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(54) **Bi-thermal heat exchanger, method and plant for its manufacture**

(57) A particularly compact bi-thermal gas-liquid heat exchanger (1) having a high heat exchange efficiency is described, preferably, but not exclusively used as a bi-thermal gas-water heat exchanger for water heating apparatuses. The heat exchanger (1) comprises at least one tube-in-tube tubular conduit (3) comprising a shaped inner tubular conduit (4) in which an inner liquid flowpath (5) for the circulation of a first heat carrier liquid is defined and an outer tubular conduit (6) mounted around the shaped inner tubular conduit (4) and defining, with the inner tubular conduit (4), at least one gap (7', 7"; 8', 8") in which an outer liquid flowpath for the circulation of a second heat carrier liquid is defmed. According to the invention, the tube-in-tube tubular conduit (3) further comprises at least one flow rate splitting element (27) arranged in the at least one gap (7', 7"; 8', 8") defmed between the shaped inner tubular conduit (4) and the outer tubular conduit (6) for splitting the flow rate of the second heat carrier liquid between a gas inlet side zone and a gas outlet side zone of the at least one gap (7', 7"; 8',8").

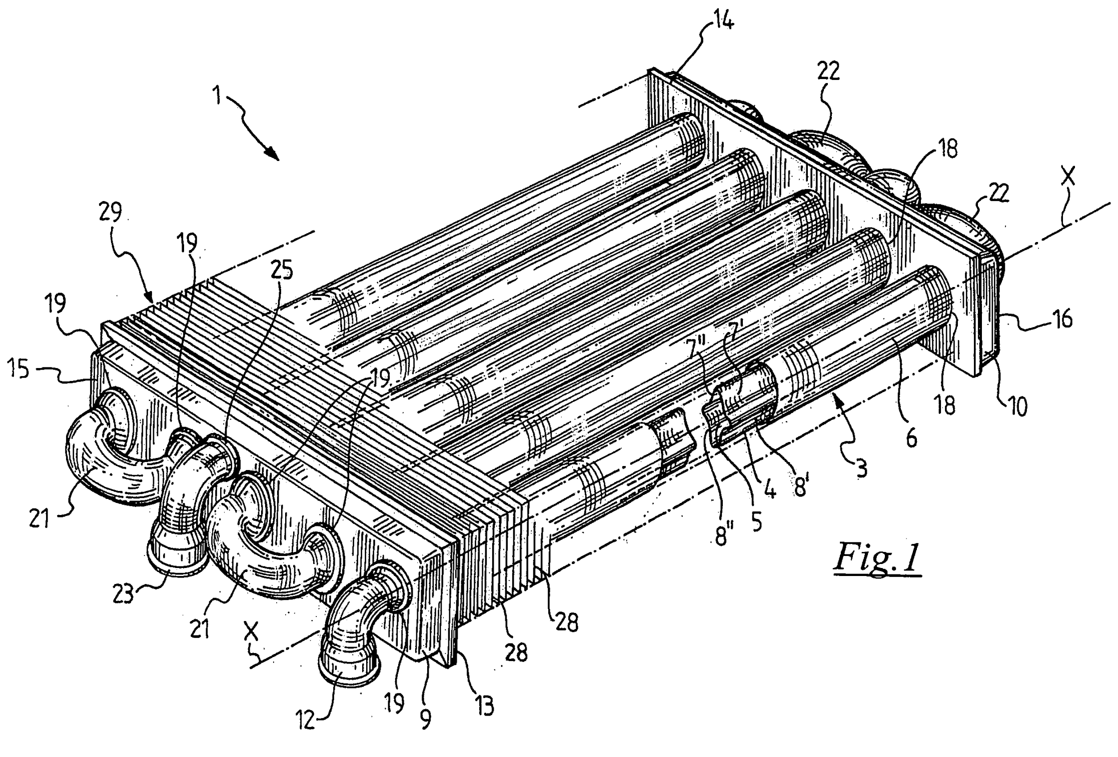

Fig.1

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Description

Background of the invention

[0001] The present invention relates to a bi-thermal heat exchanger. In particular, the invention relates to a bi-thermal gas-liquid heat exchanger, which finds a preferred though not exclusive use as a gas-water heat exchanger in water heating apparatuses intended both for domestic use and for use in blocks of buildings.

[0002] The invention also relates to a water heating apparatus including a heat exchanger of the aforementioned type, to a method and to a plant for manufacturing said heat exchanger, as well as to a method for carrying out a heat exchange between a gas, for example a heating gas constituted by combustion gases coming from a burner, and a first and a second heat carrier liquid.

[0003] Within the framework of the present description and of the subsequent claims, the term: bi-thermal gas-liquid heat exchanger, is used to indicate a heat exchanger which allows to carry out a heat exchange between a gas flowing outside of the heat exchanger, for example constituted by the combustion gases coming from a burner, and two different heat carrier liquids each circulating in respective liquid flowpaths defined in one or more tubular conduits of the so-called tube-in-tube type. More particularly, in the case of use in water heating apparatuses, the first heat carrier liquid is generally constituted by sanitary water circulating in an inner liquid flowpath and in heat exchange relationship with the hot gas and with a second heat carrier liquid which is in turn generally constituted by water for room heating or primary water, circulating in an outer liquid flowpath and in heat exchange relationship with the hot gas.

[0004] Within the framework of the present description and of the subsequent claims, the term: heat carrier liquid, is used to indicate any liquid capable of receiving/ releasing heat from/to external heat sources and of transporting the heat to different points of a system where such a liquid circulates.

Prior art

[0005] In the field of bi-thermal gas-liquid heat exchangers in general and in particular in the field of bi-thermal gas-water heat exchangers for water heating apparatuses, one of the most felt needs is nowadays that of providing compact, light and ever more inexpensive heat exchangers which are simultaneously capable of ensuring a high heat exchange efficiency.

[0006] To this end, bi-thermal tube heat exchangers, possibly provided with a finning for increasing the gas-liquid heat exchange efficiency, are known which are intended to be mounted in a gas flowpath extending in a water heating apparatus and comprising a plurality of tube-in-tube tubular conduits for liquid circulation extending along a direction substantially perpendicular to the flow of the gases flowing in the gas flowpath.

[0007] Thus, for example, patent application GB 2 409 261 in the name of the same Applicant describes a bi-thermal gas-liquid heat exchanger comprising a plurality of tube-in-tube tubular conduits each comprising a shaped inner tubular conduit in which an inner liquid flowpath for the circulation of a first heat carrier liquid is defined and an outer tubular conduit mounted around the shaped inner tubular conduit and defining with said inner tubular conduit at least one gap in which an outer liquid flowpath for the circulation of a second heat carrier liquid is defined.

[0008] In this type of bi-thermal gas-liquid heat exchanger the outer tubular conduits or, rather, the outer liquid flowpaths for the circulation of the second heat carrier liquid are connected at least partially in parallel and at least partially in series with each other.

[0009] In connection with this type of bi-thermal tube heat exchangers, the Applicant observed that it is particularly difficult to combine the desired reduction of size, weight and cost of the heat exchanger while maintaining the heat exchange efficiency, since the weight reduction of the heat exchanger, for example by reducing the number of the tube-in-tube tubular conduits, invariably leads to the occurrence of problems of heat exchange efficiency and noise problems related to internal boiling caused by the difficulty of homogeneously distributing the second heat carrier liquid (in this case the primary water for room heating) in the outer liquid flowpaths.

[0010] Attempts to solve, at least partially, these problems by intervening on the inner sections of the tubular conduits and on the size and/or the shape of the manifolds with the aim of balancing, as much as possible, the various flows in the respective tube-in-tube tubular conduits, however, invariably led to a size increase of the various components and thus to an increase of the overall size of the heat exchanger thereby frustrating any possibility of reducing the size, weight and cost of the heat exchanger.

Summary of the invention

[0011] The technical problem underlying the present invention is therefore that of providing a bi-thermal gas-liquid heat exchanger which allows to reduce the size, weight and cost maintaining the same heat exchange capacity and efficiency with respect to the heat exchangers of the prior art.

[0012] According to a first aspect thereof, the invention refers to a bi-thermal heat exchanger as defined in attached claim 1.

[0013] More particularly, the invention refers to a bi-thermal gas-liquid heat exchanger comprising:

- at least one tube-in-tube tubular conduit comprising:

  a) a shaped inner tubular conduit in which an inner liquid flowpath for the circulation of a first heat carrier liquid is defined;

b) an outer tubular conduit mounted around the shaped inner tubular conduit and defining with said inner tubular conduit at least one gap in which an outer liquid flowpath for the circulation of a second heat carrier liquid is defined;

which is **characterised in that** said at least one tube-in-tube tubular conduit further comprises at least one flow rate splitting element arranged in said at least one gap defined between the shaped inner tubular conduit and the outer tubular conduit for splitting the flow rate of the second heat carrier liquid between a gas inlet side zone and a gas outlet side zone of said at least one gap.

[0014] According to the present invention, the Applicant perceived that the desired reduction of size, weight and manufacturing cost of the heat exchanger and the best weight-power compromise can be achieved - obtaining a heat exchange efficiency substantially comparable to that of the larger and more expensive heat exchangers of the known type having the same heating power - not by intervening on the inner sections of the tubular conduits and/or on the size and the shape of the manifolds, but rather by intervening on the distribution of the flow rate of the second heat carrier liquid between a gas inlet side zone and a gas outlet side zone of the gap defined between the outer tubular conduit and the shaped inner tubular conduit of the tube-in-tube tubular conduit(s) of the heat exchanger.

[0015] In other words, the Applicant perceived that in order to solve the problem of reducing the size, weight, and cost of the heat exchanger while preserving the same heat exchange capacity and efficiency, it is necessary to optimise the fluid dynamics of the second heat carrier liquid circulating in the outer liquid flowpath defined in the tube-in-tube tubular conduit(s) by suitably splitting the flow rate of the second heat carrier liquid between the gas inlet side zone and the gas outlet side zone of such an outer liquid flowpath.

[0016] In this regard, the Applicant surprisingly observed that by suitably splitting the flow rate of the second heat carrier liquid between the gas inlet side zone and the gas outlet side zone of the aforementioned gap, it is possible to increase the speed and turbulence of the second heat carrier liquid in the gas inlet side zone achieving both a higher heat exchange efficiency and a substantial elimination of the noise problems related to internal boiling observed while attempting to reduce the number of tubular conduits of the bi-thermal gas-liquid heat exchangers of the known type.

[0017] Thanks to the presence of the aforementioned at least one flow rate splitting element and thanks to the consequent increase of the heat exchange efficiency between the gas and the liquids flowing in the tube-in-tube tubular conduit(s), it was thus possible to reduce the weight and size of the heat exchanger, for example by reducing the overall number of the tube-in-tube tubular conduits and, this, with the same heat exchange capacity and efficiency.

[0018] In the following description and in the subsequent claims, the terms: "gas inlet side zone" and "gas outlet side zone" will be used to indicate the parts of the heat exchanger and in particular of the tube-in-tube tubular conduit(s) which are impinged first and, respectively, last by the gas flow which passes through the heat exchanger itself.

[0019] In a preferred embodiment, the heat exchanger comprises a plurality of tube-in-tube tubular conduits, preferably extending in parallel with each other.

[0020] Preferably, the tube-in-tube tubular conduit(s) of the heat exchanger are substantially rectilinear or substantially spiral-shaped.

[0021] Examples of preferred embodiments of the heat exchanger of the invention therefore include heat exchangers comprising a plurality of substantially rectilinear tube-in-tube tubular conduits extending in parallel with each other and heat exchangers comprising a substantially spiral-shaped single tube-in-tube tubular conduit, according to configurations particularly suitable for a heat exchange with hot combustion gases coming from the burner of a water heating apparatus, for example a boiler of the combined type.

[0022] In a preferred embodiment, the shaped inner tubular conduit of the tube-in-tube tubular conduit(s) comprises a central portion having a multilobed cross-section.

[0023] Within the framework of the present description and of subsequent claims, the term: "multilobed cross-section" is used to indicate a cross-section comprising a plurality of suitably shaped portions extending from a central part. For the purposes of the invention, a particularly effective multilobed cross-section is the substantially spear-tip shaped cross-section as will be better apparent in the following description.

[0024] Within the framework of this preferred embodiment, the shaped inner tubular conduit of the tube-in-tube tubular conduit(s) comprises at least one gas outlet side gap and at least one gas inlet side gap with respect to a transversal centreline plane of the shaped inner tubular conduit, while the aforementioned at least one flow rate splitting element is arranged in the gas outlet side gap.

[0025] In this way, it is advantageously possible to improve the flow rate distribution of the second heat carrier liquid between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduit(s).

[0026] In a particularly preferred embodiment, the tube-in-tube tubular conduit(s) comprise(s) two gas outlet side gaps and two gas inlet side gaps with respect to the transversal centreline plane of the shaped inner tubular conduit and at least one flow rate splitting element in each of the gas outlet side gaps.

[0027] The Applicant found that in this way it is advantageously possible to distribute in an optimal manner the flow rate of the second heat carrier liquid between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduit(s).

[0028] Within the framework of this preferred embodiment, the flow rate splitting elements arranged in the gas outlet side gaps are symmetrically arranged with respect to a longitudinal centreline plane of the shaped inner tubular conduit.

[0029] In this way, it is advantageously possible to distribute the flow rate of the second heat carrier liquid in a balanced and symmetric manner in the various gaps defined between the shaped inner tubular conduit and the outer tubular conduit of the tube-in-tube tubular conduit (s), optimising the fluid dynamics and, thus the heat exchange efficiency, of the heat exchanger.

[0030] In the aforementioned preferred embodiments with a plurality of gaps, the gas outlet side gap(s) and the gas inlet side gap(s) is(are) preferably structurally independent and separated in a liquid-tight manner from each other, for example by welding the lobe tip ends of the shaped inner tubular conduit to the inner wall of the outer tubular conduit.

[0031] In this way, it is advantageously possible to obtain a structural continuity between the outer tubular conduit touched in operation by the gas flow passing through the heat exchanger and the shaped inner tubular conduit, thereby increasing the heat transmission towards the first heat carrier liquid which in this case may also occur by conduction.

[0032] In a preferred embodiment, the shaped inner tubular conduit comprises a central portion and at least one free end portion, while the aforementioned at least one flow rate splitting element is arranged along the longitudinal development of the inner tubular conduit between the central portion and the aforementioned at least one free end portion.

[0033] In this way, it is advantageously possible to distribute in the most suitable manner the flow rate of the second heat carrier liquid in the gap(s) defined between the shaped inner tubular conduit and the outer tubular conduit of the tube-in-tube tubular conduit(s), right from the inlet zone of the second heat carrier liquid optimising the fluid dynamics substantially along the entire longitudinal development of the tube-in-tube tubular conduit(s) and optimising at the same time the heat exchange efficiency of the heat exchanger.

[0034] For the purposes of the invention, the free end portion of the shaped inner tubular conduit may be of any suitable shape easily selectable by a man skilled in the art depending upon the connection requirements to the various hydraulic circuits external to the heat exchanger. Thus, for example, the free end portion of the shaped inner tubular conduit may substantially have an elliptical, circular or drop-shaped cross-section.

[0035] Preferably and with the aim of having a symmetric structure adapted to simplify the manufacturing operations of the heat exchanger, each shaped inner tubular conduit comprises a pair of flow rate splitting elements respectively arranged between the central portion and the opposite free end portions of the shaped inner tubular conduit.

[0036] For the purposes of the invention and with the aim of allowing the entry of the second heat carrier liquid in the gap(s) defined in the tube-in-tube tubular conduit (s), the outer tubular conduit mounted around the shaped inner tubular conduit is shorter than the latter, so that the opposite free end portions of the shaped inner tubular conduit project from the opposite free ends of the outer tubular conduit for a portion of predetermined length which depends upon the size of the heat exchanger and, particularly upon the size of the distribution manifolds of the second heat carrier liquid.

[0037] In a particularly preferred embodiment, the aforementioned at least one flow rate splitting element comprises a bulging element integral with said shaped inner tubular conduit.

[0038] In this way and as will be better apparent hereinafter, it is advantageously possible to provide the flow rate splitting element directly in the shaped inner tubular conduits by means of particularly simple operations of plastic deformation which may be carried out in large scale at a low cost.

[0039] In a preferred embodiment, at the flow rate splitting element the ratio between the flow section of the second heat carrier liquid in the gas outlet side zone and the flow section of the second heat carrier liquid in the gas inlet side zone of the gap(s) defined in the tube-in-tube tubular conduit(s) is comprised between 0.25 and 0.5 depending upon the number of tube-in-tube tubular conduits.

[0040] The Applicant found that in this way it is advantageously possible to distribute in an optimal manner the flow rate of the second heat carrier liquid and, thus also its speed, between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduit(s) optimising the fluid dynamics and maximising the performances of the heat exchanger.

[0041] Within the framework of the preferred embodiment in which a plurality of tube-in-tube tubular conduits is provided, the outer liquid flowpaths for the circulation of the second heat carrier liquid defined in said plurality of tube-in-tube tubular conduits are preferably connected at least partially in parallel with each other. Still more preferably, the outer liquid flowpaths defined in said plurality of tube-in-tube tubular conduits are all connected in parallel with each other.

[0042] The Applicant, in fact, observed that thanks to the presence of the flow rate splitting element in the gap (s) defined in the tube-in-tube tubular conduit(s) it is advantageously possible to achieve an optimal balancing of the flow rate distribution of the second heat carrier liquid in the various outer liquid flowpaths defined in such gaps, reducing the number of tube-in-tube tubular conduits without having any noise problems related to boiling or a reduction in the heat exchanger performance.

[0043] Furthermore, the configuration of the heat exchanger with the tube-in-tube tubular conduits in parallel with each other allows to achieve the further installation advantage of having the inlet and outlet fittings of the first and of the second heat carrier liquid at longitudinally opposite parts of the heat exchanger, as provided for by the European standards regulating the recommended layout of the various components in the water heating apparatuses.

[0044] In the preferred embodiment in which a plurality tube-in-tube tubular conduits at least partially in parallel with each other is provided, it is also possible to achieve in a very simple manner the additional advantage of being able to distribute in the desired manner and in a very flexible way the overall flow rate of the second heat carrier liquid between the various outer liquid flowpaths defined in the tube-in-tube tubular conduits and, this, by means of a suitable distribution of the flow rate splitting elements in the gap(s) of the various tube-in-tube tubular conduits. Thus, for example, it is possible to facilitate the distribution of the second heat carrier liquid towards the tube-in-tube tubular conduits farthest from the inlet zone of the second heat carrier liquid in the heat exchanger, generally defined at an inlet zone of a manifold for collecting and distributing such liquid, by simply arranging the flow rate splitting elements only in the gap(s) of the tube-in-tube tubular conduits closest to such inlet zone so as to locally increase the flowing friction within the gap(s) (in other words the pressure drops) favouring the liquid flow towards the farthest conduits.

[0045] In a preferred embodiment, the bi-thermal heat exchanger of the invention further comprises a plurality of heat exchange fins externally associated to the tube-in-tube tubular conduit(s) in order to maximise the heat exchange area with the gases flowing outside of the heat exchanger.

[0046] According to a second aspect thereof, the present invention relates to a water heating apparatus, for example a boiler, which is **characterised in that** it comprises a heat exchanger of the aforementioned type.

[0047] According to a third aspect thereof, the present invention relates to a method for manufacturing a bi-thermal gas-liquid heat exchanger of the type described above as defined in attached claim 14.

[0048] More particularly, the manufacturing method of the invention comprises the steps of:

a) providing at least a first tubular conduit,

b) shaping in a first forming station a central portion of predetermined length of said at least a first tubular conduit so as to obtain at least one partially shaped tubular conduit;

c) shaping in a second forming station at least one of the opposite end portions of the partially shaped tubular conduit obtained from step b) so as to obtain at least one free end portion having a cross-section of a predetermined shape;

d) providing in the partially shaped tubular conduit obtained from step b) at least one bulging element arranged along the longitudinal development of the shaped tubular conduit between said central portion and said at least one free end portion;

e) inserting the shaped tubular conduit obtained from step d) into at least a second tubular conduit so as to obtain a tube-in-tube tubular conduit in which at least one gap for the circulation of a heat carrier liquid is defined; said tube-in-tube tubular conduit comprising at least one flow rate splitting element arranged in said at least one gap and comprising said at least one bulging element;

f) stably associating the shaped tubular conduit to said at least a second tubular conduit.

[0049] Advantageously, the method of the invention allows to manufacture a bi-thermal gas-liquid heat exchanger having the aforementioned characteristics of inexpensiveness, compactness and thermodynamic efficiency, using a technology which is simple, inexpensive and capable of ensuring the repeatability and reproducibility at large scale of the performances of the heat exchangers produced.

[0050] In a preferred embodiment, the aforementioned step a) comprises providing a plurality of first tubular conduits, while step d) comprises providing the aforementioned at least one bulging element in at least one of the partially shaped tubular conduits obtained from step b).

[0051] Within the framework of this preferred embodiment, the aforementioned step e) comprises inserting the shaped tubular conduits obtained from step d) into a corresponding plurality of second tubular conduits so as to obtain a plurality of tube-in-tube tubular conduits.

[0052] In this way, it is advantageously possible to manufacture a bi-thermal heat exchanger of the type comprising a plurality of tube-in-tube tubular conduits in a simple and inexpensive manner.

[0053] In respective preferred embodiments of the method of the invention, the first tubular conduit and the second tubular conduit can be substantially rectilinear or substantially spiral-shaped so as to allow to manufacture the various types of bi-thermal gas-liquid heat exchangers described above.

[0054] In a particularly preferred embodiment, the shaping step b) is carried out so as to shape the central portion of the first tubular cylindrical conduit(s) according to a multilobed cross-section.

[0055] Within the framework of this preferred embodiment, furthermore, the shaping step b) is carried out in such a manner that the central portion of said at least one shaped tubular conduit has a multilobed cross-section comprising two lobes extending along a transversal centreline plane and two lobes extending along a longitudinal centreline plane of said at least one shaped tubular conduit, while the step d) is carried out so as to provide at least one bulging element in each of the grooves defined between one of the two lobes extending along said longitudinal centreline plane and the two lobes extending along said transversal centreline plane.

[0056] In this way, it is advantageously possible to obtain the preferred structure of the heat exchanger described above, as well as the related advantages.

[0057] In a preferred embodiment, the steps c) of shaping and d) of providing said at least one bulging element are carried out simultaneously.

[0058] Within the framework of this preferred embodiment, furthermore, the aforementioned at least one bulging element is provided by inserting a shaped punch into at least one free end portion, preferably into both the opposite free end portions, of the shaped tubular conduit obtained from step b).

[0059] Preferably, such a shaped punch has a cross-section of predetermined shape, for example a shape mating with the shape which is to be imparted to the free end portion of the shaped tubular conduit, and a length equal to the length of such a free end portion of the shaped tubular conduit obtained from step d).

[0060] In this way, it is advantageously possible to manufacture in an efficient manner an inner tubular conduit having the desired shape, with the minimum number of operating steps and using simple and low cost plastic deformation techniques.

[0061] In a particularly preferred embodiment, the step d) of providing said at least one bulging element is carried out so as to maintain substantially constant the perimetrical development of the partially shaped tubular conduit obtained from step b).

[0062] In this way, it is advantageously possible to manufacture the inner tubular conduit in an efficient manner, using low cost plastic deformation techniques, such as for example drawing.

[0063] Within the framework of this preferred embodiment and still in order to simplify the manufacturing operations and reducing the costs thereof, the method of the invention thus provides to carry out steps b), c) and d) by means of plastic deformation, preferably by cold shaping.

[0064] In a preferred embodiment, the method of the invention may also further comprise the step of stably associating a plurality of heat exchange fins to the tube-in-tube tubular conduit obtained from step e), so as to obtain, if required, a heat exchanger having a greater exchange surface.

[0065] According to a fourth aspect thereof, the invention relates to a plant for manufacturing a bi-thermal gas-liquid heat exchanger of the type described above as defined in attached claim 25.

[0066] More particularly, the plant of the invention comprises:

a) a first forming station comprising:

a1) a first shaped core of predetermined length having a multilobed cross-section, and

a2) a first mould including two first half shells defining therebetween a first moulding cavity having a shape substantially mating with the shape of said first shaped core, said first half-shells having a predetermined length;

b) a second forming station comprising:

b1) a second mould including:

i) a central section comprising two second half-shells defining therebetween a second moulding cavity having a shape substantially mating with the shape of said first shaped core, said second half-shells having a length substantially equal to the length of the first half-shells of said first mould;

ii) at least one intermediate section of predetermined length laterally arranged with respect to said central section and comprising two half-shells defining therebetween a third moulding cavity having a multilobed cross-section having a larger area with respect to the cross-section area of the second moulding cavity in at least a portion of the third moulding cavity;

iii) two axially opposite end sections of predetermined length and each comprising two half-shells defining therebetween a fourth moulding cavity having a section of predetermined shape;

b2) at least one shaped punch having a shape substantially mating with the shape of said fourth moulding cavity.

[0067] Similarly to the manufacturing method described above, the aforementioned plant also allows to manufacture an inexpensive, compact and thermodynamically efficient bi-thermal heat exchanger, employing a simple and low cost technology, capable of ensuring the repeatability and reproducibility at large scale of the performances of the heat exchangers produced.

[0068] In a preferred embodiment and in order to have a symmetric structure of the shaped inner tubular conduits manufactured by means of the aforementioned plant, the second mould comprises two intermediate sections of predetermined length arranged at axially opposite parts of said central section and each comprising two half-shells defining therebetween a third moulding cavity having a multilobed cross-section having a larger area with respect to the cross-section area of the second moulding cavity in at least a portion of the third moulding cavity.

[0069] In this way, it is also advantageously possible to simplify the manufacturing operations of the heat exchanger thanks to the symmetric structure of the shaped inner tubular conduits manufactured in the second forming station.

[0070] In a preferred embodiment, the aforementioned shaped punch has a length substantially equal to the length of the two axially opposite end sections of the second mould.

[0071] Preferably, the shaped punch has a cross-section of predetermined shape, for example a shape mating with the shape which is to be imparted to the free end portion of the shaped tubular conduit, for example substantially elliptical, circular, drop-shaped, or of any other suitable shape depending upon the connection requirements to the various hydraulic circuits external to the heat exchanger.

[0072] In this way and as outlined above, it is advantageously possible to manufacture an inner tubular conduit having the desired shape in an efficient manner and employing simple and low cost plastic deformation techniques.

[0073] The manufacturing plant of the invention also comprises, as will be better apparent in the following, further stations known *per se* for assembling the tube-in-tube tubular conduits, optionally with a plurality of heat exchange fins, and for the connection of the same to the manifolds for the distribution of the second heat carrier liquid and/or to fittings for a connection with the units external to the heat exchanger.

[0074] According to a fifth aspect thereof, the present invention lastly relates to a method as defined in attached claim 27 for carrying out a heat exchange between a gas and a first and a second heat carrier liquid by means of a bi-thermal gas-liquid heat exchanger of the type described above.

[0075] More particularly, the heat exchange method of the invention comprises the step of feeding the second heat carrier liquid to said at least one outer liquid flowpath defined in said at least one gap of said at least one tube-in-tube tubular conduit, and is **characterised in that** said feeding step of the second heat carrier liquid is carried out by splitting the flow rate of the second heat carrier liquid fed to said at least one tube-in-tube tubular conduit between a gas inlet side zone and a gas outlet side zone of said at least one gap by means of at least one flow rate splitting element arranged in said gap.

[0076] The heat exchange method of the invention advantageously allows, as described above, to suitably balance the speed and turbulence of the second heat carrier liquid in the gas inlet side zone of the gap(s) formed in the tube-in-tube tubular conduits, thereby achieving both a better heat exchange efficiency and the substantial elimination of the noise problems related to internal boiling.

[0077] In a preferred embodiment and as outlined above, the shaped inner tubular conduit of the tube-in-tube tubular conduits comprises a central portion having a multilobed cross-section defining at least one gas inlet side gap with respect to a transversal centreline plane of the shaped inner tubular conduit, while the splitting of the second heat carrier liquid in the outer liquid flowpath(s) is carried out by feeding to the aforementioned at least one gas inlet side gap at least 50%, preferably at least 65%, of the total flow rate of the second heat carrier liquid entering the outer liquid flowpath(s) of the tube-in-tube tubular conduit(s).

[0078] The Applicant found that in this way it is advantageously possible to distribute the flow rate and, thus also the speed, of the second heat carrier liquid in an optimal manner between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduit (s) optimising the fluid dynamics of the second heat carrier liquid and maximising the performances of the heat exchanger.

[0079] In a further preferred embodiment, the bi-thermal gas-liquid heat exchanger comprises a plurality of tube-in-tube tubular conduits, while the second heat carrier liquid is fed at least partially in parallel to the outer liquid flowpaths defined in said plurality of tube-in-tube tubular conduits.

[0080] Still more preferably, the second heat carrier liquid is fed in parallel to all the outer liquid flowpaths defined in said plurality of tube-in-tube tubular conduits.

[0081] In this way, and as outlined above, it is advantageously possible to achieve an optimal balancing of the flow rate distribution of the second heat carrier liquid in the various outer liquid flowpaths defined in the tube-in-tube tubular conduits obtaining at the same time the maximum reduction of the number of tube-in-tube tubular conduits without having, however, any noise problem of boiling or any reduction of the heat exchanger performances.

Brief description of the drawings

[0082] Additional features and advantages of the invention will be better apparent from the following description of a preferred embodiment of a bi-thermal gas-liquid heat exchanger according to the present invention, of a plant for its manufacture and of a water heating apparatus incorporating such a heat exchanger, description which is provided hereinafter, for exemplifying and non-limiting purposes, with reference to the attached drawings. In the drawings:

- figure 1 is a perspective view, in partial cross-section, of a bi-thermal gas-liquid heat exchanger according to a preferred embodiment of the present invention,
- figure 2 is a top view of the heat exchanger of figure 1,
- figure 3 is a side view, seen from the inlet side of the first heat carrier liquid and the outlet side of the second heat carrier liquid, of the heat exchanger of figure 1,

- figure 4 is a perspective view, at an enlarged scale, of some details of the heat exchanger of figure 1,

- figure 5 is a perspective view, at an enlarged scale, of a shaped inner tubular conduit of one of the tube-in-tube tubular conduits of the heat exchanger of figure 1,

- figure 6 is a schematic side view of a detail of a mould of a first forming station of a plant for manufacturing the heat exchanger of figure 1 in a first operating step of the method for manufacturing such a heat exchanger,

- figure 7 is a cross-sectional view of the first forming station of figure 6 in said first operating step of the method for manufacturing the heat exchanger of figure 1,

- figure 8 is a side view of a detail of the mould of the first forming station of figure 6 in a second operating step of the method for manufacturing the bi-thermal gas-liquid heat exchanger of figure 1,

- figure 9 is a cross-sectional view of the first forming station of figure 6 in said second operating step of the method for manufacturing the heat exchanger of figure 1,

- figure 10 is a schematic side view of some details of a second forming station of the plant for manufacturing the heat exchanger of figure 1 in a further operating step of the method for manufacturing such a heat exchanger,

- figures 11, 12 and 13 are respective cross sections of a mould of the second forming station of figure 10 taken along lines XI-XI, XII-XII and XIII-XIII of figure 10,

- figure 14 is a side view of some details of the second forming station of the plant for manufacturing the bi-thermal gas-liquid heat exchanger of figure 1 in a further operating step of the method for manufacturing such a heat exchanger,

- figure 15 schematically represents a water heating apparatus incorporating the bi-thermal gas-liquid heat exchanger of figure 1.

Detailed description of the currently preferred embodiments of the invention

[0083] In the figures, a bi-thermal gas-liquid heat exchanger according to a preferred embodiment of the invention is generally indicated at 1.

[0084] More particularly, the heat exchanger 1 is suitable for use as a heat exchanger adapted to simultaneously heat hot water for room heating or primary water and sanitary water in water heating apparatuses, such as for example a boiler 2 of the so-called combined type schematically illustrated in figure 15 and which will be described hereinafter.

[0085] The heat exchanger 1 comprises a plurality of tube-in-tube tubular conduits 3, substantially rectilinear and parallel with each other, having an longitudinal axis x-x extending along a first predetermined direction.

[0086] In the preferred embodiment illustrated, each of the tube-in-tube tubular conduits 3 comprises a shaped inner tubular conduit 4 in which an inner liquid flowpath 5 is defined for the circulation of a first heat carrier liquid, in this preferred example sanitary water, and an outer tubular conduit 6 mounted around the shaped inner tubular conduit 4 and defining with the latter at least one gap in which an outer liquid flowpath is defined for the circulation of a second heat carrier liquid, in this preferred example hot water for room heating or primary water.

[0087] According to the invention, each of the tube-in-tube tubular conduits 3 further comprises at least one flow rate splitting element 27, arranged in the aforementioned gap defmed between the shaped inner tubular conduit 4 and the outer tubular conduit 6 for splitting the flow rate of the second heat carrier liquid between a gas inlet side zone and a gas outlet side zone of said gap.

[0088] In the preferred embodiment illustrated, the shaped inner tubular conduit 4 comprises a central portion having a multilobed cross-section, for example having a substantially spear-tip-shaped cross-section, so as to define in each of the tube-in-tube tubular conduits 3 at least one gas outlet side gap and at least one gas inlet side gap, more particularly a couple of gas outlet side gaps 7', 7" and a couple of gas inlet side gaps 8', 8", with respect to a transversal centreline plane π_{Tc} of the shaped inner tubular conduit 4 (see Fig. 4).

[0089] In the preferred embodiment illustrated, therefore, a plurality of gas outlet side gaps 7', 7" and gas inlet side gaps 8' and 8'' for the circulation of the hot water for room heating is defined between each shaped inner tubular conduit 4 and each outer tubular conduit 6.

[0090] In the preferred embodiment illustrated, the gas inlet side gaps 8' and 8'' and the gas outlet side gaps 7', 7" are structurally independent and separated in a liquid tight manner with respect to each other by welding the tip ends of the lobes of the shaped inner tubular conduit 4 to the inner wall of the outer tubular conduit 6.

[0091] In this way, it is advantageously possible to obtain a structural continuity between the outer tubular conduit 6 touched in operation by the gas flow passing through the heat exchanger 1 and the shaped inner tubular conduit 4, thereby increasing the heat transmission towards the first heat carrier liquid which in this case may also occur by conduction.

[0092] In the preferred four-gaps embodiment illustrated, each of the tube-in-tube tubular conduits 3 thus comprises a couple of flow rate splitting elements 27 (only one of which is visible in the figures) arranged in the gas outlet side gaps 7', 7" at the opposite free end portions of the outer tubular conduits 6 and symmetrically arranged with respect to a longitudinal centreline plane π_{Lc} of the shaped inner tubular conduits 4 and of the tube-in-tube tubular conduits 3 (see Fig. 4).

[0093] According to the invention, the flow rate splitting elements 27 exert the important function of suitably splitting the flow rate of the second heat carrier liquid (hot water for room heating) between the gas inlet side gaps 8', 8" and the gas outlet side gaps 7', 7" optimising the fluid dynamics characteristics of the second heat carrier liquid entering the aforementioned gaps and achieving a higher heat exchange efficiency.

[0094] More particularly, the flow rate splitting elements 27 allow to increase the speed and turbulence of the second heat carrier liquid in the gas inlet side gaps 8', 8" increasing the heat exchange with the gas flowing outside of the heat exchanger 1 and avoiding at the same time any noise problems related to internal boiling.

[0095] Preferably, the flow rate splitting elements 27 are substantially constituted by a bulging element integral with the shaped inner tubular conduits 4 and obtained by means of cold plastic deformation according to the techniques illustrated more in detail hereinafter.

[0096] In a particularly preferred embodiment, the ratio at the flow rate splitting elements 27 between the flow section of the second heat carrier liquid in the gas outlet side zone, that is, the flow cross-section defined by the gaps 7' and 7'' and the flow section of the second heat carrier liquid in the gas inlet side zone, that is, the flow cross-section defined by the gaps 8' and 8'' is comprised between 0.25 and 0.5.

[0097] In this way, it is advantageously possible to split the flow rate of the second heat carrier liquid and, thus also its speed, in an optimal manner between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduits 3 optimising the fluid dynamics characteristics of the second heat carrier liquid circulating within the tube-in-tube tubular conduits 3 and maximising the performances of the heat exchanger 1.

[0098] In the preferred embodiment illustrated, the tube-in-tube tubular conduits 3 are associated, preferably at longitudinally opposite parts, to respective manifolds 9, 10 for collecting and distributing the second heat carrier liquid (hot water for room heating), which manifolds are in fluid communication with the gaps 7', 7", 8' and 8".

[0099] In this way, the gaps 7', 7", 8' and 8'' and the manifolds 9 and 10 define in the heat exchanger 1 an outer liquid flowpath for the circulation of the second heat carrier liquid (hot water for room heating), while the shaped inner tubular conduits 4 define the aforementioned inner liquid flowpath 5 intended for the circulation of the first heat carrier liquid (sanitary water).

[0100] In a way conventional *per se*, the heat exchanger 1 is provided with an inlet fitting 11 and an outlet fitting 12 for the first heat carrier liquid (sanitary water) respectively associated to the free ends of a first and of a second shaped inner tubular conduit 4, indicated in the figures with references 4a and 4b, of the plurality of tube-in-tube tubular conduits 3 (see Fig. 2).

[0101] Preferably, the inner tubular conduits 4a and 4b are arranged at laterally opposite parts of the plurality of tube-in-tube tubular conduits 3.

[0102] In a way conventional *per se*, each manifold 9, 10 comprises a respective rear wall 13, 14 and a respective front wall 15, 16 preferably substantially planar and parallel with each other.

[0103] A respective plurality of openings 17, 18 (see Fig. 1 and 4) adapted to house the axially opposite ends of the outer tubular conduits 6 of the tube-in-tube tubular conduits 3 is formed in each of the rear walls 13, 14. On the other hand, in the front walls 15, 16 is formed a corresponding plurality of openings 19, 20 adapted to house axially opposite ends of the shaped inner conduits 4 of the tube-in-tube tubular conduits 3, which inner conduits extend within the manifolds 9, 10 so as to substantially project from the front walls 15, 16 at such openings 19, 20, as may be better observed in figures 1, 3 and 4.

[0104] This allows both to associate the fittings 11, 12 to the shaped inner conduits 4 as described above, and to provide connections between such inner conduits 4 which will be better illustrated hereinafter.

[0105] In the preferred embodiment illustrated, the shaped inner tubular conduit 4 of each of the tube-in-tube tubular conduits 3 comprises a central portion 4' and at least one free end portion 4" while the flow rate splitting elements 27 are arranged along the longitudinal development of the inner tubular conduit 4 between the central portion 4' and said at least one free end portion 4", still more preferably between the opposite free end portions 4".

[0106] In the preferred embodiment illustrated, therefore, the shaped inner tubular conduit 4 of each of the tube-in-tube tubular conduits 3 has a cross-section which varies in the longitudinal direction: the cross-section, in fact, is substantially lanceolate at the central portion 4', preferably substantially elliptical at the opposite free end portions 4" associated to the openings 19, 20 formed in the front walls 15, 16 of the manifolds 9, 10 and preferably having an intermediate shape between the two at the opposite intermediate portions 4"' extending at the flow rate splitting elements 27 (see Fig. 5).

[0107] Preferably, the cross-section of the outer tubular conduit 6 is, on the other hand, constant along the longitudinal development thereof and, still more preferably, is substantially elliptical.

[0108] For the purposes of the invention and in order to allow the entry of the second heat carrier liquid into the gas inlet side gaps 8', 8" and into the gas outlet side gaps 7', 7" defined in the tube-in-tube tubular conduits 3, the outer tubular conduits 6 are shorter than the shaped inner tubular conduits 4.

[0109] In this way, the opposite free end portions 4" of the shaped inner tubular conduit 4 project from the opposite free ends of the outer tubular conduit 6 for a portion of predetermined length which depends upon the size of the heat exchanger 1 and, in particular, upon the size of the manifolds 9, 10 for distributing the second heat carrier liquid (see Fig. 4).

[0110] The shaped inner conduits 4 are preferably connected in series to each other; still more preferably, the inner conduits 4 are connected to each other so as to define a substantially coil-shaped inner liquid flowpath for the circulation of the first heat carrier liquid (sanitary water), extending between the inlet fitting 11 and the outlet fitting 12 of the sanitary water. Such a flowpath is obtained by associating a plurality of U-shaped fittings 21, 22 to free end pairs of the shaped inner conduits 4 at the openings 19, 20 formed in the front walls 15, 16 of the manifolds 9, 10.

[0111] In a way conventional *per se*, the heat exchanger 1 is provided with an inlet fitting 23 and with an outlet fitting 24 of the second heat carrier liquid (water for room heating or primary water) respectively associated to respective openings 25, 26 formed in the front walls 15, 16 of the manifolds 9, 10 (see Fig. 2).

[0112] Preferably, the inlet 23 and outlet 24 fittings of the second heat carrier liquid are arranged at laterally opposite parts of a longitudinal centreline plane π_{Le} of the heat exchanger 1 (see Fig. 2).

[0113] In this way, it is possible to accomplish a liquid connection between the manifolds 9, 10 of the heat exchanger 1 and a primary water external circuit of the water heating apparatus 2 which will be briefly outlined hereinafter.

[0114] In the preferred embodiment illustrated, all the tube-in-tube tubular conduits 3 are connected in parallel with each other so as to achieve the installation advantage of having the inlet 11 and outlet 12 fittings of the first heat carrier liquid (sanitary water) and the inlet 23 and outlet 24 fittings of the second heat carrier liquid (water for room heating or primary water) arranged at longitudinally opposite parts of the heat exchanger 1, as provided for by the European standards regulating the recommended layout of the various components in water heating apparatuses.

[0115] In the preferred embodiment illustrated, therefore, the outer liquid flowpaths defined in the gaps 7', 7'', 8' and 8'' for the circulation of the second heat carrier liquid defined in the tube-in-tube tubular conduits 3 are connected in parallel with each other as schematically illustrated by the arrows L2 in Fig. 2.

[0116] In a preferred embodiment of the heat exchanger 1, not illustrated, it is also possible to achieve very easily the additional advantage of being able to distribute in a very flexible manner the overall flow rate of the second heat carrier liquid between the various outer liquid flowpaths of the tube-in-tube tubular conduits 3 by means of a suitable distribution of the flow rate splitting elements 27 in the gas outlet side gaps 7', 7" of the tube-in-tube tubular conduits 3. Thus, for example, it is possible to facilitate the distribution of the second heat carrier liquid towards the tube-in-tube tubular conduits 3 farthest from the inlet fitting 23 of the second heat carrier liquid into the inlet manifold 9 of such liquid, by providing the flow rate splitting elements 27 only in the gas outlet side gaps 7', 7" of the tube-in-tube tubular conduits 3 closest to the inlet fitting 23, so as to locally increase the flowing friction within the gaps, that is the local pressure drops, favouring the liquid flow towards the tube-in-tube tubular conduits 3 farthest from the inlet fitting 23.

[0117] Preferably, the heat exchanger 1 also comprises a plurality of heat exchange fins 28 (only partially shown in figures 1, 2 and 4) externally associated to the tube-in-tube tubular conduits 3, for example by means of braze welding. These heat exchange fins 28 are preferably parallel with each other and pitchwise spaced from one another so as to define a plurality of gas passages; in a way known *per se*, the heat exchange fins 28 are packed between the manifolds 9, 10 and form, together with the tube-in-tube tubular conduits 3, a finned tube bundle generally indicated at 29.

[0118] Preferably, all the elements forming the heat exchanger 1 described above are made of a suitable metal having good heat conductivity characteristics, for example copper or aluminium.

[0119] Preferred embodiments of a plant and of a method according to the invention for manufacturing the bi-thermal gas-liquid heat exchanger 1 described above will be described hereinafter with particular reference to figures 6-13.

[0120] In the preferred embodiment illustrated in these figures, a plant 30 for manufacturing the bi-thermal gas-liquid heat exchanger 1 comprises a first forming station 31, schematically illustrated in figures 6-9, adapted to impart a substantially multilobed cross-section, for example a substantially spear-tip shape as illustrated in Fig. 1, to the central portion 4' of the shaped inner tubular conduits 4 of the tube-in-tube tubular conduits 3 of the heat exchanger 1.

[0121] The first forming station 31 comprises in turn a shaped core 32 having a multilobed cross-section, in this case substantially spear-tip-shaped, and a first mould 33 including two first half-shells 34, 35 defining therebetween a first moulding cavity 36 having a shape substantially mating with the shape of the shaped core 32.

[0122] Both the shaped core 32 and the first half-shells 34, 35 of the first mould 33 have a predetermined length easily selectable by a man skilled in the art depending upon the manufacturing requirements and upon the length of the heat exchanger to be manufactured; in particular, the shaped core 32 may have the same length of the shaped inner tubular conduits 4 of the heat exchanger 1 or may have a length longer than these conduits, while the length of the first half-shells 34, 35 is preferably substantially equal to the length of the central portion 4' of the shaped inner tubular conduits 4 to be manufactured.

[0123] The plant 30 further comprises a second forming station 37, schematically illustrated in figures 10-13, adapted to impart to the opposite free end portions 4" of the shaped inner tubular conduits 4 a cross-section of predetermined shape, for example substantially elliptical as illustrated in Fig. 5, and at the same time to integrally form the flow rate splitting elements 27 in the intermediate portion 4"' of the inner tubular conduits 4.

[0124] The second forming station 37 comprises in particular a second mould 38 including a plurality of adjacent longitudinal sections:

i) a central section 39 comprising two second half-shells 40, 41, preferably structurally identical to the first half-shells 34, 35 of the first mould 33, the second half-shells 40, 41 defining therebetween a second moulding cavity 42 having a shape substantially mating with the shape of the first shaped core 32 (but absent from the second forming station 37; see figures 10 and 11);

ii) two intermediate sections 43 of predetermined length arranged at axially opposite parts of the central section 39, each comprising two half-shells 44, 45 defining therebetween a third moulding cavity 46 having a multilobed cross-section having a larger cross-sectional area with respect to the cross-sectional area of the second moulding cavity 42 in at least a portion of the third moulding cavity 46 so as to allow the formation of the flow rate splitting elements 27 (see figures 10 and 12);

iii) two axially opposite end sections 47, having a predetermined length and each comprising two half-shells 48, 49 defining therebetween a fourth moulding cavity 50 having a cross-section of predetermined shape, preferably substantially elliptical (see figures 10 and 13).

[0125] The second forming station 37 further comprises at least one shaped punch 51, preferably a pair of shaped punches 51, each having a shape substantially mating with the shape of the fourth moulding cavity 50 and mounted on respective supporting elements 52.

[0126] In a preferred embodiment, the shaped punches 51 have a length substantially equal to the length of the two axially opposite end sections 47 of the second mould 38, so as to suitably shape the opposite free end portions 4" of the shaped inner tubular conduits 4 in the fourth moulding cavities 50.

[0127] As will be apparent to those skilled in the art, the plant 30 described above and schematically illustrated in figures 6-14 also comprises suitable devices, known *per se* and not shown, for feeding the tubular conduits to be formed to the first forming station 31, for introducing the first shaped core 32 into the tubular conduits to be shaped, for opening and closing the half-shells 34, 35 of the first mould 33, for transporting the partially shaped tubular conduits from the first forming station 31 to the second forming station 37, for opening and closing the half-shells 40, 41, 44, 45, 48 and 49 of the second mould 38, for introducing/extracting the shaped punches 51 in/from the fourth moulding cavity 50 and lastly for unloading the shaped inner tubular conduits 4 from the second forming station 37.

[0128] Furthermore, it is also apparent to those skilled in the art that the plant 30 schematically illustrated in figures 6-14 may comprise forming stations 31, 37 adapted to house a plurality of conduits to be shaped (and not only one as schematically illustrated in the figures for the sake of simplicity) so as to suitably increase the hourly productivity of the plant 30.

[0129] Lastly, it is apparent to those skilled in the art that the plant 30 schematically illustrated in figures 6-14 may comprise further stations, known *per se* and not shown, for assembling the tube-in-tube tubular conduits 3 and for connecting them, for example by means of conventional braze welding operations, to the manifolds 9, 10 for collecting and distributing the second heat carrier liquid, to the fittings 11, 12 and 23, 24 for the connection with the units external to the heat exchanger and to the fittings 21, 22 for accomplishing the substantially coil-shaped inner liquid flowpath for the circulation of the first heat carrier liquid (sanitary water).

[0130] A method according to the invention for manufacturing the bi-thermal gas-liquid heat exchanger 1 which may be carried out by means of the previously described plant 30 will now be described.

[0131] In an initial step of the method, at least a first tubular conduit and preferably, as outlined above, a plurality of essentially cylindrical tubular conduits having a predetermined length equal to the length which is to be imparted to the shaped inner tubular conduits 4 are provided, for example by means of conventional extrusion operations.

[0132] The aforementioned essentially cylindrical tubular conduits are then fed in a way known *per se*, for example by means of an automatic feeder, to the first forming station 31 of the plant 30 in such a manner that each tubular conduit is housed in the first moulding cavity 36 defined between the half-shells 34, 35 of the first mould 33 as schematically illustrated in Fig. 6 and 7.

[0133] Once the essentially cylindrical tubular conduits have been correctly positioned in the first moulding cavity 36, the first shaped core 32 is then introduced into the tubular conduits to be shaped by means of a suitable insertion and extraction device (not illustrated) so as to achieve the configuration schematically illustrated in Fig. 7.

[0134] In a subsequent step, a central portion 4' of a predetermined length of the essentially cylindrical tubular conduits housed in the first moulding cavity 36 are shaped in the first forming station 31 of the plant 30 by closing the half-shells 34, 35 of the first mould 33 against the first shaped core 32 as schematically illustrated in Fig. 9.

[0135] In this way and since the first shaped core 32 and the first moulding cavity 36 have a substantially lanceolate cross-section, a corresponding plurality of partially shaped tubular conduits 4 is obtained having:

i) a central portion 4' having the final desired shape having a multilobed cross-section having two lobes extending along a transversal centreline plane π_{Tc} and two lobes extending along a longitudinal centreline plane π_{Lc} of the tubular conduits, that is, having a substantially spear-tip-shaped cross-section, and

ii) opposite end portions extending beyond the first mould 33 and having an intermediate cross-section between the initial cylindrical one and the final one.

[0136] Since the first mould 33 is shorter than the essentially cylindrical tubular conduits to be shaped, in fact, the opposite end portions of these conduits extending beyond the mould 33 are not'directly subjected to the shaping action carried out in the first moulding cavity 36, but are in any case subject to a certain deformation as a consequence of the lateral compression of the tubular conduits exerted by the half-shells 34, 35.

[0137] The partially shaped tubular conduits thus obtained are then transported, in a way known *per se* (not shown), to the second forming station 37 of the plant 30 in such a manner that each partially shaped tubular conduit is entirely housed in the second mould 38, having substantially the same length of the tubular conduits, as schematically illustrated in Fig. 14.

[0138] In this way, the central portion 4' of each partially shaped inner tubular conduit 4 being formed is housed in the second moulding cavity 42 having a mating cross-section, each of the opposite free end portions 4" of each of these conduits is housed in the fourth moulding cavity 50 having a substantially elliptical cross-section, while each of the portions 4"' of each of these conduits extending between the central portion 4' and the free end portions 4" is housed in the third moulding cavity 46 having a multilobed cross-section having a larger cross-section area with respect to the cross-section area of the second moulding cavity 42.

[0139] In a subsequent step, the final shape is then imparted to each of the partially shaped tubular conduits 4 thus inserted in the second mould 38 by closing the half-shells 40, 41, 44, 45, 48 and 49 as schematically illustrated in Fig. 11-13.

[0140] In a preferred embodiment of the method, the closure of the half-shells 40, 41, 44, 45, 48 and 49 and the simultaneous insertion of the punches 51 into each of the fourth moulding cavities 50 allow to carry out in a single shaping step:

a) the shaping of the free end portions 4" of each of the partially shaped tubular conduits 4 obtained from the previous shaping step performed in the first forming station 31 by means of the punches 51, so as to obtain the opposite free end portions 4" having a cross-section of substantially elliptical shape;

b) the provision of the bulging elements 27, each constituting a flow rate splitting element, in each of the partially shaped tubular conduits 4 obtained from the previous shaping step carried out in the first forming station 31. By means of this shaping operation, the flow rate splitting elements 27 are in particular provided along the longitudinal development of the shaped tubular conduit 4 between the central portion 4' having a substantially lanceolate cross-section and the opposite free end portions 4" having a cross-section of substantially elliptical shape (see Fig. 14).

[0141] Preferably, this shaping step is carried out so as to provide a flow rate splitting element 27 in each of the grooves defined between one of the two lobes extending along the longitudinal centreline plane π_{Lc} and the two lobes extending along the transversal centreline plane π_{Tc} of each of the shaped tubular conduits 4 thus obtained, according to the configuration illustrated in Fig. 5.

[0142] Advantageously, the Applicant found that the step of providing the flow rate elements 27 is accomplished by means of the punch 51 simultaneously with the plastic deformation of the opposite free end portions 4" of the partially shaped tubular conduits 4 obtained from the previous shaping step without undertaking any further specific action. The Applicant, in fact, observed that during the plastic deformation operation the insertion of the punch 51 into the fourth moulding cavity 50 deforms, in a substantially radial direction, part of the material which constitutes the tubular conduit 4 being formed expanding this material against the inner walls of the third moulding cavity 46 the shape of which thus determines the final shape of the flow rate splitting elements 27.

[0143] In this preferred embodiment, the method of the invention thus allows to shape at will the flow rate splitting elements 27 by simply shaping the third moulding cavity 46 in a suitable manner and by exploiting the plastic deformation action of the punch 51, an element already present in the apparatuses for manufacturing the bi-thermal heat exchangers of known type.

[0144] In other words, the manufacturing method and the manufacturing plant 30 of the present invention allow to form the flow rate splitting elements 27 in the shaped inner tubular conduits 4 of the tube-in-tube tubular conduits 3 of the heat exchanger 1 thanks to the new configuration of the second mould 38 of the second forming station 37 described above.

[0145] Preferably, furthermore, the step of providing the flow rate splitting elements 27 is carried out so as to maintain substantially constant the perimetrical development of each partially shaped tubular conduit 4 obtained from the previous shaping step. In this way, it is advantageously possible to use to manufacture the shaped inner tubular conduits 4 low-cost plastic deformation techniques which may be carried out by cold working, such as for example drawing techniques.

[0146] In a subsequent step, the shaped tubular conduits 4 are then unloaded from the second forming station 37 and introduced into a corresponding plurality of second tubular conduits 6 having a suitable cross-section, for example substantially elliptical, so as to form the tube-in-tube tubular conduits 3 described above.

[0147] The tube-in-tube tubular conduits 3 are then completed by stably associating the shaped tubular conduits 4 to the second tubular conduits by means of conventional braze welding operations.

[0148] In a preferred embodiment, the method further comprises the steps of stably associating the heat exchange fins 28 to the tube-in-tube tubular conduits 3 thus obtained, of associating the manifolds 9, 10 to such conduits and of associating the fittings 11, 12, 21, 22 to the shaped tubular conduits 4 and the fittings 23, 24 to the manifolds 9, 10, carried out in a way known *per se*, so as to obtain the bi-thermal gas-liquid heat exchanger 1 illustrated above.

[0149] A water heating apparatus 2, for example a boiler of the so-called combined type, in which the bi-thermal gas-liquid heat exchanger 1 described above may be installed, will now be described with reference to figure 15.

[0150] The boiler 2 comprises a combustion module 53 in which are conventionally supported a burner 54 and the bi-thermal gas-liquid heat exchanger 1, which is transversally crossed by the combustion gases G which are subsequently vented by means of a hood 55.

[0151] The boiler 2 also comprises a primary hydraulic circuit 56 for the circulation of the second heat carrier liquid (hot water for room heating or primary water) including in turn:

- a conduit 57 for feeding to the heat exchanger 1 the primary water coming from the room heating plant (not shown) connected to the inlet fitting 23 for feeding the primary water to the heat exchanger 1,
- a circulation pump 58 mounted in the conduit 57,
- a conduit 59 for withdrawing heated primary water from the heat exchanger 1 connected to the outlet fitting 24 for withdrawing the primary water from the heat exchanger 1, and
- an expansion vessel 60 connected to the conduit 57 and adapted to compensate the thermal expansions which the hot water for room heating undergoes.

[0152] The boiler 2 also comprises a secondary hydraulic circuit 61 for the circulation of hot sanitary water including in turn:

- a conduit 62 for feeding to the heat exchanger 1 the cold sanitary water coming from the water mains and connected to the inlet fitting 11 for feeding the sanitary water to the heat exchanger 1,
- a conduit 63 for delivering the heated sanitary water from the heat exchanger 1 to one or more user points external to the boiler 2 and connected to the outlet fitting 12 for withdrawing the sanitary water from the heat exchanger 1.

[0153] As may be seen in figure 15, the preferred configuration of the heat exchanger 1 with the tube-in-tube tubular conduits 3 in parallel with each other allows to achieve the installation advantage of having the inlet 11 and outlet 12 fittings of the first heat carrier liquid and the inlet 23 and outlet 24 fittings of the second heat carrier liquid at longitudinally opposite parts of the heat exchanger 1, as provided for by the European standards regulating the recommended layout of the various components in water heating apparatuses.

[0154] Lastly, the boiler 2 comprises a conduit 64 for feeding a suitable gaseous fuel, for example methane gas, to the burner 54 and a valve 65 intended for intercepting the conduit 64 and for regulating the flow rate of the gas fed to the burner itself.

[0155] In a way conventional *per se*, the aforementioned conduits 57, 59, 62, 63 and 64 are provided with respective fittings 57', 59', 62', 63' and 64' adapted to allow their connection respectively to the room heating plant, to the water mains and to the sanitary water users and to an external gas distribution system.

[0156] The operation of the boiler 2 described above, regulated by a control unit known *per se* (not shown), is entirely conventional and will not be illustrated in detail hereinafter.

[0157] By means of the aforementioned bi-thermal gas-liquid heat exchanger 1, it is possible to carry out a method for carrying out a heat exchange between the combustion gases generated by the burner 54, the hot water for room heating and the sanitary water by means of the operating steps illustrated hereinafter.

[0158] In a first step, the water for room heating (the second heat carrier liquid) is fed to the outer liquid flowpaths defined in the gaps 7', 7", 8' and 8'' formed in the tube-in-tube tubular conduits 3.

[0159] In a second step, subsequent to or simultaneous with the previous one, a high temperature gas phase G is generated - in this case constituted by the combustion gases generated by the burner 54 of the boiler 2 - flowing with an ascending motion (downwards-upwards) passing through the gas passages defined between the heat exchange fins 28 to which they transfer part of their sensible heat.

[0160] In this way, a portion of the heat transferred by the combustion gases to the fins 28 and to the outer tubular conduits 6 is transferred in turn by the latter essentially by conduction, both to the first heat carrier liquid (sanitary water) and to the second heat carrier liquid (water for room heating) which flows in the aforementioned outer liquid flowpaths, liquids which are thus heated to the desired temperature.

[0161] If the delivery of hot sanitary water (the first heat carrier liquid) is required, the sanitary water is circulated in the inner liquid flowpath 5 defined in the shaped inner tubular conduits 4, in such a manner that during such circulation, the cold sanitary water can be heated both by the combustion gases, and by the water for room heating flowing in the outer liquid flowpaths defined in the gaps 7', 7", 8' and 8'' of the tube-in-tube tubular conduits 3.

[0162] In this step, the heat exchange method of the invention provides that the step of feeding the water for room heating is carried out by distributing the flow rate of the water for room heating fed to the tube-in-tube tubular conduits 3 between the gas inlet side gaps 8' and 8'' and the gas outlet side gaps 7', 7" by means of the flow rate splitting elements 27 arranged in the latter gaps.

[0163] In this way and as outlined above, it is advantageously possible to optimise the fluid dynamics characteristics, in particular speed and turbulence, of the water for room heating in the gaps 8', 8" of the gas inlet side zone achieving both a greater heat exchange efficiency and the substantial elimination of the noise problems related to internal boiling.

[0164] Preferably, the distribution of the water for room heating in the outer liquid flowpaths is carried out by feeding to the gas inlet side gaps 8', 8" at least 65% of the flow rate of the second heat carrier liquid entering the outer liquid flowpaths of the tube-in-tube tubular conduits 3.

[0165] In this way and as outlined above, it is advantageously possible to split the flow rate and, thus also the speed, of the water for room heating in an optimal manner between the gas inlet side zone and the gas outlet side zone of the tube-in-tube tubular conduits 3 optimising the fluid dynamics and maximising the performances of the heat exchanger 1.

[0166] Preferably, the water for room heating is fed in parallel to the outer liquid flowpaths defined in the tube-in-tube tubular conduits 3.

[0167] In this way and as outlined above, the flow rate splitting elements 27 advantageously allow to balance in an optimal manner the distribution of the flow rate of the water for room heating in the various outer liquid flowpaths defined in the tube-in-tube tubular conduits 3 obtaining at the same time the maximum reduction of the number of tube-in-tube tubular conduits 3 without having any noise problems related to boiling or any performance decrease of the heat exchanger 1.

[0168] The operating steps of the heat exchange method of the invention illustrated above are in particular carried out whenever there is a circulation of the second heat carrier liquid (hot water for room heating) in the outer liquid flowpaths defined in the gaps 7', 7" and 8', 8" of the tube-in-tube tubular conduits 3. This circulation may occur in two circumstances: either in room heating mode, that is, when hot water is required by the room heating plant or when hot sanitary water is required and the boiler 2 is provided with a diverter valve (not shown in the figures) adapted to intercept the delivery conduit 59 to the room heating plant so as to circulate a part of the hot water for room heating in a liquid flowpath defined inside the boiler 2 and including in addition to the diverter valve, a conduit extending between such a valve and the conduit 57, the pump 58, a part of the conduit 57, the heat exchanger 1 and a part of the conduit 59.

[0169] According to several tests performed with the bi-thermal gas-liquid heat exchanger 1 of the invention, the Applicant found that the heat exchanger 1 is capable to achieve a heat exchange efficiency comparable to that of the bi-thermal heat exchangers of the known type having the same heating power, even having a definitely lower size and cost with respect to the latter.

[0170] Clearly, a man skilled in the art may introduce modifications and variants to the invention described hereinbefore in order to meet specific and contingent application requirements, variants and modifications which anyway fall within the scope of protection as defined in the attached claims.

Claims

1. Bi-thermal gas-liquid heat exchanger (1) comprising:

   - at least one tube-in-tube tubular conduit (3) comprising:

     a) a shaped inner tubular conduit (4) in which an inner liquid flowpath (5) for the circulation of a first heat carrier liquid is defined;

     b) an outer tubular conduit (6) mounted around the shaped inner tubular conduit (4) and defining with said inner tubular conduit (4) at least one gap (7', 7"; 8', 8") in which an outer liquid flowpath for the circulation of a second heat carrier liquid is defined;

   characterised in that said at least one tube-in-tube tubular conduit (3) further comprises at least one flow rate splitting element (27) arranged in said at least one gap (7', 7"; 8', 8") defined between the shaped inner tubular conduit (4) and the outer tubular conduit (6) for splitting the flow rate of the second heat carrier liquid between a gas inlet side zone and a gas outlet side zone of said at least one gap (7', 7"; 8', 8").

2. Heat exchanger (1) according to claim 1, comprising a plurality of tube-in-tube tubular conduits (3).

3. Heat exchanger (1) according to claim 1 or 2, wherein said at least one tube-in-tube tubular conduit (3) is substantially rectilinear or substantially spiral-shaped.

4. Heat exchanger (1) according to claim 1, wherein said shaped inner tubular conduit (4) comprises a central portion (4') having a multilobed cross-section.

5. Heat exchanger (1) according to claim 4, wherein said at least one tube-in-tube tubular conduit (3) comprises at least one gas outlet side gap (7', 7") and at least one gas inlet side gap (8', 8") with respect to a transversal centreline plane (π_{Tc}) of the shaped inner tubular conduit (4), and wherein said at least one flow rate splitting element (27) is arranged in said at least one gas outlet side gap (7', 7").

6. Heat exchanger (1) according to claim 5, wherein said at least one tube-in-tube tubular conduit (3) comprises two gas outlet side gaps (7', 7") and two gas inlet side gaps (8', 8") with respect to a transversal centreline plane (π_{Tc}) of the shaped inner tubular conduit (4), and wherein said at least one tube-in-tube tubular conduit (3) comprises at least one flow rate splitting element (27) in each of the gas outlet side gaps (7', 7").

7. Heat exchanger (1) according to claim 6, wherein the flow rate splitting elements (27) arranged in the gas outlet side gaps (7', 7") are symmetrically arranged with respect to a longitudinal centreline plane (π_{Lc}) of the shaped inner tubular conduit (4).

8. Heat exchanger (1) according to any one of the preceding claims, wherein the shaped inner tubular conduit (4) comprises a central portion (4') and at least one free end portion (4") and wherein said at least one flow rate splitting element (27) is arranged along the longitudinal development of the inner tubular conduit (4) between said central portion (4') and said at least one free end portion (4").

9. Heat exchanger (1) according to any one of the preceding claims, wherein said at least one flow rate splitting element (27) comprises a bulging element integral with said shaped inner tubular conduit (4).

10. Heat exchanger (1) according to any one of the preceding claims, wherein at the flow rate splitting element (27) the ratio between the flow section of the second heat carrier liquid in the gas outlet side zone and the flow section of the second heat carrier liquid in the gas inlet side zone of said at least one gap (7', 7"; 8', 8") is comprised between 0.25 and 0.5.

11. Heat exchanger (1) according to claim 2, wherein the outer liquid flowpaths for the circulation of the second heat carrier liquid defined in said plurality of tube-in-tube tubular conduits (3) are at least partially connected in parallel with each other.

12. Heat exchanger (1) according to claim 1, further comprising a plurality of heat exchange fins (28) externally associated to said at least one tube-in-tube tubular conduit (3).

13. Water heating apparatus (2) comprising a bi-thermal gas-liquid heat exchanger (1) according to any one of the preceding claims.

14. Method for manufacturing a bi-thermal gas-liquid heat exchanger (1) according to any one of claims 1-12, **characterised in that** it comprises the steps of:

a) providing at least a first tubular conduit,
b) shaping in a first forming station (31) a central portion of predetermined length of said at least a first tubular conduit so as to obtain at least one partially shaped tubular conduit;
c) shaping in a second forming station (37) at least one of the opposite end portions of the partially shaped tubular conduit obtained from step b) so as to obtain at least one free end portion having a cross-section of predetermined shape;
d) providing in the partially shaped tubular conduit obtained from step b) at least one bulging element arranged along the longitudinal development of the shaped tubular conduit between said central portion (4') and said at least one free end portion;
e) inserting the shaped tubular conduit (4) obtained from step d) into at least a second tubular conduit (6) so as to obtain a tube-in-tube tubular conduit (3) in which at least one gap (7', 7"; 8', 8") for the circulation of a heat carrier liquid is defined; said tube-in-tube tubular conduit (3) comprising at least one flow rate splitting element (27) arranged in said at least one gap (7', 7"; 8', 8") and comprising said at least one bulging element;
f) stably associating the shaped tubular conduit (4) to said at least a second tubular conduit (6).

15. Method according to claim 14, wherein said step a) comprises providing a plurality of first tubular conduits and wherein said step d) comprises providing said at least one bulging element in at least one of the partially shaped tubular conduits obtained from step b).

16. Method according to claim 15, wherein said step e) comprises inserting the shaped tubular conduits (4) obtained from step d) into a corresponding plurality of second tubular conduits (6) so as to obtain a plurality of tube-in-tube tubular conduits (3).

17. Method according to any one of claims 14-16, wherein said at least a first tubular conduit and said at least a second tubular conduit (6) are substantially rectilinear or substantially spiral-shaped.

18. Method according to claim 14, wherein said shaping step b) is carried out so as to shape the central portion (4') of the first tubular conduits according to a multilobed cross-section.

19. Method according to claim 18, wherein said shaping step b) is carried out in such a manner that the central portion (4') of said at least one shaped tubular conduit (4) has a multilobed cross-section comprising two lobes extending along a transversal centreline plane (π_{Tc}) and two lobes extending along a longitudinal centreline plane (π_{Lc}) of said at least one shaped tubular conduit (4) and wherein said step d) is carried out so as to provide at least one bulging element in each of the grooves defined between one of the two lobes extending along said longitudinal centreline plane (π_{Lc}) and the two lobes extending along said transversal centreline plane (π_{Tc}).

20. Method according to any one of claims 14-19, wherein said steps c) of shaping and d) of providing said at least one bulging element are carried out simultaneously and wherein said at least one bulging element is provided by inserting a shaped punch (51) into at least one free end portion (4") of the partially shaped tubular conduit obtained from step b).

21. Method according to claim 20, wherein said shaped punch (51) has a cross-section of predetermined shape and a length equal to the length of said free end portion (4") of said shaped tubular conduit (4) obtained from step d).

22. Method according to any one of claims 14-19, wherein said step d) of providing said at least one bulging element is carried out so as to maintain substantially constant the perimetrical development of the partially shaped tubular conduit obtained from step b).

23. Method according to any one of claims 14-22, wherein said steps b), c) and d) are carried out by means of plastic deformation, preferably by cold shaping.

24. Method according to any one of claims 14-23, further comprising the step of stably associating a plurality of heat exchange fins (28) to the tube-in-tube tubular conduit (3) obtained from step e).

25. Plant (30) for manufacturing a bi-thermal gas-liquid heat exchanger (1) according to any one of claims 1-12, comprising:

a) a first forming station (31) comprising:

a1) a first shaped core (32) of predetermined length having a multilobed cross-section, and
a2) a first mould (33) including two first half-shells (34, 35) defining therebetween a first moulding cavity (36) having a shape substantially mating with the shape of said first shaped core (32), said first half-shells (34, 35) having a predetermined length;

b) a second forming station (37) comprising:

b1) a second mould (3 8) including:

i) a central section (39) comprising two second half-shells (40, 41) defining therebetween a second moulding cavity (42) having a shape substantially mating with the shape of said first shaped core (32), said second half-shells (40, 41) having a length substantially equal to the length of the first half-shells (34, 35) of said first mould (33);
ii) at least one intermediate section (43) of predetermined length laterally arranged with respect to said central section (39) and comprising two half-shells (44, 45) defining therebetween a third moulding cavity (46) having a multilobed cross-section having a larger area with respect to the cross-section area of the second moulding cavity (42) in at least a portion of the third moulding cavity (46);
iii) two axially opposite end sections (47) of predetermined length and each comprising two half-shells (48, 49) defining therebetween a fourth moulding cavity (50) having a cross-section of predetermined shape;

b2) at least one shaped punch (51) having a shape substantially mating with the shape of said fourth moulding cavity (50).

26. Plant according to claim 25, wherein said shaped punch (51) has a length substantially equal to the length of the two axially opposite end sections (47) of the second mould (38).

27. Method for carrying out a heat exchange between a gas and a first and a second heat carrier liquid by means of a bi-thermal gas-liquid heat exchanger (1) comprising:

- at least one tube-in-tube tubular conduit (3) comprising:

a) a shaped inner tubular conduit (4) in which an inner liquid flowpath (5) for the circulation of a first heat carrier liquid is defined;
b) an outer tubular conduit (6) mounted around the shaped inner tubular conduit (4)

and defining with said inner tubular conduit (4) at least one gap (7', 7"; 8', 8") in which at least one outer liquid flowpath for the circulation of a second heat carrier liquid is defined;

said method comprising the step of feeding the second heat carrier liquid to said at least one outer liquid flowpath defined in said at least one gap (7', 7"; 8', 8") of said at least one tube-in-tube tubular conduit (3),

characterised in that said feeding step of the second heat carrier liquid is carried out by splitting the flow rate of the second heat carrier liquid fed to said at least one tube-in-tube tubular conduit (3) between a gas inlet side zone and a gas outlet side zone of said at least one gap (7', 7"; 8', 8") by means of at least one flow rate splitting element (27) arranged in said gap (7', 7"; 8', 8").

28. Method according to claim 27, wherein the shaped inner tubular conduit (4) of said at least one tube-in-tube tubular conduit (3) comprises a central portion (4') having a multilobed cross-section defining at least one gas inlet side gap (8', 8") with respect to a transversal centreline plane (π_{Tc}) of the shaped inner tubular conduit (4), and wherein the splitting of the second heat carrier liquid in said at least one outer liquid flowpath is carried out by feeding to said at least one gas inlet side gap (8', 8") at least 50% of the total flow rate of the second heat carrier liquid entering said outer liquid flowpath.

29. Method according to any one of claims 27 or 28, wherein said bi-thermal gas-liquid heat exchanger (1) comprises a plurality of tube-in-tube tubular conduits (3) and wherein the second heat carrier liquid is fed at least partially in parallel to the outer liquid flowpaths defined in said plurality of tube-in-tube tubular conduits (3).

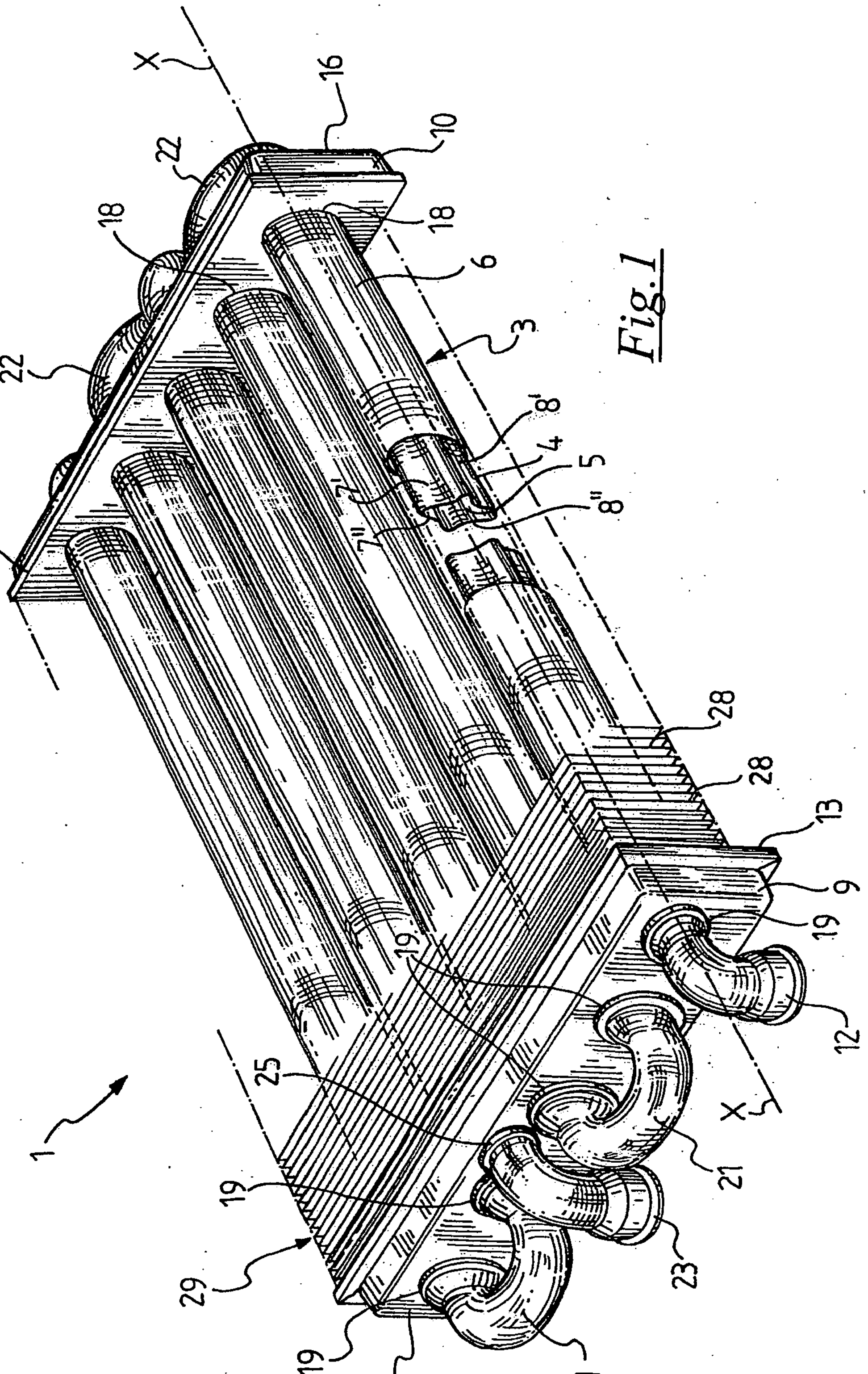

Fig.1

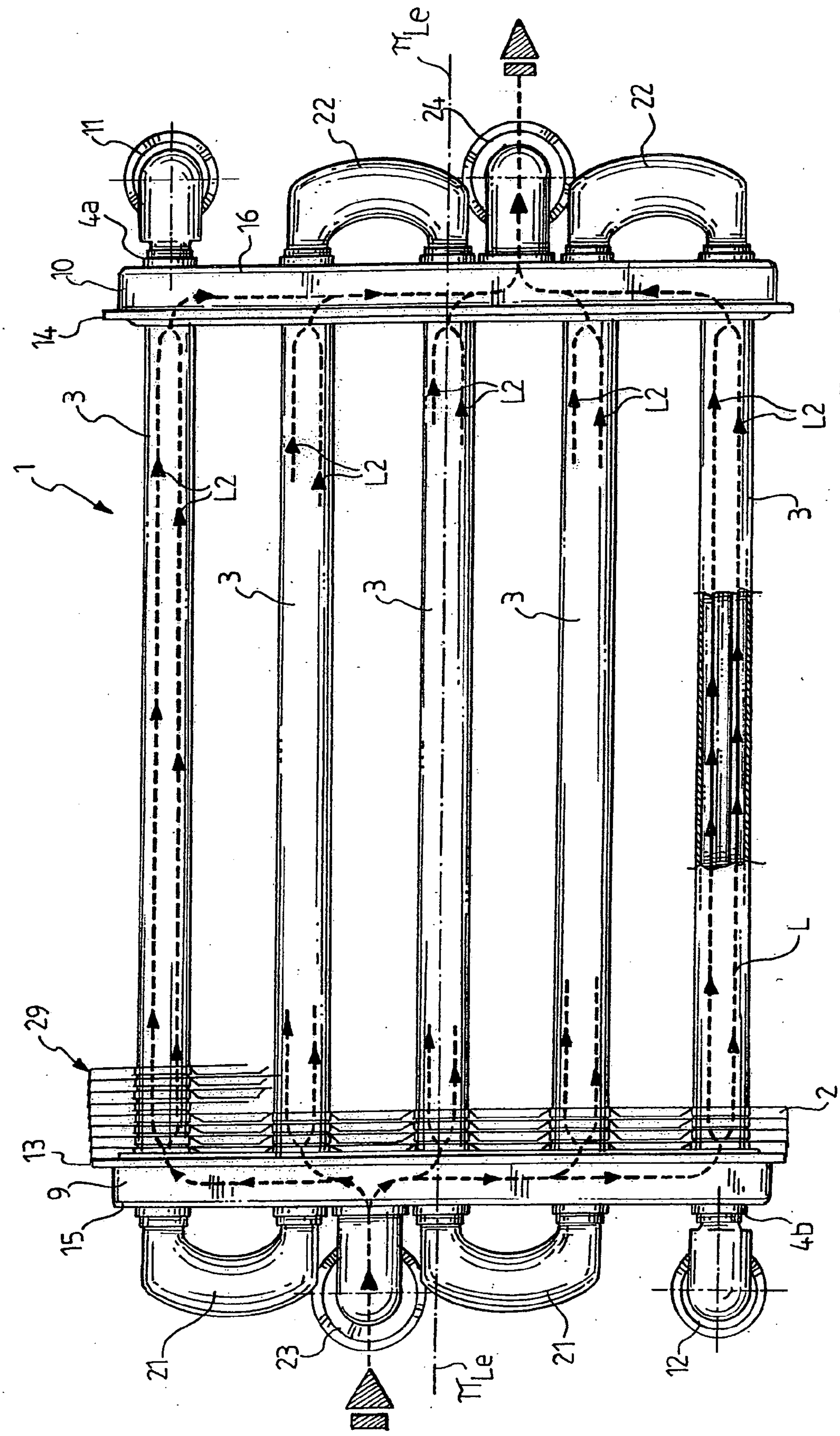

Fig. 2

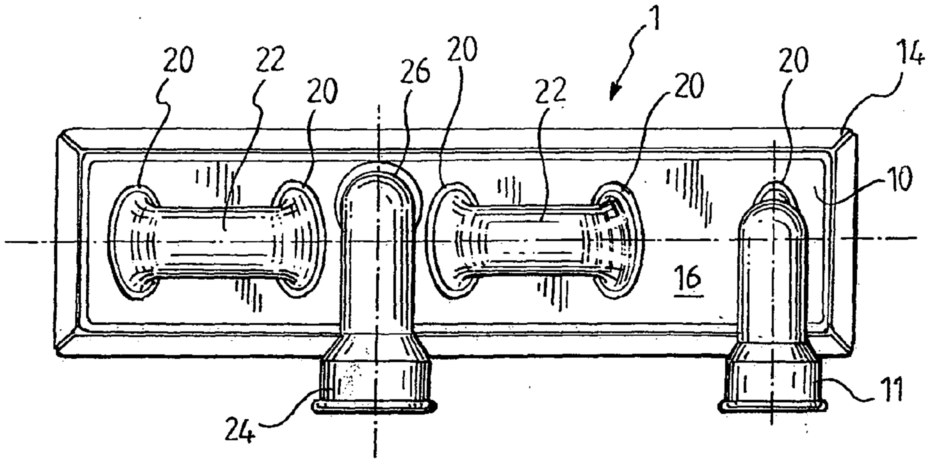

Fig.3

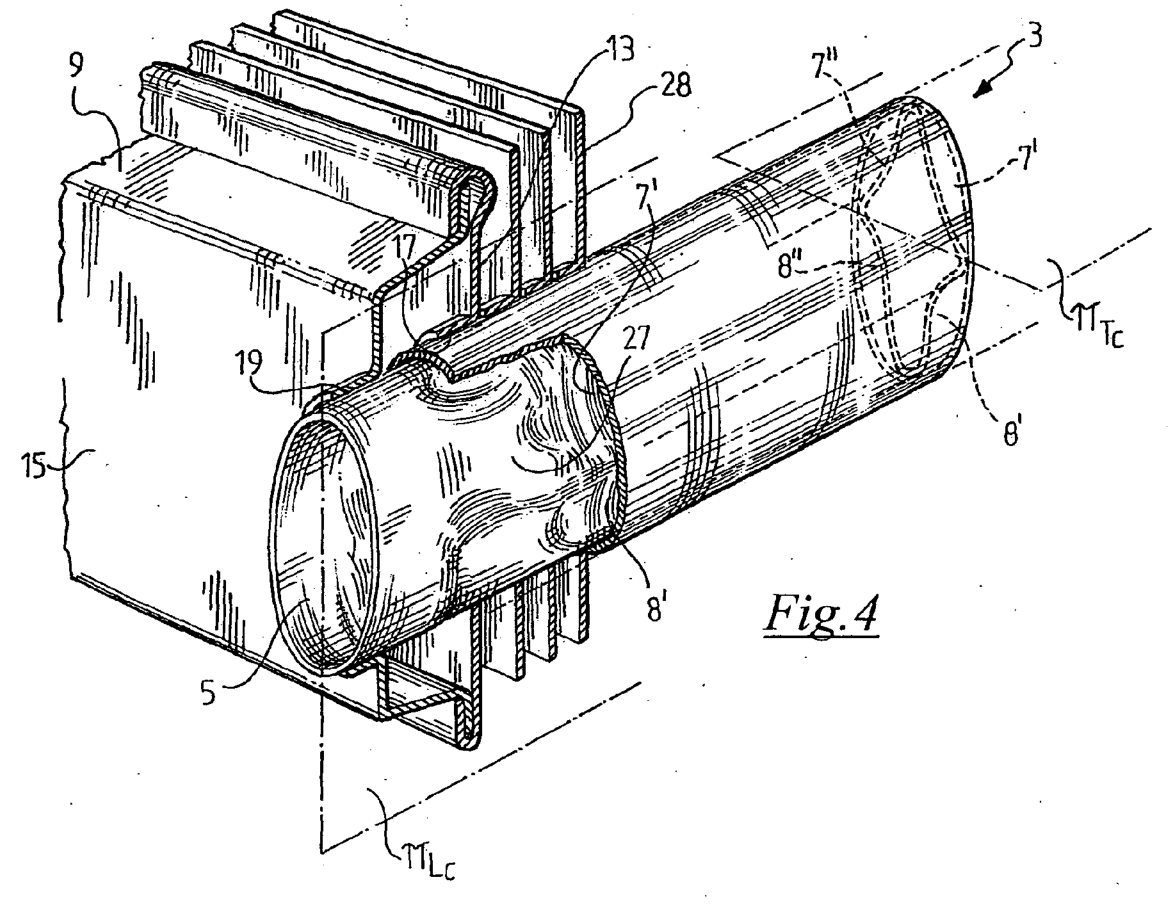

Fig.4

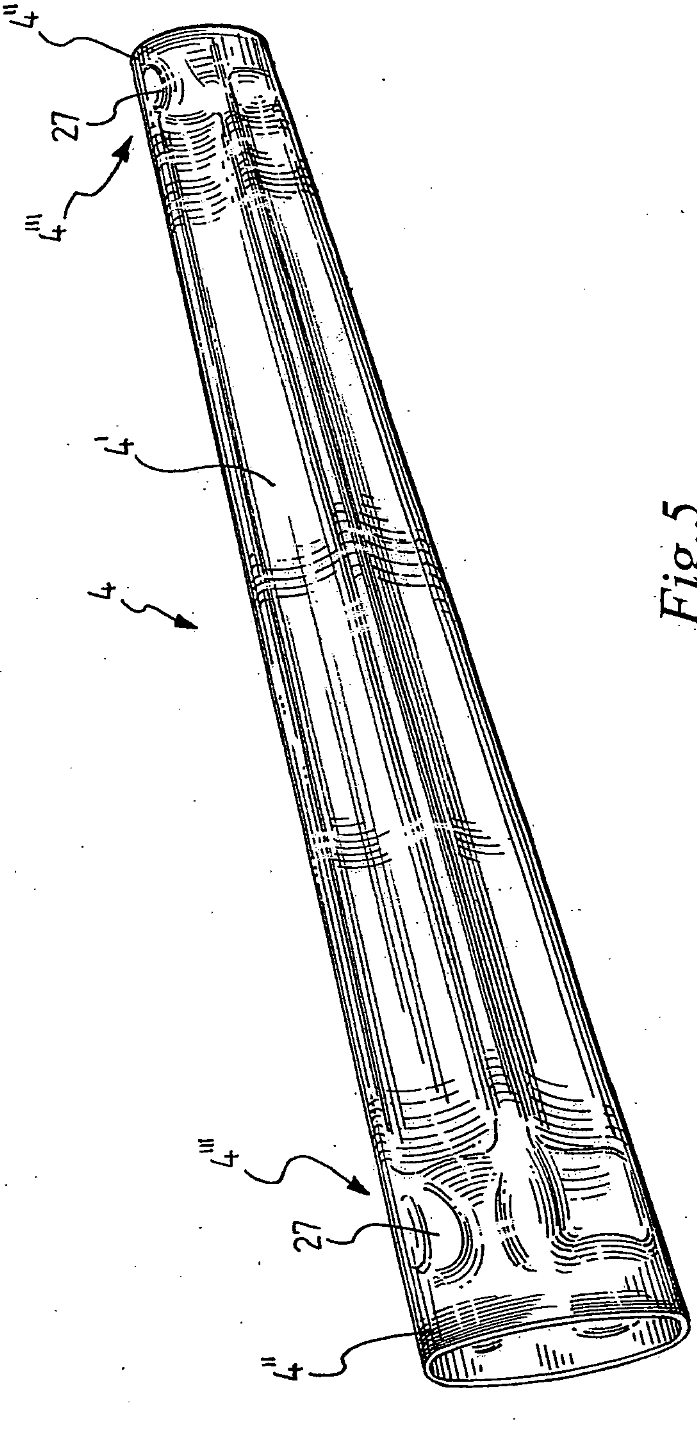

Fig.5

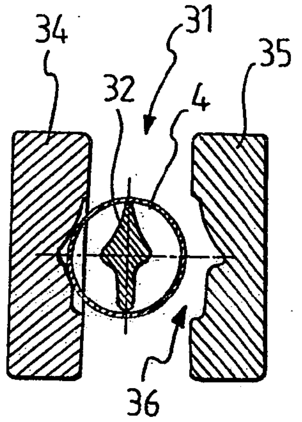

Fig.7

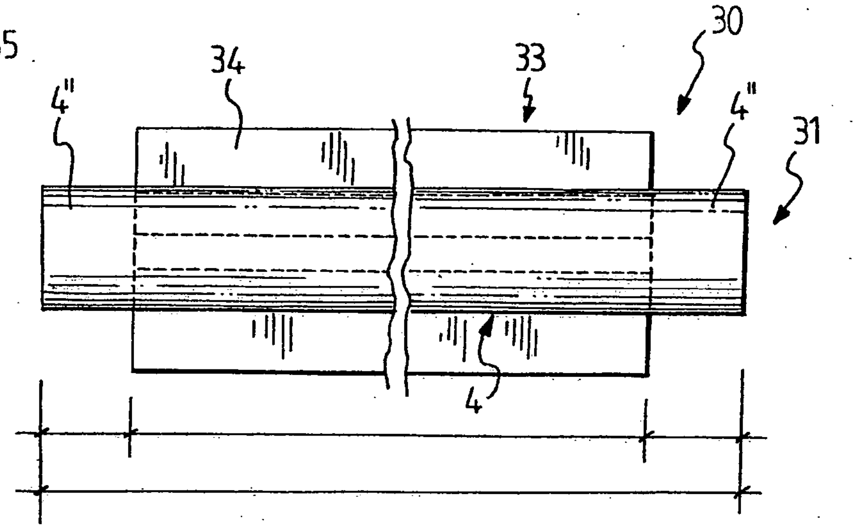

Fig.6

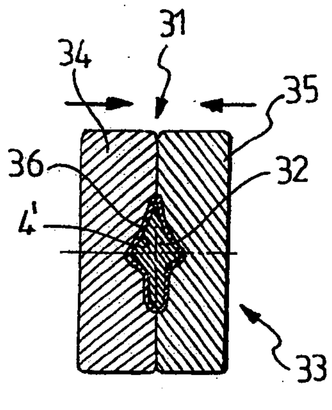

Fig.9

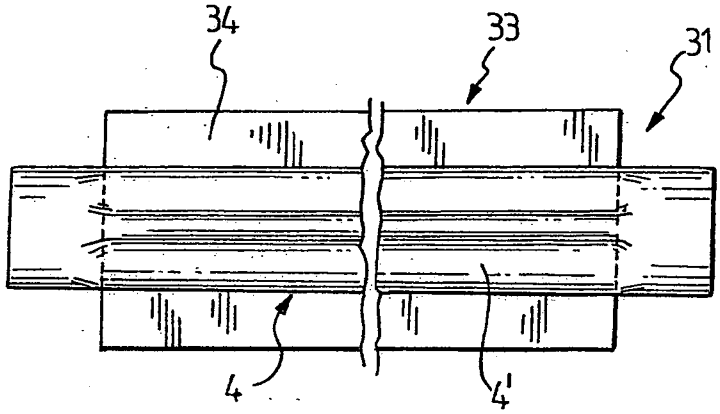

Fig.8

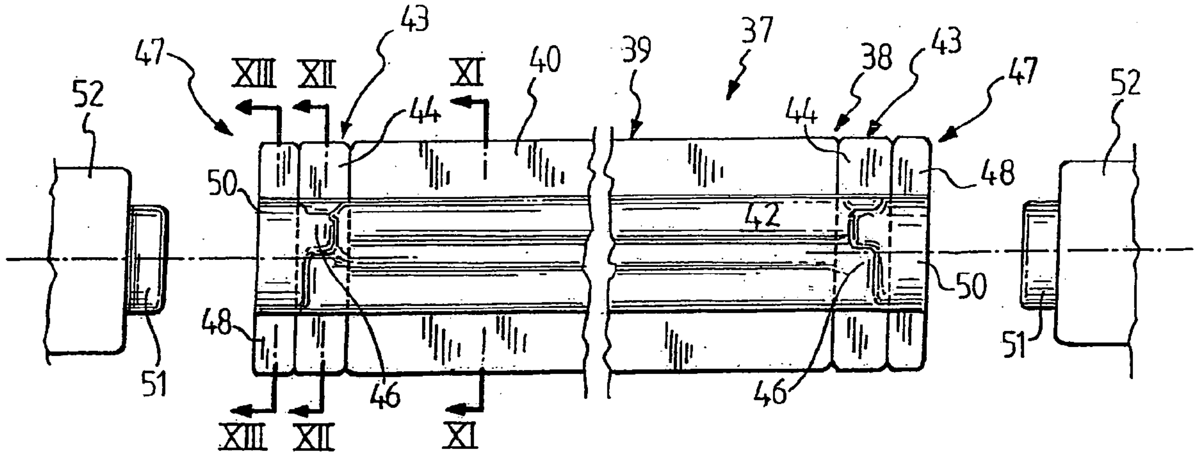

Fig.10

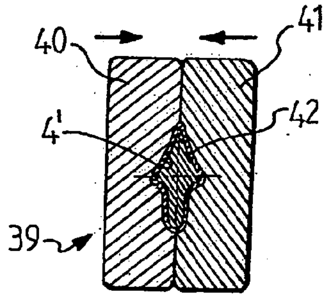

Fig.11

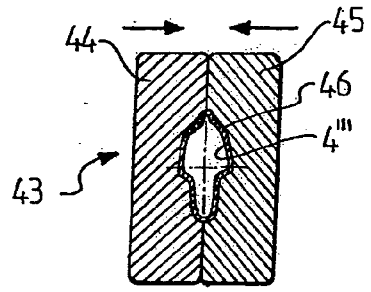

Fig.12

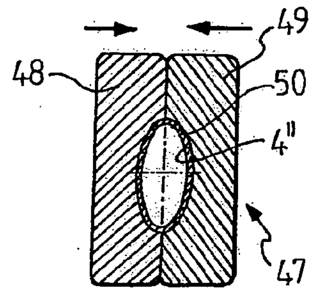

Fig.13

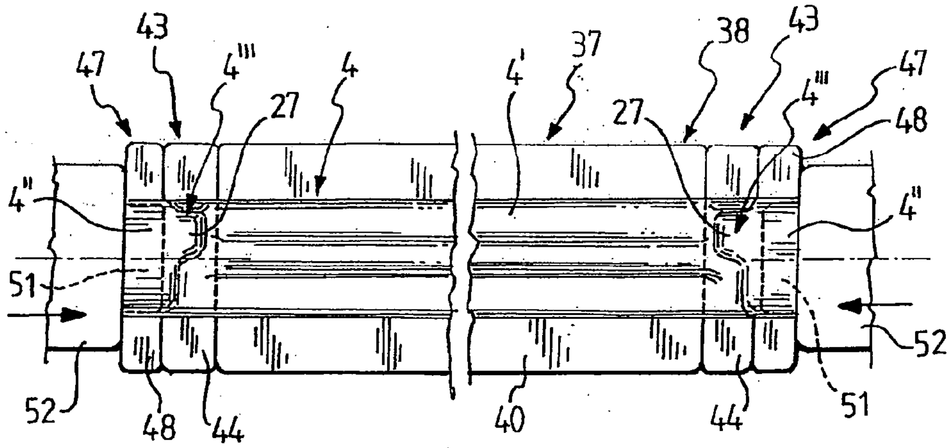

Fig.14

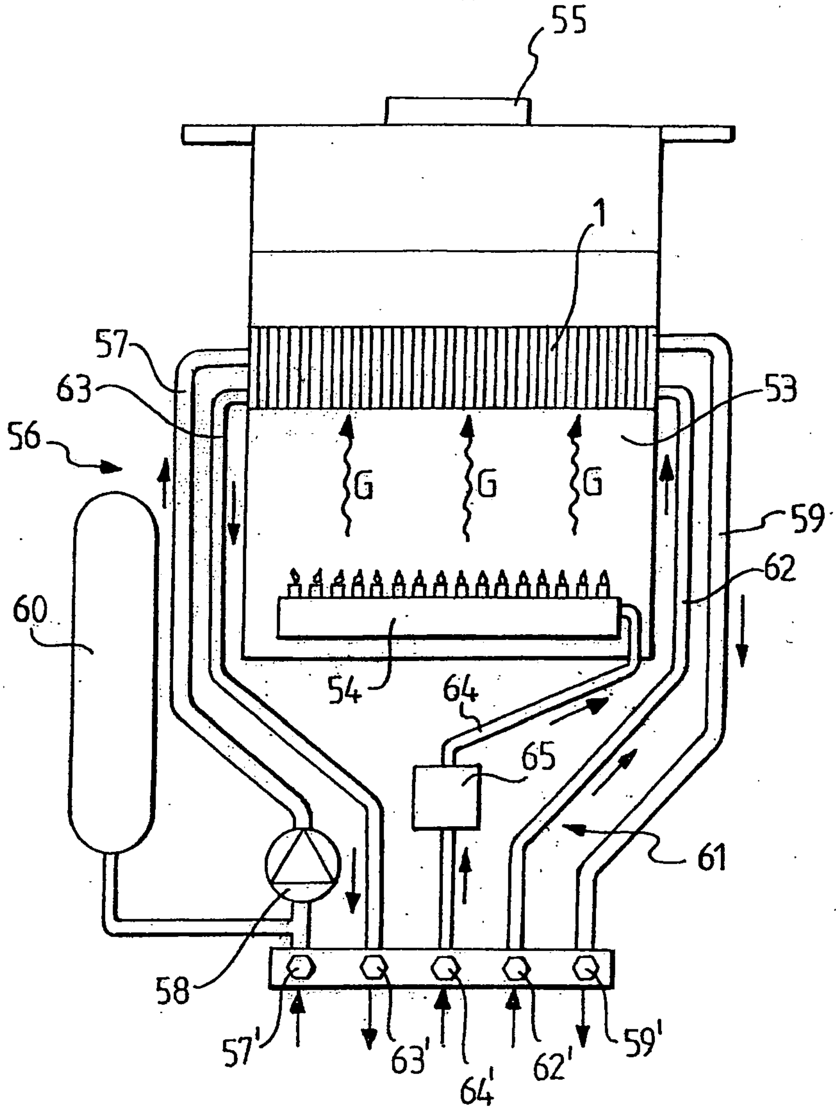

Fig. 15

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EUROPEAN SEARCH REPORT

Application Number
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Place of search	Date of completion of the search	Examiner
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