METHOD

TECHNICAL FIELD

[0001] The present patent application relates to method for manufacturing a heat-exchanger and in particular a heat-exchanger suitable for energy transfer between a plate and a fluid circuit in accordance with the preamble of claim **1**.

BACKGROUND OF THE INVENTION

[0002] With increasing cost for domestic heating the demand for alternative and environmentally friendly alternatives is increasing. One such alternative is to utilize the energy readily available in the form of solar energy. In order to make use of the energy provided by the sun it is common to use thermal solar collectors. These thermal solar collectors can e.g. be based on the principle of letting the sun irradiate a dedicated surface in order to be absorbed by and heat that surface and thereafter transferring the heat from that surface to a fluid medium, facilitating transport of the heat to a desired location. Thus there is an increasing need for heat exchangers, and in particular heat exchangers suitable for energy absorption in solar energy systems.

[0003] When manufacturing thermal solar collectors it is often preferred to manufacture large so called full plate absorbers, where tubing for heat transfer is provided on a fairly large homogeneous absorber plate. The tubing is usually provided as a continuous loop attached to the absorber plate in accordance with a predetermined pattern.

[0004] When manufacturing such full plate absorber heat exchangers today it is common to initially prepare a skeletal structure of tubing essentially corresponding to the desired predetermined tubing pattern. The skeletal tubing structure is thereafter positioned on the homogeneous absorber plate where after it is affixed thereto, usually by welding or soldering the skeletal tubing structure to the homogeneous absorber plate.

[0005] However, several problems are associated with the above manufacturing method. The skeletal tubing structure is usually very instable and requires a substantial working surface in the workshop for its preparation. Due to the instability of the skeletal tubing structure the work of correctly positioning the skeletal tubing structure on the homogeneous absorber plate is usually quite cumbersome and time consuming. The instability in combination with residual stress in the skeletal tubing structure also makes it virtually impossible to achieve a close to one hundred percent contact between the tubing and the homogeneous absorber plate, which of course has a negative effect on the heat transfer capability of the heat exchangers manufactured in accordance with this known method.

[0006] Taking the above into account there is a need for an improved method for manufacturing such full plate absorber heat exchangers.

SUMMARY OF THE INVENTION

[0007] One object of the invention is to provide a method for manufacturing a heat-exchanger, and in particular a heat-exchanger suitable for energy transfer between a plate and a fluid circuit, the method providing for eliminating or reducing one or more of the problems described above.

[0008] This object is achieved in accordance with the characterizing portion of claim **1**.

[0009] Thanks to the provision of a method comprising: preparing a sheet metal plate; preparing a predetermined length of continuous metal tubing; successively applying said length of metal tubing to said sheet metal plate, said successive application including: bringing said metal tubing into close contact with said sheet metal plate; and affixing said metal tubing to said sheet metal plate, an improved flexible and cost efficient manufacturing method providing for the manufacture of heat exchangers having good measurement tolerances and thus able to provide good thermal contact between the tubing and the sheet metal plate and thus providing high efficiency is provided.

[0010] Preferred embodiments are listed in the dependent claims.

DESCRIPTION OF DRAWINGS

[0011] In the following, the invention will be described in greater detail with reference to attached drawings, in which

[0012] FIG. **1** is a schematic illustration of a system for manufacturing a heat-exchanger in accordance with the method of the present invention,

[0013] FIG. **2** is a schematic illustration of the means for performing the step of instantaneous application, positioning and affixing of the metal tubing to the sheet metal plate in accordance with the method of the present invention,

[0014] FIG. **3** illustrates schematically the means for performing the step of providing the metal tubing with bends for forming a predetermined circuit pattern during the successive application of the tubing to said sheet metal plate in accordance with the method of the present invention.

[0015] Still other objects and features of the present invention will become apparent from the following detailed description considered in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for purposes of illustration and not as a definition of the limits of the invention, for which reference should be made to the appended claims. It should be further understood that the drawings are not necessarily drawn to scale and that, unless otherwise indicated, they are merely intended to conceptually illustrate the structures and procedures described herein.

DESCRIPTION OF EMBODIMENTS

[0016] A schematic illustration of a system for manufacturing a heat-exchanger in accordance with the method of the present invention is illustrated in FIG. **1**. The system comprises a storage **1** of sheet metal plates **2** of a predetermined size. A handling system **3**, such as a pre-programmed robotic handling system, is provided for handling the sheet metal plates **2**. However, it is obvious that any suitable handling system could be used, including manual handling of the sheet metal plates **2**.

[0017] The handling system **3** is arranged to take one sheet metal plate **2** from the storage **1** and transfer it to an alignment unit **4**, where the sheet metal plate **2** will be released and positioned in a pre-determined well defined position. Once the sheet metal plate **2** has taken the pre-determined well defined position, the handling system **3** will once again take the sheet metal plate **2** and transfer it to a plane working table **5**. Due to the alignment step, exact positioning on the plane working table **5** is greatly facilitated. The sheet metal plate **2** will thereafter be fixed in a working position on the plane working table **5**. The sheet metal plate **2** is preferable fixed to the plane working table **5** using vacuum suction, whereby the sheet metal plate **2** is brought into close contact with the plane working table **5**, thus providing an essentially plane working surface on the sheet metal plate **2**.

[**0018**] A coil (not shown) of continuous metal tubing **6**, preferably copper tubing, is provided. In a preferred embodiment, a predetermined length of continuous metal tubing **6** is prepared in a sequence of steps which includes, straightening the metal tubing **6**, cutting the metal tubing **6** to the predetermined length required for the finalized product and winding the predetermined length of metal tubing upon a spool **7**.

[**0019**] The tubing **6** is provided for carrying a fluid medium for transferring the heat from the sheet metal absorber plate **2** to e.g. a domestic heating system. The preferred fluid medium for these kinds of systems is usually water. In order to prevent damages to such solar collector system, the water used need to be of a certain quality. In systems placed in areas where the temperature go below 0° Celsius, an anti-freezing liquid shall also be added to the water. The anti-freezing liquid may be glycol or glycol with corrosion inhibitors.

[**0020**] In the preferred embodiment, a tubing application unit **8**, e.g. carried by a second pre-programmed robotic system **9**, will thereafter be provided with the spool **7** containing the predetermined length of continuous metal tubing **6**. However, in an alternative embodiment tubing **6** could be fed directly from the coil (not shown) to the tubing application unit **8**, which could comprise means for performing the above steps of straightening the metal tubing **6** prior to application and cutting the metal tubing **6** to the predetermined length required for the finalized product. As illustrated in FIG. **1**, the working table **5** carrying the sheet metal plate **2** will be moved in the direction of the dotted arrows **17** and into the operating reach of the second pre-programmed robotic system **9** carrying the tubing application unit **8**.

[**0021**] As illustrated schematically in FIG. **2**, the tubing application unit **8** is arranged for successively applying the length of metal tubing **6** to the sheet metal plate **2**. In the preferred embodiment, where the predetermined length of metal tubing **6** is provided upon a spool **7**, the tubing **6** is fed in the direction of arrow **10** towards a predetermined position on the sheet metal **2** plate via a truing device, e.g. consisting of a number of rolls **11**. Thereafter the metal tubing **6** is brought into close contact with the sheet metal plate **2**, e.g. by pressing the metal tubing **6** towards the sheet metal **2** plate using at least one guide wheel **12**. The tubing **6** brought into close contact with the sheet metal plate **2** is then instantaneously affixed to the sheet metal plate **2**.

[**0022**] In the preferred embodiment affixing is effected through welding the metal tubing **6** to the sheet metal plate **2**. Laser welding is the preferred method of joining. Laser welding is particularly suited for the production in large volumes of the full plate absorber heat exchanger. As the tubing **6** has been brought into close contact with the sheet metal plate **2** it is possible to, by means of lasers **14** emitting laser beams **18**, achieve welds **13** providing for highly efficient thermal transfer. Welds **13** are suitably provided at both sides of the tubing **6** simultaneously during the welding operation. As the tubing **6** only needs to be brought into close contact with the sheet metal plate **2** at the weld point itself, the entire complex of tolerance problems is restricted to one point.

[**0023**] In use the sun irradiates the absorber plate **2**, where the thermal energy of the sun is absorbed and transported by the plate **2** towards a weld **13**. The thermal energy is led through the weld **13** and into the tubing **6**, why the ability of the weld **13** to transfer thermal energy is critical. Thereafter the thermal energy will be transferred to a fluid medium circulating in the tubing **6** and utilized for transporting the thermal energy to a different location. It will be obvious for the person skilled in the art that the same applies in the inverse direction, i.e. where the thermal energy of a fluid medium circulating in the tubing **6** is transferred to the tubing **6** and via the welds **13** to a plate **2** arranged to emit thermal energy to its surroundings.

[**0024**] In the preferred embodiment the full plate absorber heat-exchanger is engineered through laser welding of copper tubing **6** on to a homogeneous absorber plate **2**, preferably an aluminum or copper sheet metal plate **2**. This manufacturing method gives a very good thermal contact between the pipe tubing **6** and the plate **2**. The method in accordance with the present invention also allows for a very high extent of flexibility when it comes to the design of the absorber. The copper tube **6** is preferably welded to the backside of the absorber plate **2**, leaving a smooth surface and an essentially uniform color on the visible side of the absorber. Laser welding produces an essentially homogenous color tone and flat absorber surface that complies with the stringent aesthetic demands and at the same time provides superior performance.

[**0025**] The visible side of the absorber metal plate **2** is preferably pre-coated with a multi-layer selective surface. In the case of aluminum plates **2**, the multi-layer selective coating is preferably deposited on an anodized aluminum substrate using the Physical Vapor Deposition technique (PVD). High infrared (IR) reflection ensures a low thermal emission coefficient (ϵ). Oxide layers on the top are optimized for a very high solar absorption coefficient (α) and resistance against environmental influences. This surface often has a blue color tone.

[**0026**] In the case of a copper plate **2**, it is coated through a magnetron sputtering process. A reactive process is used to produce a CERMET multi-layer coating with a graded refractive index, where very small metallic particles are dispersed in an amorphous dielectric matrix. The metal content is decreasing to the upper layers. Absorption is achieved by scattering effects at the metallic particles and the surrounding dielectric matrix. In addition, such multi-layer thin films use interference effects between semi-transparent layers to trap energy. Therefore an antireflection coating is applied on the surface of the layer stack, which also has the function of a protective film. A special metallic coating is applied to the top of the substrate as a barrier layer to prevent corrosion of the substrate and diffusion of the substrate material into the upper layers, which enhances the durability of the coating drastically. At the same time it promotes the adhesion of the subsequent deposited layers.

[0027] It will be obvious to the person skilled in the art that the coating of the visible side of the absorber metal plate **2** as suggested for aluminum plates above can be used also for copper plates **2** and that the coating suggested for copper plates **2** can be used also for aluminum plates **2**. Furthermore, it will be obvious to the person skilled in the art that coating can be provided using any suitable method of surface treatment, such as painting.

[0028] As illustrated schematically in FIG. **3**, in accordance with the inventive method the metal tubing **6** is arranged to be fed in the direction of arrow **10** and successively applied and affixed to the sheet metal plate **2** and provided with bends in order to form a predetermined circuit pattern upon the sheet metal plate **2**. The circuit pattern can be optimized to provide maximum efficiency in heat transfer.

[0029] In a preferred embodiment the tubing application unit **8** includes means for feeding the tubing **6**, the truing device (e.g. the rolls **11**), the means (e.g. guide wheel **12**) for bringing the tubing **6** into close contact with the sheet metal plate **2**, the means (e.g. the lasers **14**) for affixing the tubing **6** to the sheet metal plate **2** as well as means **15** for providing the tube bends, all of which are arranged at one and the same tool which is carried by a pre-programmed robotic system **9**, why no exchange of tools is necessary during the application process. The robotic system **9** provides for highly accurate positioning when applying and affixing the tubing **6** circuit to the sheet metal absorber plate **2**. The robotic system **9** also provides the means for exactly controlling the forming of the tube bends and the forming of the predetermined circuit pattern upon the sheet metal plate **2**. In the case of laser welding being used for affixing the tubing **6** to the sheet metal plate **2**, positioning of the points of impact of the laser beams **18** is suitably achieved through the application unit **8**"floating" on the surface of the working table **5**, independent of the vertical positioning of the robotic system **9** carrying the application tool. Hereby targeting is independent of the positioning accuracy of the robotic system **9** or how plane the underlying working surface is. It will be obvious for the person skilled in the art that other height sensing methods can be used for positioning of the points of impact of the laser beams **18** emitted by the lasers **14**.

[0030] During the successive application to the sheet metal plate **2** the metal tubing **6** is provided with bends for forming the predetermined circuit pattern. In the preferred embodiment these tube bends are formed using bending rolls **15**. These bending rolls **15** for forming the tube bends preferably consists of a pair of bending rolls **15** arranged to be positioned one bending roll **15** on each side of the metal tubing **6** and arranged to force the tubing **6** to form the bends through the pair of bending rolls **15** being continuously repositioned with respect to the sheet metal plate **2** during the successive application of the tubing **6**. A bend is provided as the robotic system **9** turns the tubing application unit **8** in order to apply tubing **6** in a new direction. In order to provide the bend the tubing section preceding the bend must first have been affixed to the plate **2**, e.g. through welding. During the turning operation, e.g. in the direction of arrow **16**, the affixing, e.g. welding, is paused and the pair of bending rolls **15** are positioned one on each side of the tubing **6**. During continued successive application of the tubing **6** the pair of bending rolls **15** are continuously repositioned as the tubing application unit **8** is being repositioned by the pre-programmed robotic system **9**, thus creating the bend. It will be obvious to the person skilled in the art, that using the above setup a prerequisite for forming a bend will be that the tubing section preceding the bend must first have been affixed to the plate **2**, e.g. through welding. Once the bend is completed affixing operations, e.g. welding operations, are resumed.

[0031] Once the predetermined circuit pattern is completed the sheet metal plate **2** is removed from the working table **5** by the handling system **3** taking it and at the same time releasing the vacuum suction. The finalized heat-exchanger is thereafter transferred to a storage area (not shown) for finalized products awaiting transfer to another location for integration into a complete heating system.

[0032] In accordance with the present invention is also envisaged a system for manufacturing a heat-exchanger arranged to perform the above method. Hereby is provided for cost efficient manufacture of high performance heat exchangers.

[0033] The invention is not limited to the above-described embodiments, but may be varied within the scope of the following claims.

[0034] It will be obvious to one skilled in the art that the method for manufacturing a heat-exchanger in accordance with present invention is suitable not only for the manufacture of the products exemplified above, but also can be used for manufacturing other types of heat-exchanger products, such as heating panels, cooling panels and panels for so called chilled ceiling systems.

[0035] Thus, while there have been shown and described and pointed out fundamental novel features of the invention as applied to a preferred embodiment thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements and/or method steps which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. Moreover, it should be recognized that structures and/or elements and/or method steps shown and/or described in connection with any disclosed form or embodiment of the invention may be incorporated in any other disclosed or described or suggested form or embodiment as a general matter of design choice. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

1. A method for manufacturing a heat-exchanger and in particular a heat-exchanger suitable for energy transfer between a plate and a fluid circuit, the method comprising:

preparing a sheet metal plate;

preparing a predetermined length of continuous metal tubing;

successively applying said length of metal tubing to said sheet metal plate, said successive application comprising bringing said metal tubing into close contact with said sheet metal plate and affixing said metal tubing to said sheet metal plate,

wherein said metal tubing is successively applied and affixed to said sheet metal plate to form a predetermined circuit pattern upon said sheet metal plate;

wherein said metal tubing during said successive application to said sheet metal plate is provided with bends for forming said predetermined circuit pattern;

wherein said tube bends are formed using bending rolls;

wherein said bending rolls for forming said tube bends comprise a pair of bending rolls arranged to be positioned with one bending roll on each side of said metal tubing and arranged to force said tubing to form said bends through said pair of bending rolls being continuously repositioned with respect to said sheet metal plate during said successive application of said tubing.

2. The method according to claim 1, wherein said affixing comprises welding said metal tubing to said sheet metal plate.

3. The method according to claim 2, wherein said affixing through welding comprises laser welding.

4. The method according to claim 1, wherein said close contact between said metal tubing and said sheet metal plate comprises pressing said metal tubing towards said sheet metal plate using at least one guide wheel.

5. The method according to claim 1, wherein preparing said sheet metal plate comprises placing said sheet metal plate on a plane surface and affixing it thereto.

6. The method according to claim 1, wherein preparing said predetermined length of continuous metal tubing comprises cutting said metal tubing to said predetermined length and winding said predetermined length of metal tubing upon a spool.

7. The method according to claim 1, wherein a tubing section preceding an intended bend is affixed to said sheet metal plate and said bending rolls are part of a tubing application unit adapted to be carried by a robotic system such that said intended bend is provided as the robotic system turns the tubing application unit in order to apply tubing in a new direction.

8. A system for manufacturing a heat-exchanger, wherein the system is arranged to perform the method according to claim 1.

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