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- (54) Benævnelse: **Fremstillingsmåde for svejsede forbindelser mellem indre rør og rørstøtteplader i et rørbundt til en produkt-til-produkt shell-and-tube varmeveksler ved hjælp af en hjælpeanordning, og hjælpeanordning til en sådan fremstillingsmåde**
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DE-A1- 2 341 808
DE-A1-102011 111 095
FR-A1- 2 349 395
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Method for producing welded connections between inner tubes and tube support plates of a tube bundle for a product-to-product shell-and-tube heat exchanger by means of an auxiliary device, and auxiliary device for a production method of this type

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Description

TECHNICAL FIELD

The invention relates to a method for producing welded connections between inner tubes and tube support plates of a tube bundle for a product-to-product shell-and-tube heat exchanger by means of an auxiliary device (see Claim 1), wherein the relevant tube support plate is welded by its end face that faces the inner tubes. The production method is carried out in the manner known per se with the following steps: (i) orienting the inner tubes with assigned plate inner bores arranged in the tube support plate in such a way that the inner tubes and the plate inner bores are aligned with one another; (ii) fixing the relevant inner tube and the tube support plate to one another in an unwelded starting position by means of a form fit that is effective radially and in opposing directions, wherein more than one plate inner bore is defined and therefore a tube layout pattern is established by means of the tube support plate for assigned inner tubes arranged in parallel with one another; (iii) immovably fixing a number of inner tubes required in each case to one another as a whole according to the tube layout pattern and in the relevant form fit with the tube support plate by means of the auxiliary device.

Furthermore, the invention relates to an auxiliary device for a production method of this type, a tube bundle welded with such a production method and a product-to-product shell-and-tube heat exchanger having at least such a tube bundle, see Claims 3, 8 and 11.

PRIOR ART

A wide variety of heat exchangers are utilized in the food and drinks industry in order to heat-treat food products. The relevant selection, for example plate or tubular heat exchangers in their highly diverse embodiments, is made according to the food product to be treated. The tubular heat exchanger is suitable both for low-viscosity products such as milk and other dairy products, beverages, and juices as well as for medium- to high-

viscosity products such as concentrates, soups, or desserts and, moreover, also for those products that additionally contain fibers and/or pulp. As a general rule, for the purposes of heat treatment, the product flows through the so-called inner tubes and a heat transfer medium, for example steam or water, flows around said inner tubes, preferably in the counter flow, from outside in a housing surrounding the inner tubes, preferably a shell tube.

A particularly energy-efficient embodiment of the known tubular heat exchangers is a so-called shell-and-tube heat exchanger (see **Fig. 1**). Said shell-and-tube heat exchanger consists of a plurality of tube bundles (**Figs. 2a, 2b, 3**), each of which comprises multiple inner tubes connected in parallel which have a common inlet and a common outlet for the product. The relevant group of inner tubes or, respectively a so-called set of inner tubes is enclosed by the shell tube, which is in each case equipped with a connection nozzle opening into or, respectively out of said shell tube radially for a heat transfer medium close to its ends. The heat transfer medium flows through the shell tube, preferably counter to the tube flow in the inner tubes, a product flow.

The inner tubes penetrate a plate inner bore on both sides and at each end in a so-called tube support plate (**Fig. 3**) and are in each case connected at their tube end to the tube support plate, and indeed at the end face thereof facing away from the inner tubes (front side of the tube support plate), preferably by means of a circumferential round weld. Instead of a welded connection, other firmly bonded connections with or without additional material are also possible. Consequently, there is a circumferential annular gap between the outside of the inner tube and the assigned plate inner bore in the tube support plate, which circumferential annular gap extends from the circumferential firmly bonded connection point between the inner tube and the tube support plate through the tube support plate right into an interior space for the tube bundle or, respectively of the shell tube that is supplied with the heat transfer medium. Said circumferential annular gap is not problematic as long as the heat transfer medium only exclusively remains a heat transfer medium such as water or steam and is not substituted by a food product.

Admittedly, if, for reasons of an improved heat transfer efficiency in a shell-and-tube heat exchanger, a so-called product-to-product heat transfer is to take place, then the aforementioned circumferential annular gap becomes problematic because product can settle here. At best, said product can only be cleaned off using particularly intensive and long-lasting in-flow cleaning in excessive doses, so-called cleaning-in-place (CIP), the aim of which is to convert the circumferential annular gap into a microbiologically sound condition for the following product run.

Particularly in the case of regeneratively operated heat transfer systems, in which, for example, the heat arising during the cooling of an end product is utilized for preheating a product which still has to be treated, this is known to result in a higher energy efficiency or, respectively cost-effectiveness in the case of heat exchange from product to product (P-P) than in the case of heat transfer from product to heat transfer medium to product (P-W-P), because the passage of heat can be improved by means of a greater logarithmic temperature difference as well as higher flow speeds of the product flows (higher Reynolds number) and the heat exchange surfaces can be reduced in size as a result. Moreover, thanks to the higher Reynolds numbers, tube bundles having greater tube lengths can be realized, resulting in cost reductions.

In the known form, from a sanitary or even aseptic point of view, shell-and-tube heat exchangers are only suitable for product-to-product heat exchange at the cost of cleaning in excessive doses. It has therefore been proposed (**JP 2020 117 121**) that an additional round weld be created on the back side of the tube support plate, i.e., on the end face of the tube support plate that faces the inner tubes, in order to thereby close the problematic annular gap against the ingress of product. One disadvantage of a relevant circumferential round weld on the front side and additionally on the back side of the tube support plate is that a closed annular space or, respectively annular gap is formed between the two round welds or, respectively the two other firmly bonded connections, which annular space or gap poses a risk to food safety if the round welds or, respectively firmly bonded connections are not produced perfectly or free of pores. Carrying out a check in this regard is only possible with difficulty or even impossible. There is then the risk that

microorganisms settle in the closed annular space, which can re-contaminate a subsequent product.

A heat exchanger having opposite head plates with holes is known from **DE 23 41 808**
5 **A1** (disclosing features and steps of the preambles of Claims 1, 3, 8 and 11), wherein the
holes interconnect assigned inner tubes congruently. The diameter of the inner tube is
equal to the diameter of the relevant head plates. The head plate is designed in the form
of a projection in the peripheral region of the hole and towards the inner tube. The
projection and inner tube are interconnected via butt welding over the entire wall
10 thickness of the inner tube, wherein the butt welding is designed as orbital welding of the
inner side of the inner tube. The fixing of the inner tube with respect to the head plate
takes place in the course of the welding process via suitable holding means.

In **US 2 996 600 A**, a welded connection between a tube and a tube support plate is
15 described within the framework of a tubular heat exchanger. The tube has an inner
diameter to which the diameter of a bore assigned to the tube in the tube support plate
corresponds. The tube and the tube support plate are welded to one another in such a way
that the inner diameter of the tube and the diameter of the bore are aligned with one
another. The necessary orientation and centering of the tube on the tube support plate in
20 this regard are achieved by means of a recess on the tube support plate into which the
tube engages. A reversal of this principle is likewise disclosed, in which a recess is
provided on the tube end to be connected, which recess encloses a neck surrounding the
bore in the tube support plate from outside. The relevant form-fit region between the tube
and the tube support plate is welded by means of an orbitally circulating welding tool,
25 starting from the inside of the inner diameter of the tube and of the bore of the tube support
plate, in a single pass and continuously from radially inside to radially outside.

A device for fastening a tube in a tube sheet by means of so-called inner bore welding is
known from **FR 2 349 395 A**, wherein the tube is inserted into a bore in the tube sheet
30 over a certain distance and a welding electrode is inserted within the bore and the tube,
which welding electrode executes a relative rotational movement with respect to the edge

of the tube and to the bore. This results in a weld that connects the entire wall thickness of the tube to a corner region of the solid tube sheet facing the tube.

A wide variety of proposals are disclosed in **WO 2014 060 425 A1** or, respectively **US 2015/267 973 A1** as to how the connection in question between an inner tube and a tube support plate of a tube bundle of a shell-and-tube heat exchanger can be made while preventing a circumferential annular gap between the outside of the inner tube and the bore in the tube support plate.

A device for horizontally assembling heat exchangers is disclosed in **DE 15 01 463 A**, in which a tube bundle held together by means of holders, the tube ends of the tubes of which tube bundle open into assigned bores of a tube sheet, is introduced into a shell of the heat exchanger, which is open on both sides. The holders obviously remain on and in the tube bundle, even after assembly and during operation of the heat exchanger.

Features for embedding the tubes of the tube bundle in the tube sheet and for connecting said tubes of the tube bundle to said tube sheet (for example, welded connections) are not disclosed. It can be presumed that the individual tubes of the tube bundle are pushed through assigned bores in the tube sheet and connected in a firmly bonded manner, presumably welded, at the open tube ends to the end face of the tube sheet that faces away from the tubes. As already mentioned above, welded connections of this type bring about a problematic annular gap between the outer diameter of the relevant tube and the inner diameter of the receiving bore in the tube sheet.

The features from the prior art indicated above, in the context of the configuration of a welded connection between the inner tube and tube support plate (**US 2 996 600 A**) as well as in the context of a holder or, respectively auxiliary device, by means of which the tubes of a tube bundle are held together (**DE 15 01 463 A**), in combination with one another, form the generic basis for the subject-matter of the present invention.

Proceeding from the aforementioned prior art, an object of the present invention is to create a production method of the generic type, which, by means of an auxiliary device,

guarantees a welded connection between the inner tubes and the tube support plate of a tube bundle for a product-to-product shell-and-tube heat exchanger that is safe from a hygienic and sanitary point of view, that is dimensionally accurate, and that is of a high reproducible quality. Moreover, an aim of the invention is to indicate an auxiliary device
5 for carrying out the production method according to the invention.

SUMMARY OF THE INVENTION

This object is achieved by a production method having the features of Claim 1. An advantageous configuration of the production method according to the invention is the
10 subject-matter of the assigned subclaim. An auxiliary device according to the invention for a production method of this type is the subject-matter of the coordinate Claim 3. Advantageous embodiments of the auxiliary device are described in the assigned subclaims. A tube bundle according to the invention is the subject-matter of the
15 coordinate claim 8. Advantageous configurations of the tube bundle are claimed in the assigned subclaims. A product-to-product shell-and-tube heat exchanger according to the invention having at least one such tube bundle is the subject-matter of the coordinate Claim 11.

20 With regard to the method, the invention proceeds from a method for producing welded connections between inner tubes and tube support plates of a tube bundle for a product-to-product shell-and-tube heat exchanger by means of an auxiliary device, wherein the relevant tube support plate is welded by its end face that faces the inner tubes, carried out with the following steps (i) to (iii) which are known per se:

- 25 (i) Orienting the inner tubes with assigned plate inner bores arranged in the tube support plate in such a way that the inner tubes and the plate inner bores are aligned with one another, i.e., their rotational axes extend coaxially.
- (ii) Fixing the relevant inner tube and the tube support plate to one another in an unwelded starting position by means of a form fit that is effective radially and in
30 opposing directions, wherein more than one plate inner bore is defined and therefore a tube layout pattern is established by means of the tube support plate for assigned inner tubes arranged in parallel with one another.

The radial fixing acts in both directions, the axial fixing is restricted to the inner tube abutting the tube support plate in the one direction and being capable of being detached therefrom in the reverse direction.

- (iii) Immovably fixing a number n of inner tubes required in each case to one another as a whole according to the tube layout pattern and in the relevant form fit with the tube support plate by means of the auxiliary device.

The tube support plate establishes a tube layout pattern for the arrangement of assigned inner tubes arranged in parallel with one another by defining more than one inner bore. The number n of possible inner tubes is two and more, wherein an arrangement with $n = 7$ inner tubes is preferred, one of which is arranged centrally in the tube support plate and the others are arranged so as to be evenly distributed around a single pitch circle that extends concentrically to the center of the tube support plate. The auxiliary device serves to immovably fix the inner tubes to one another.

In the case of the production method according to the invention, in the sense of the problem to be solved, the inventive basic idea is not only to provide a solution for a single inner tube, as disclosed in the prior art, but rather to propose a solution for a group or, respectively a set of inner tubes extending in parallel with one another in a continuous welding process that covers all the inner tubes of the set one after the other.

The object that forms the basis of the invention is achieved according to the production method by the following additional steps (iv) to (viii):

- (iv) Pressing the end face of the tube support plate against the end face of the inner tubes in the direction of the inner tube longitudinal axes of the inner tubes for the duration of the welding operations for all the inner tubes with a first form fit, which is effective both radially and axially and in each case in opposing directions, wherein the plate inner bore and a tube inner bore of the inner tube have inner diameters of equal size. The pressing prevents or, respectively minimizes undesired formations of gaps between the end faces of the inner tubes and the tube support plate, which can be caused by means of the thermal input during welding.

- (v) Immovably fixing the number n of inner tubes required in each case to one another as a whole according to the tube layout pattern by means of a second, detachable form fit of the auxiliary device.

The second form fit preferably dispenses with a force-fitting component, wherein said configuration also includes an optionally present central inner tube.

- (vi) Making a circumferential round weld orbitally, starting from the plate and the tube inner bore, in a single pass and continuously from radially inside to radially outside, wherein at least one axial form fit depth of the first form fit is covered by a weld width of the circumferential round weld.

The welding preferably takes place without additional material and in a protective gas atmosphere that is suitable for the materials to be connected. The axial form fit depth is matched to a weld width that results under the given welding and wall thickness conditions. The axial form fit depth may not exceed a possible weld width. A circumferential round weld is to be understood to mean a weld that is self-contained, i.e., without local interruptions.

- (vii) Welding the inner tubes to the tube support plate one after the other.

All the welded connections in this regard are made once the inner tubes have taken up the arrangement position which is immovably established by means of the auxiliary device.

- (viii) Detaching and removing the auxiliary device from the welded tube arrangement.

In order to minimize material stresses in the course of the whole of the welding process over all the welded connections, a welding sequence is provided such that, if present, initially an inner tube arranged centrally in the tube support plate and subsequently the external inner tubes arranged on a pitch circle around the central inner tube are welded to the tube support plate, in each case in the opposite order.

With regard to the device, the invention proceeds from an auxiliary device for a method for producing welded connections between inner tubes and tube support plates of a tube bundle for a product-to-product shell-and-tube heat exchanger, wherein the welded connection is designed in the manner known per se as follows:

- The inner tube, with its tube inner bore, is connected to an end face of the disk-shaped tube support plate that faces the inner tubes in a plane perpendicular to an inner tube longitudinal axis, which tube support plate comprises a plate inner bore.
- The tube inner bore and the plate inner bore have inner diameters of equal size and are oriented so as to be aligned with one another,
- In an unwelded starting position, the inner tube and the tube support plate are fixed to one another by means of a first form fit, which is effective both radially and axially and in each case in opposing directions.
- A circumferential round weld is made orbitally, starting from the tube inner bore, in a single pass and continuously from radially inside to radially outside,
- A weld width of the circumferential round weld covers at least one axial form fit depth of the first form fit.

The object that forms the basis of the invention is achieved with an auxiliary device according to the invention for the production method according to the invention by the following features:

- Within the framework of the auxiliary device, a first and a second holding ring half are provided, which form a closed ring.
- The holding ring halves touch in a parting plane that extends through a center of the auxiliary device, and the holding ring halves form a non-displaceable second form fit in the parting plane.
- The tube support plate establishes a tube layout pattern for the arrangement of inner tubes arranged in parallel with one another by defining more than one provided plate inner bore.
- The tube layout pattern is reproduced in the holding ring halves in such a way that inner tubes arranged so as to be evenly distributed around a single pitch circle are in each case enclosed at most by one half by the holding ring halves, wherein the opening of the relevant enclosing contour faces the center of the holding ring halves.
- These conditions are met by corresponding dimensioning of an inner diameter of the holding ring halves that are closed to form a ring, wherein the dimensioning depends on the number of the inner tubes located on the pitch circle.

- The parting plane additionally extends through at least one inner tube longitudinal axis lying on the pitch circle. As a result, it is guaranteed that the holding ring halves enclose all the inner tubes and can fix them as a whole and that, once all the inner tubes have been welded to the tube support plate, it is possible to detach and remove the holding ring halves from the welded tube arrangement.
- Holding means are provided, which engage displaceably in the holding ring halves in each case on the periphery of the holding ring halves and in a star shape oriented toward the center.
- The lateral surfaces of the holding means are in each case tangent on both sides to adjacent inner tubes arranged on the pitch circle.
- If necessary, the holding means fix an inner tube arranged in the center by means of their relevant end face facing the center and are in each case detachably fixed in this position themselves.

15 An auxiliary device according to the invention which is designed in accordance with the aforementioned features is suitable for receiving tube arrangements having at least two inner tubes in itself as intended.

20 It is sufficient if the second form fit fixes the first and the second holding ring half to one another in the radial direction. The fixing of the holding ring halves in the axial direction to one another expediently takes place in that, as provided, the first and the second holding ring half are detachably interconnected by means of a connection means, for example a connection screw, arranged on the periphery of the first and the second holding ring half, which are arranged diametrically to one another.

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If the auxiliary device is located in the closed position and it fixes an intended number of inner tubes in this position so that said inner tubes can be welded to the assigned tube support plate according to the production method according to the invention, then the holding means that fix the inner tubes in the second form fit are themselves in each case immovably fixed in the assigned holding ring half by means of a securing means, for example a securing screw.

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A particularly advantageous tube layout pattern is characterized in that seven inner tubes are provided, wherein one inner tube is located coaxially in the center of the auxiliary device and six inner tubes are arranged so as to be evenly distributed around the pitch circle, and in that the parting plane additionally extends through two diametrically
5 arranged inner tubes. In this arrangement, the inner tube longitudinal axes of three adjacent inner tubes in each case form the corners of an equilateral triangle, as a result of which the radial distance of all the adjacent inner tubes in each case is equal since, as a general rule, all the inner tubes have an outer diameter of equal size. Under these boundary conditions, the heat transfer and heat transition conditions are approximately
10 the same for all the inner tubes, if the special flow conditions of the central inner tube with respect to the other inner tubes located on the pitch circle are disregarded.

A shift of the circumferential round weld partially or fully into the tube support plate brings about a discontinuous progression of the connection cross-sections from the
15 relatively small connection cross-section of the inner tube to the solid cross-section of the tube support plate in the known manner. A progression of this kind is unfavorable in terms of strength.

It is possible to produce a tube bundle which consists of a plurality of inner tubes for a
20 product-to-product shell-and-tube heat exchanger according to the problem to be solved according to the invention by means of the method according to the invention for producing welded connections between inner tubes and tube support plates and the auxiliary device according to the invention, and the unfavorable cross-sectional progression mentioned above can also be prevented. This is achieved in that the welded
25 connection is designed as a circumferential round weld and the tube support plate, radially spaced apart on the outside of the circumferential round weld, comprises a circumferential, axially extending plate cut-out in the shape of an annular gap and designed such that the wall thickness of the tube support plate to be welded to the circumferential round weld assumes a value that is between one and two tube wall
30 thicknesses.

The present invention provides that the method for producing welded connections between inner tubes and tube support plates is carried out by means of an auxiliary device according to the invention with its proposed embodiments.

- 5 The production method according to the invention and the auxiliary device according to the invention are based on the welded connection according to the invention between inner tubes and tube support plates of the tube bundle for a product-to-product shell-and-tube heat exchanger. Said welded connection guarantees that the circumferential annular gap mentioned above and that is problematic from a hygienic and sanitary point of view
10 between the outer diameter of the inner tube and the inner diameter of the assigned plate inner bore is prevented.

Furthermore, the present invention has set itself the aim of optimizing the tube bundle according to the invention produced by means of the welded connection according to the
15 invention within the framework of a further configuration. Said configuration is basically characterized in that

- the inner tube, with its tube inner bore, is connected to an end face of the disk-shaped tube support plate that faces the inner tubes in a plane perpendicular to an inner tube longitudinal axis, which tube support plate comprises a plate inner bore,
- 20 • the tube inner bore and the plate inner bore have inner diameters of equal size and are oriented so as to be aligned with one another,
- in an unwelded starting position, the inner tube and the tube support plate are fixed to one another by means of a first form fit, which is effective both radially and axially and in each case in opposing directions,
- 25 • a circumferential round weld is made orbitally, starting from the plate and the tube inner bore, in a single pass and continuously from radially inside to radially outside,
- a weld width of the circumferential round weld covers at least one axial form fit depth of the first form fit, and
- the circumferential round weld is positioned such that the weld width engages in the
30 tube support plate at most by the form fit depth, when viewed from the side of the inner tube.

If the circumferential round weld is positioned such that the weld width engages in the tube support plate at most by the form fit depth, when viewed from the side of the inner tube, the tube support plate merely has to be countersunk or, respectively drilled out to the outer diameter of the inner tube and at most to the form fit depth. Thanks to this quantitative configuration, it is guaranteed that a gap no longer exists between the outer diameter of the inner tube and the inner bore in the tube support plate that is not spanned by the circumferential round weld. Countersinking to less than the form fit depth shifts a part of the width of the circumferential round weld into a tube region upstream of the tube support plate.

Another known proposal likewise provides a remedy as regards the unfavorable cross-sectional progression and in particular improves the strength properties under changing mechanical and/or thermal loads. Said proposal provides that the circumferential round weld, based on the tube support plate, is positioned by an upstream axial form fit distance of the first form fit from the tube support plate, wherein a neck is formed in the tube support plate in this region to a wall thickness between one and two tube wall thicknesses.

Furthermore, the present invention allows the production of a product-to-product shell-and-tube heat exchanger comprising at least one tube bundle, which is in each case welded according to one of its proposed configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

A more detailed representation of the invention is set out in the following description and the appended figures of the drawing as well as in the claims. The invention can be realized in a wide variety of configurations of a production method of the generic type. Furthermore, the invention is achieved in a wide variety of embodiments of an auxiliary device according to the invention for the production method according to the invention. A tube bundle for a product-to-product shell-and-tube heat exchanger, welded using the method for producing welded connections between inner tubes and tube support plates by means of the auxiliary device, as well as a product-to-product heat exchanger comprising at least one tube bundle, are likewise the subject-matter of the invention. The

production method, the auxiliary device, the tube bundle as well as the product-to-product heat exchanger are described below with reference to a preferred exemplary embodiment with regard to the drawing, wherein:

- 5 **Fig. 1** shows a schematic and perspective representation of a shell-and-tube heat exchanger according to the prior art;
- Fig. 2a** shows a perspective representation of a tube bundle according to the prior art having a number of inner tubes and in a view onto an end face (front side) of the tube support plate facing away from the inner tubes and an end
- 10 face (back side) of the tube support plate facing the inner tubes;
- Fig. 2b** shows a perspective representation of the tube bundle according to **Fig. 2a** from the reverse viewing direction to **Fig. 2a**;
- Fig. 3** shows a meridian section through a tube bundle according to **Figs. 2a, 2b** according to the prior art, embedded in a housing for supplying and
- 15 evacuating a heat transfer medium;
- Fig. 4** shows a meridian section through a first welded connection between an inner tube and a tube support plate in conjunction with a welding tool according to the prior art;
- Fig. 4a** shows an enlarged representation of a second configuration according to
- 20 the prior art that is an alternative configuration to the configuration of the first welded connection according to **Fig. 4**;
- Fig. 4b** shows an enlarged representation of a third configuration according to the prior art that is an alternative configuration to the configuration of the first welded connection according to **Fig. 4**;
- 25 **Fig. 5** shows a meridian section through a welded connection according to the invention between an inner tube and a tube support plate in conjunction with a welding tool in the form of a fourth configuration according to the invention;
- Fig. 6** shows a meridian section through a fifth configuration according to the
- 30 prior art that is an alternative configuration to the configuration of the first welded connection according to **Fig. 4**;

Fig. 7 shows a perspective representation of a tube support plate designed according to the invention for seven inner tubes;

Fig. 7a shows a perspective representation in meridian section through the tube support plate along a section line identified by “C-C” in **Fig. 7**;

5 **Fig. 7b** shows a view in meridian section of the tube support plate according to **Fig. 7a**;

Fig. 8 shows a perspective representation in an overall view of a closed auxiliary device without inner tubes according to the invention;

Fig. 9 shows a perspective representation in an overall view of the closed auxiliary device according to **Fig. 8** with inner tubes fixed therein; and

10 **Fig. 10** shows a view of the closed auxiliary device according to **Fig. 9** in a viewing direction identified by “G” in **Fig. 9**.

Fig. 1 shows an exemplary embodiment of a shell-and-tube heat exchanger 100 according to the prior art, in which, as a general rule, a plurality of tube bundles 10 having connection bends 5 are fluidically connected in series. The tube bundle 10 according to the prior art consists of a set of multiple inner tubes 16 (see **Figs. 2a, 2b**) that extend in parallel with one another and are also fluidically connected in parallel, that each penetrate a relevant plate inner bore 17 in a first and a second tube support plate 12, 14 at their ends (**Fig. 3**), that are supported there and that are welded to the tube support plate circumferentially on their tube outer diameter of the tube end on the end face (front side) of the tube support plate 12, 14 that faces the inner tubes 16. Each set of inner tubes 16 is arranged in an outer tube or, respectively shell tube 15 (**Figs. 1, 3**). A product, for example a food product, is conducted through the inner tubes 16, and a so-called heat transfer medium, for example water or steam, flows around the outside of the inner tubes 16 within the outer tube 15. Furthermore, **Figs. 2a, 2b** each show an annular gap S that is formed between an outer diameter of each inner tube 16 and the respectively assigned plate inner bore 17 within the tube support plate 12, 14 (**Fig. 3**).

30 The tube bundle 10 known from the prior art (**Fig. 3** - only the components that are relevant here are designated; see also **DE 94 03 913 U1**) consists, in its central part which is shown with an interruption, of the outer tube 15 (or, respectively outer shell) that

delimits an outer channel 15* and that comprises, based on the position in the representation, an outer shell flange (not designated) arranged on the left-hand side at the fixed bearing and an outer shell flange (not designated) arranged on the right-hand side at the floating bearing. A first housing comprising a second inlet 22 adjoins said outer shell flange at the floating bearing and a second housing comprising a second outlet 24 adjoins the outer shell flange at the fixed bearing. A number n of inner tubes 16 that extend axially parallel to the outer tube 15 through the outer channel 15* together form an inner channel 16* supported at the ends in each case in the left-hand tube support plate 12, which is part of a fixed bearing, and the right-hand tube support plate 14, which is part of a floating bearing. Said inner tubes 16 are welded to the end face of the respectively assigned tube support plate 12, 14 that faces the inner tubes 16 on their tube outer diameter via a circumferential weld SN. This overall arrangement is introduced into the outer tube 15 via an opening (not designated in greater detail) on the second housing and is clamped together with the second housing via a fixed-bearing exchanger flange that receives a first inlet 18, with the interposition of a seal in each case. The inner tube 16, the inner tube longitudinal axis of which is designated by R, comprises a tube inner bore 16a having an inner diameter D. The tube support plates 12, 14 at the fixed bearing and at the floating bearing each have a plate rotational axis A that are arranged coaxially with one another and that, in turn, extend coaxially with the inner tube longitudinal axis R of a central inner tube 16. The tube support plate 14 at the floating bearing is connected to a connection nozzle at the floating bearing that receives a first outlet 20.

Depending on the arrangement of the relevant tube bundle 10 in the shell-and-tube heat exchanger 100 and its relevant circuitry, the inner tubes 16 can, based on the position in the representation, be flowed through by a first product P1 which is to be heat-treated via the first inlet 18 either from left to right to the first outlet 20 or vice versa. In the case of the respectively adjacent tube bundle 10, which is connected in series with the tube bundle 10 described above in each case via the connection bend 5, these inlet and outlet relationships are in each case reversed accordingly.

The outer channel 15* can be supplied with a heat transfer medium such as water or steam. In the case of so-called product-to-product heat exchange, the heat transfer

medium is a second product P2. The flow through the outer channel 15* can take place from the second inlet 22 to the second outlet 24 or vice versa. Depending on the orientation of the flow guidance in the inner tubes 16 and in the inner channel 15*, heat exchange then takes place in a flow in the same or in the opposite direction.

- 5 In the case of product-to-product heat exchange, the annular gap S which has already been mentioned in connection with **Figs. 2a, 2b** is problematic with regard to cleaning, because the second product P2, which can penetrate here during the product run, can only be cleaned off completely by means of CIP in excessive doses or, in particularly difficult conditions, cannot be cleaned off in this way to a sufficient extent before the next product
- 10 run.

Welded connections

- The annular gap S disclosed in **Figs. 2a, 2b** and **3** is eliminated if the welded connection is designed between the inner tube 16 and the tube support plate 12, 14, as shown on the
- 15 basis of a first welded connection in **Fig. 4** and known per se. The first welded connection is characterized in that the inner tube 16, with its tube inner bore 16a, is connected to an end face of the disk-shaped tube support plate 12, 14 that faces the inner tube 16 in a plane perpendicular to the inner tube longitudinal axis R, which tube support plate comprises the plate inner bore 17. The tube inner bore 16a and the plate inner bore 17
- 20 preferably have inner diameters D of equal size and are oriented so as to be aligned with one another. Based on the tube support plate 12, 14, a circumferential round weld 36 is positioned at a distance from the tube support plate 12, 14 by an upstream axial form fit distance B2 of a first form fit F1, wherein a neck is formed in the tube support plate 12, 14 in this region up to a tube wall thickness d.

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- In an unwelded starting position, the inner tube 16 and the tube support plate 12, 14 are fixed to one another by means of the first form fit F1, which is effective both radially and axially and in each case in opposing directions. To this end, the tubular neck of the tube support plate 12, 14 comprises a plate inner recess 26 that is oriented coaxially with the
- 30 inner tube longitudinal axis R, that has an axial form fit depth B1 in the axial direction, and that engages coaxially around the outside of a tube outer recess 32 that has the same form fit depth B1.

A welding tool 40 is introduced into the plate inner bore 17 up to the planned location of the weld 36 in the direction of the inner tube longitudinal axis R. The welding tool 40 makes the circumferential round weld 36 with an orbital movement U by means of a welding electrode 42 that is oriented perpendicularly to the plate and tube inner bore 17, 16a, and preferably makes said weld in a single pass and continuously from radially inside to radially outside. A weld width b of the circumferential round weld 36 is set up such that it covers at least the axial form fit depth B1 of the first form fit F1.

10 In the course of the individual welding operation and throughout the entire welding sequence of all the welding operations for a set of inner tubes 16 which are to be welded to the assigned tube support plate 12, 14, the inner tubes 16 and the tube support plate 12, 14 are pressed against one another by means of a pressing force PR.

15 The inner tube 16 deployed with the inner diameter D, the tube wall thickness d, as well as an inner tube length L is, as a general rule, a slim, thin-walled inner tube 16 that is to be welded to the tube support plate 12, 14 which is, as a general rule, solid and which has a plate wall thickness B. The specific respective quantitative dimensions depend on the size of the tube bundle 10 and on the heat transfer capacity thereof and can therefore only
20 be indicated approximately in a general consideration by the following dimension ratios:

$$D/d > 10; L/D > 100 \text{ and } B/d > 10.$$

Fig. 4a shows a second welded connection according to the prior art between the inner tube 16 having the inner bore 16a and the tube support plate 12, 14 having the plate inner bore 17 of equal diameter. In an unwelded starting position, the inner tube 16 having the tube wall thickness d and the tube support plate 12, 14 are fixed to one another by means of the first form fit F1, which is effective both radially and axially and in each case in opposing directions. To this end, the tubular neck of the tube support plate 12, 14 with its upstream axial form fit distance B2 comprises a plate outer recess 28 that is oriented
25 coaxially with the inner tube longitudinal axis R, that has a recess wall thickness a, that has the axial form fit depth B1 in the axial direction, and that engages coaxially in a tube inner recess 30 that has the same form fit depth B1.

A third welded connection according to the prior art between the inner tube 16 having the tube inner bore 16a and the tube support plate 12, 14 having the plate inner bore 17 of equal diameter is depicted in **Fig. 4b**. Here, in order to realize the first form fit F1, the plate inner recess 26, which engages coaxially around the outside of the full tube wall thickness d with the axial form fit depth B1, is only located in the neck of the tube support plate 12, 14, wherein the radial dimension of the wall thickness of the neck, which extends over the upstream axial form fit distance B2, exceeds the tube wall thickness d by the recess wall thickness a .

Furthermore, the first to third welded connections of **Figs. 4, 4a** and **4b** are each characterized in that the circumferential round weld 36, based on the tube support plate 12, 14, is positioned at a distance from the tube support plate 12, 14 by the upstream axial form fit distance of the first form fit F1, wherein a neck is formed in the tube support plate 12, 14 in this region to a wall thickness of between one and two tube wall thicknesses d .

In a fourth welded connection according to the invention (**Fig. 5**) and in a fifth welded connection according to the prior art (**Fig. 6**), the inner tube 16, the tube inner bore 16a of which comprises the same inner diameter D as the plate inner bore 17 in the tube support plate 12, 14, engages with the full tube wall thickness d and with the axial form fit depth B1 directly into the end face of the tube support plate 12, 14 in order to realize the first form fit F1.

In the case of the embodiment according to **Fig. 6**, the axial form fit depth B1 of the plate inner recess 26 is maximal and indeed dimensioned such that the required weld width b completely covers the axial form fit depth B1 and, consequently, completely engages in the tube support plate 12, 13, when viewed from the side of the inner tube 16. This situation arises in that the circumferential round weld 36 is positioned such that the weld width b engages in the tube support plate 12, 14 at most by the axial form fit depth, when viewed from the side of the inner tube 16.

In the case of the embodiment according to the invention according to **Fig. 5**, the axial form fit depth B1 of the plate inner recess 26 is dimensioned such that only part of the necessary weld width b of the circumferential round weld 36 is within the tube support plate 12, 14 and the other part covers a portion of the externally exposed inner tube 16.

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Furthermore, in order to prevent a discontinuous, and in the present case abruptly changing cross-sectional progression of the wall thicknesses to be welded, the fourth welded connection according to the invention according to **Fig. 5** is modified with respect to the fifth welded connection according to the prior art according to **Fig. 6** in that the tube support plate 12, 14, radially spaced apart on the outside of the circumferential round weld 36, comprises a circumferential, axially extending plate cut-out 34 in the shape of an annular gap. In terms of its radial distance from the weld 36 and its radial width, said cut-out is designed such that the wall thickness of the tube support plate 12, 14 to be welded to the circumferential round weld 36 assumes a value that is between one and two tube wall thicknesses d (see also **Figs. 7a, 7b**).

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Method

The first to fifth configurations of the welded connections described in **Figs. 4, 4a, 4b, 5** and **6** are realized according to the object with a production method according to the invention by means of an auxiliary device 50 according to the invention (**Figs. 8, 9** and **10**). The production method proceeds from the fact that the tube support plate 12, 14 establishes a tube layout pattern M (**Fig. 7**) for the arrangement of assigned inner tubes 16 arranged in parallel with one another by defining more than one plate inner bore 17. The relevant plate rotational axis A of the tube support plate 12, 14 does not necessarily have to be occupied by an inner tube 16. The limiting restriction for a number n of inner tubes 16 is given when a single possible pitch circle T (**Fig. 10**; a multiple pitch circle arrangement cannot be realized with the proposed auxiliary device 50) can no longer receive the inner tubes 16 to be arranged thereon under the required heat transfer conditions (required distances of the inner tubes 16 from one another).

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The auxiliary device 50 immovably fixes the number n of inner tubes 16 required in each case to one another as a whole according to the tube layout pattern M and in the relevant

first form fit F1 with the tube support plate 12, 14 by means of a second form fit F2 (**Figs. 9, 10**). For the duration of the welding operations for all the inner tubes 16, the tube support plate 12, 14 is pressed against the inner tubes 16 by means of the pressing force PR in the direction of the inner tube longitudinal axes R (**Fig. 9**; tube support plate 12, 14 is not depicted) and the inner tubes 16 are welded one after the other to the tube support plate 12, 14.

With regard to this, an advantageous welding sequence provides that, if present, initially the central inner tube 16 and subsequently the external inner tubes 16 arranged on the pitch circle T around the central inner tube 16 are welded to the tube support plate 12, 14, in each case in the opposite order.

Auxiliary device

The auxiliary device 50 (**Figs. 8, 9, 10**) according to the invention makes possible a welded connection which is designed as follows:

- The inner tube 16, with its tube inner bore 16a, is connected to an end face of the disk-shaped tube support plate 12, 14 that faces the inner tubes 16 in a plane perpendicular to the inner tube longitudinal axis R, which tube support plate comprises a plate inner bore 17.
- The tube inner bore 16a and the plate inner bore 17 have inner diameters D of equal size and are oriented so as to be aligned with one another.
- In an unwelded starting position, the inner tube 16 and the tube support plate 12, 14 are fixed to one another by means of the first form fit F1, which is effective both radially and axially and in each case in opposing directions.
- The circumferential round weld 36 is made orbitally, starting from the plate and the tube inner bore 17, 16a, in a single pass and continuously from radially inside to radially outside.
- The weld width b of the circumferential round weld 36 covers at least the axial form fit depth B1 of the first form fit F1.

The auxiliary device 50 consists of a first and a second holding ring half 50.1, 50.2 which form a closed ring after being joined to one another. The holding ring halves 50.1, 50.2 touch in a parting plane E that extends through a center Z of the auxiliary device 50, and the holding ring halves 50.1, 50.2 form the non-displaceable second form fit F2 in this parting plane E via a parting plane contour 50.1a and a parting plane counter-contour 50.2a (**Figs. 8, 10**).

The second form fit F2 preferably fixes the first and the second holding ring half 50.1, 50.2 to one another in the radial direction. The first and the second holding ring half 50.1, 50.2 are, moreover, advantageously detachably interconnected by means of a connection means 56, for example a connection screw, arranged on the periphery of the first and the second holding ring half 50.1, 50.2, which are arranged diametrically to one another. As a result, the radially oriented second form fit F2 is additionally fixed and an axial displacement of the holding ring halves 50.1, 50.2 with respect to one another is prevented.

The tube support plate 12, 14 establishes the tube layout pattern M for the arrangement of inner tubes 16 arranged in parallel with one another (**Figs. 7, 7a, 7b**) by defining more than one provided plate inner bore 17. The tube layout pattern M is reproduced in the holding ring halves 50.1, 50.2 in such a way that inner tubes 16 arranged so as to preferably be evenly distributed around a single pitch circle T are in each case enclosed at most by one half by the holding ring halves 50.1, 50.2 (**Fig. 10**), wherein the opening of the relevant enclosing contour faces the center Z of the auxiliary device 50. The parting plane E additionally extends through at least one inner tube longitudinal axis R of an inner tube 16 lying on the pitch circle T. Holding means 52, for example preferably cylindrical holding bolts, are provided, which engage displaceably in the holding ring halves 50.1, 50.2 in the direction of the holding ring longitudinal axis r in each case on the periphery of the holding ring halves 50.1, 50.2 and with a holding means longitudinal axis r in a star shape oriented towards the center Z. The lateral surfaces of the holding means 52 are in each case tangent on both sides to adjacent inner tubes 16 arranged on the pitch circle T. Furthermore, if necessary, the holding means 52 fix an inner tube 16 arranged in the center Z by means of their relevant end face facing the center Z and are in each case detachably

fixed in this position themselves (**Fig. 10**). The holding means 52 are in each case preferably immovably fixed in the assigned holding ring half 50.1, 50.2 by means of a securing means 54, preferably by means of a securing screw.

- 5 In the exemplary embodiment of a particularly advantageous tube layout according to **Figs. 7, 7a, 7b**, seven plate inner bores 17 are provided, wherein one plate inner bore 17 is located coaxially with the plate rotational axis A of the tube support plate 12, 14 and six plate inner bores 17 are arranged so as to be evenly distributed around the pitch circle T (**Figs. 8, 9, 10**). In this case, the parting plane E additionally extends through two
10 diametrically arranged inner tubes 16 or, respectively plate inner bores 17 (**Fig. 10**).

The fixing of the inner tubes 16 in the auxiliary device 50 by means of holding means 52 can also take place in another manner to that described above, for example by means of displaceable and securable molded parts that can be inserted in the axial direction from
15 the side of the auxiliary device 50 facing away from the tube support plate 12, 14 into an annular, detachably separable auxiliary device 50 between the inner tubes 16 and immovably fix the inner tubes 16 to one another. Any configuration of the auxiliary device 50 that immovably fixes the set of inner tubes 16 to one another during the welding sequence by means of the second form fit F2 and adjusts the inner tubes 16 as a whole in
20 the first form fit F1 with respect to the tube support plate 12, 14 and presses said inner tubes against the tube support plate by means of the pressing force PR makes it possible to carry out the method according to the invention for producing welded connections between inner tubes 16 and tube support plates 12, 14 of a tube bundle 10 for a product-to-product shell-and-tube heat exchanger 100.

25

Tube bundle

The present invention furthermore claims a tube bundle 10 for a product-to-product shell-and-tube heat exchanger 100, as it is known in its basic construction in the prior art and depicted by way of example in **Fig. 3** in conjunction with **Figs. 2a, 2b**. In contrast to this
30 known embodiment, the problematic annular gap S is prevented in that the tube bundle 10 is welded in this region using a method for producing welded connections between inner tubes 16 and tube support plates 12, 14 according to Claim 1 or 2, wherein the welded connection is designed as a circumferential round weld 36 and the tube support

plate 12, 14, radially spaced apart on the outside of the circumferential round weld 36, comprises a circumferential, axially extending plate cut-out 34 in the shape of an annular gap. The cut-out 34 is designed such that the wall thickness of the tube support plate 12, 14 to be welded to the circumferential round weld 36 assumes a value that is between one
 5 and two tube wall thicknesses d .

Furthermore, the present invention claims a tube bundle 10 for a product-to-product shell-and-tube heat exchanger 100, as it is known in its basic construction in the prior art and depicted by way of example in **Fig. 3** in conjunction with **Figs. 2a, 2b**. In contrast to this
 10 known embodiment, the problematic annular gap S is prevented in that the tube bundle 10 is carried out in this region with the method for producing welded connections between inner tubes 16 and tube support plates 12, 14 by means of an auxiliary device 50 according to any one of Claims 3 to 7.

15 The tube bundle 10 welded using the method for producing welded connections between inner tubes 16 and tube support plates 12, 14 according to Claim 8 and by means of the auxiliary device 50 according to Claim 9 comprises a welded connection which is designed in such a way

- that the inner tube 16, with its tube inner bore 16a, is connected to an end face of the
 20 disk-shaped tube support plate 12, 14 that faces the inner tubes 16 in a plane perpendicular to an inner tube longitudinal axis R , which tube support plate comprises a plate inner bore 17,
- that the tube inner bore 16a and the plate inner bore 17 have inner diameters D of equal size and are oriented so as to be aligned with one another,
- 25 • that in an unwelded starting position, the inner tube 16 and the tube support plate 12, 14 are fixed to one another by means of a first form fit $F1$, which is effective both radially and axially and in each case in opposing directions,
- that a circumferential round weld 36 is made orbitally, starting from the plate and the tube inner bore 17, 16a, in a single pass and continuously from radially inside to
 30 radially outside,
- that a weld width b of the circumferential round weld 36 covers at least one axial form fit depth $B1$ of the first form fit $F1$, and

- that the circumferential round weld 36 is positioned such that the weld width b engages in the tube support plate 12, 14 at most by the axial form fit depth $B1$, viewed from the side of the inner tube 16.

5 Furthermore, the present invention claims a product-to-product shell-and-tube heat exchanger having at least one tube bundle 10, as it is known in its basic construction in the prior art and depicted by way of example in **Fig. 3** in conjunction with **Figs. 2a, 2b**. In contrast to this known design, the problematic annular gap S is prevented in that the tube bundle 10 is configured in this region according to any one of Claims 8 to 10.

LIST OF REFERENCE NUMERALS OF THE ABBREVIATIONS USED

	100	Shell-and-tube heat exchanger
	5	Connection bend
5	10	Tube bundle
	12	First tube support plate
	14	Second tube support plate
	15	Outer tube (shell tube)
10	15*	Outer channel
	16	Inner tube
	16a	Tube inner bore
	16*	Inner channel
15		
	17	Plate inner bore
	18	First inlet
	20	First outlet
	22	Second inlet
20	24	Second outlet
	26	Plate inner recess
	28	Plate outer recess
	30	Tube inner recess
	32	Tube outer recess
25	34	Plate cut-out
	36	Circumferential round weld
	40	Welding tool
	42	Welding electrode
30		
	50	Auxiliary device
	50.1	First holding ring half

	50.1a	Parting plane contour
	50.2	Second holding ring half
	50.2a	Parting plane counter-contour
	52	Holding means (bolt)
5	54	Securing means (screw)
	56	Connection means (screw)
	A	Plate rotational axis
	B	Plate wall thickness
10	B1	Axial form fit depth
	B2	Upstream axial form fit distance
	D	Inner diameter
	E	Parting plane
	F1	First form fit
15	F2	Second form fit
	L	Inner tube length
	M	Tube layout pattern
	P1	First product
	P2	Second product
20	PR	Pressing force
	R	Inner tube longitudinal axis
	S	Annular gap
	SN	Weld
	T	Pitch circle
25	U	Orbital movement
	Z	Center
	a	Recess wall thickness
	b	Weld width
30	d	Tube wall thickness
	n	Number (inner tubes; inner bores)
	r	Holding means longitudinal axis

$D/d > 10$	Ratio of the tube inner diameter of the inner tube to the tube wall thickness
$L/D > 100$	Ratio of the inner tube length to the tube inner diameter of the inner tube
$B/d > 10$	Ratio of the plate wall thickness to the tube wall thickness

PATENTKRAV

1. Fremstillingsmåde for svejsede forbindelser mellem indre rør (16) og rørstøtteplader (12, 14) i et rørbundt (10) til en produkt-til-produkt shell-and-tube varmeveksler (100) ved hjælp af en hjælpeanordning (50), hvorved den respektive rørstøtteplade (12, 14) sammensvejses ved dens endeflade, som vender mod de indre rør (16), hvilken fremgangsmåde udføres med de følgende trin (I) til (III):

- 10 (I) orientering af de indre rør (16) i forhold til tilknyttede pladesidigt indre boringer (17), som er arrangeret i rørstøttepladen (12, 14) på en sådan måde, at de indre rør (16) og de pladesidigt indre boringer (17) flugter med hinanden;
- (II) fastgørelse af de respektive indre rør (16) og rørstøttepladen (12, 14)
- 15 til hinanden i en ikke-svejset udgangsposition ved hjælp af en formpasning, som er effektiv radialt og i modsatte retninger, hvorved mere end een pladesidigt indre boring (17) er defineret, og der derved fastlægges et rør-layoutmønster (M) ved hjælp af rørstøttepladen (12, 14) for tilordnede indre rør (16), som er arrangeret parallelt med
- 20 hinanden;
- (III) ikke-bevægelig fastgørelse af et respektivt nødvendigt antal (n) af indre rør (16), og som helt og holdent svarer til hinanden i rør-layoutmønsteret (M) og i respektiv formpasning til rørstøttepladen (12, 14) ved hjælp af hjælpeanordningen (50),

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kendetegnet ved de følgende yderligere trin IV til VIII:

- (IV) presning af rørstøttepladens (12, 14) endeflade mod de indre rørs (16) endeflade i retningen for de indre rørs (16) længdeakse (R) under
- 30 varigheden af svejseoperationerne for alle de indre rør (16) med en første formpasning (F1), som er effektiv både radialt og aksialt og i respektive modsatte retninger,

hvorved den pladesidigt indre boring (17) og en rørsidigt indre boring (16a)
 i det indre rør (16) har indvendig diameter (D) med samme størrelse,
 (V) ubevægelig fiksering af det respektive nødvendige antal (n) af indre
 rør (16) til hinanden som helhed svarende til rør-layoutmønsteret (M) ved
 5 hjælp af en anden løsbar formpasning (F2) af hjælpeanordningen (50),
 (VI) fremstilling af en rundtgående rundsvejsning (36) orbitalt, begyndende
 fra den pladesidige og den rørsidigt indre boring (17, 16a) i en enkelt
 arbejdsoperation og kontinuerligt fra radialt indre til radialt ydre, hvorved i
 det mindste en aksial formpasningsdybde (B1) i den første formpasning
 10 (F1) er dækket af en svejsesømbredde (b) for den rundtgående
 rundsvejsning (36),
 (VII) svejsning, successivt, af de indre rør (16) til rørstøttepladen (12, 14),
 og
 (VIII) løsgørelse og fjernelse af hjælpeanordningen (50) fra det svejsede
 15 rørarrangement.

2. Fremstillingsmåde ifølge krav 1,

kendetegnet ved, at

der er tilvejebragt en svejsesekvens, således at først et indre rør (16), der er
 20 arrangeret centralt i rørstøttepladen (12, 14), og dernæst de respektive ydre af
 de indre rør (16), der er arrangeret på en delkreds (T) rundt om det centrale
 inderrør (16), er svejset til rørstøttepladen (12, 14) i overfor liggende rækkefølge.

3. Hjælpeanordning (50) for en fremgangsmåde til fremstilling af svejsede
 25 forbindelser mellem indre rør (16) og rørstøtteplader (12, 14) i et rørbundt (16) til
 en produkt-til-produkt shell-and-tube varmeveksler (100), hvorved den svejsede
 forbindelse er udformet på en som sådan kendt måde, således at

- 30 • det indre rør (16), med dets i røret indre boring (16a), er forbundet til
 en endeflade på den skiveformede rørstøtteplade (12, 14), som vender
 mod det indre rør (16) i et plan vinkelret på en længdeakse (R) for et
 indre rør, hvilken rørstøtteplade omfatter en pladesidigt indre boring
 (17),

- rørets indre boring (16a) og pladens indre boring (17) har inderdiameter (D) af samme størrelse og er orienteret, så de flugter med hinanden,
- 5 i en ikke-svejset begyndelsesposition er det indre rør (16) og rørstøttepladen (12, 14) fikseret i forhold til hinanden ved hjælp af en første formpasning (F1), som både radiale og aksiale er effektive og i respektive modsatte retninger,
- en rundtgående rundsvejsning (36) er udført orbitalt, begyndende fra den indre boring (17, 16a) i pladen og røret, ved en enkelt arbejdsoperation og kontinuerligt fra radiale inderst til radiale yderst, og
- 10 • en svejse sømbredde (b) af den rundtgående rundsvejsning (36) dækker mindst en aksial formpasningsdybde (B1) af den første formpasning (F1),

15 kendetegnet ved, at

- der er tilvejebragt en første og en anden holderinghalvpart (50.1, 50.2), som danner en lukket ring,
- 20 • holderinghalvparterne (50.1, 50.2) berører hinanden i et skilleplan (E), der strækker sig gennem et centrum (Z) i hjælpeanordningen (50), og holderinghalvparterne (50.1, 50.2) med hinanden danner en ikke-forskydelig, anden formpasning (F2) i deleplanet (E),
- rørstøttepladen (12, 14) ved fastlæggelsen af mere end en pladesidigt indre boring (17) etablerer et rør-layoutmønster (M) til arrangementet af inderrør (16), der er arrangeret som indbyrdes parallelle,
- 25 • rør-layoutmønsteret (M) er afbildet i holderinghalvparterne (50.1, 50.2) på en sådan måde, at respektive indre rør (16), der er arrangeret som jævnt fordelt rundt om en enkelt delkreds (T), højst er indesluttet med halvdelen af holderinghalvparterne (50.1, 50.2), hvorved åbningen i
- 30 den respektive omsluttende kontur vender mod centret (Z) for holderinghalvparterne (50.1, 50.2),
- at skilleplanet (E) desuden strækker sig gennem mindst en længdeakse for det indre rør, og som ligger på delkredsen (T),

- der er tilvejebragt holdemidler (52), som forskydeligt griber ind i de respektive holderinghalvparter (50.1, 50.2) på periferien af holderinghalvparterne (50.1, 50.2) og i stjerneform er orienteret mod centrum (Z),
- 5 • de respektive holdemidler (52) tangerer tilgrænsende indre rør (16), som er arrangeret på delkredsen (T), og
- holdemidler (52) med deres respektive endeflade, som vender mod centret (Z), i givet fald fikserer et i centrum (Z) arrangeret indre rør (16) og i denne position selv i hvert tilfælde løsbart er fikseret i denne
- 10 position.

4. Hjælpeanordning (50) ifølge krav 3,

kendetegnet ved, at

- den anden formpasning (F2) fikserer den første og den anden holderinghalvpart
- 15 (50.1, 50.2) i radial retning i forhold til hinanden.

5. Hjælpeanordning (50) ifølge krav 3 eller 4,

kendetegnet ved, at

- de respektive holdemidler (52) ved hjælp af et fastgørelsesmiddel (54)
- 20 ubevægeligt er fikseret i den tilknyttede holderinghalvpart (50.1, 50.2).

6. Hjælpeanordning (50) ifølge et af kravene 3 til 5,

kendetegnet ved, at

- den første og den anden holderinghalvpart (50.1, 50.2) løsbart er forbundet til
- 25 hinanden ved hjælp af et forbindelsesmiddel (56), der er arrangeret på periferien af den første og den anden holderinghalvpart (50.1, 50.2), og som er arrangeret diametralt i forhold til hinanden.

7. Hjælpeanordning (50) ifølge et af kravene 3 til 6,

30 **kendetegnet ved, at**

- syv indre rør (16) er tilvejebragt, hvorved et indre rør (16) befinder sig koaksialt i centrum (Z), og seks indre rør (16) er arrangeret jævnt fordelt rundt langs delkredsen (T), og
- skilleplanet (E) ydermere strækker sig gennem to diametralt arrangerede indre rør (16).

5

8. Rørbundt (10) til en produkt-til-produkt shell-and-tube varmeveksler (100), omfattende indre rør (16) og rørstøtteplader (12, 14), hvilke dele er svejset ved anvendelse af en fremgangsmåde til fremstilling af svejsede forbindelser mellem indre rør (16) og rørstøtteplader (12, 14) ifølge krav 1 eller 2,

10

kendetegnet ved, at

den svejsede forbindelse er udført som en rundtgående rundsvejsning (36), og rørstøttepladen (12, 14), i en radial afstand på ydersiden af den rundtgående rundsvejsning (36), omfatter en rundtgående pladeudskæring (34), som strækker sig aksialt, med form som en ringformet spalte og udformet således, at vægtykkelsen af rørstøttepladen (12, 14), som svejses til den rundtgående rundsvejsning (36), antager en værdi, der ligger mellem en og to rørvægstykker (d).

15

20 9. Rørbundt (10) ifølge krav 8,

kendetegnet ved, at

fremgangsmåden til fremstilling af svejsede forbindelser mellem indre rør (16) og rørstøtteplader (12, 14) kan udføres ved hjælp af en hjælpeanordning (50) ifølge et af kravene 3 til 7.

25

10. Rørbundt ifølge krav 8 eller 9, med indre rør (16) og rørstøtteplader (12, 14) og med den svejsede forbindelse mellem de indre rør (16) og rørstøttepladerne (12, 14), hvorved den svejsede forbindelse er udført således, at

30

- det indre rør (16), med dets i røret indre boring (16a) er forbundet til en endeflade på den skiveformede rørstøtteplade (12, 14), som vender mod de indre rør (16) i et plan vinkelret på en længdeakse (R) for et

indre rør, hvilken rørstøtteplade omfatter en pladesidigt indre boring (17),

- 5 • rørets indre boring (16a) og pladens indre boring (17) har indre diametre (D) af samme størrelse og er orienteret, så de flugter med hinanden,
- i en ikke-svejset begyndelsesposition er det indre rør (16) og rørstøttepladen (12, 14) fikseret i forhold til hinanden ved hjælp af en første formpasning (F1), som både radialt og aksialt er effektiv og i respektive modsatte retninger,
- 10 • en rundtgående rundsvejsning (36) er udført orbitalt, begyndende fra den indre boring (17, 16a) i pladen og røret, ved en enkelt arbejdsoperation og kontinuerligt fra radialt inderst til radialt yderst, og
- en svejsesømbredde (b) af den rundtgående rundsvejsning (36) dækker mindst en aksial formpasningsdybde (B1) af den første
- 15 formpasning (F1), og
- den rundtgående rundsvejsning (36) er positioneret således, at svejsesømbredden (b) maksimalt griber ind i rørstøttepladen (12, 14) med den aksiale formpasningsdybde (B1), set fra siden af det indre rør (16).

20

11. Produkt-til-produkt, shell-and-tube varmeveksler (100) med mindst eet rørbundt (10) ifølge et af kravene 8 til 10.

Fig. 1
(Prior art)

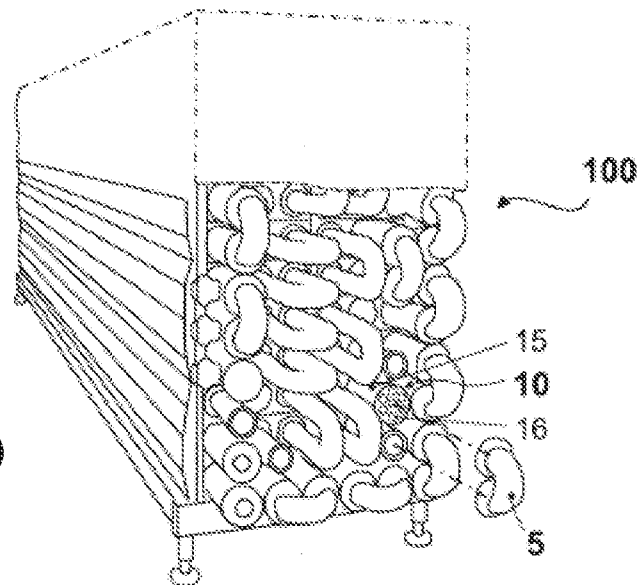


Fig. 2a

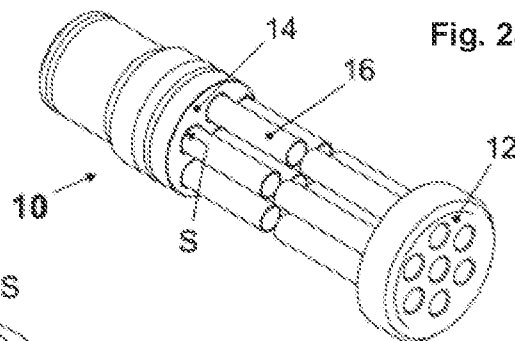
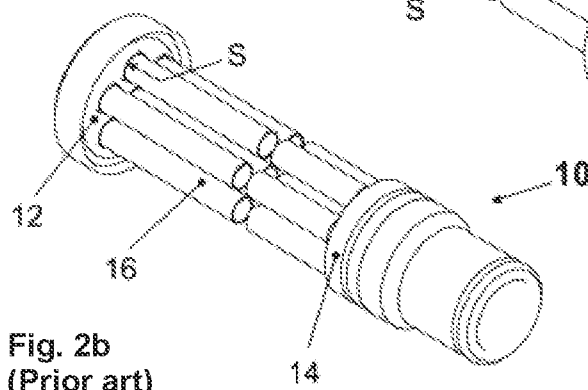


Fig. 2b
(Prior art)



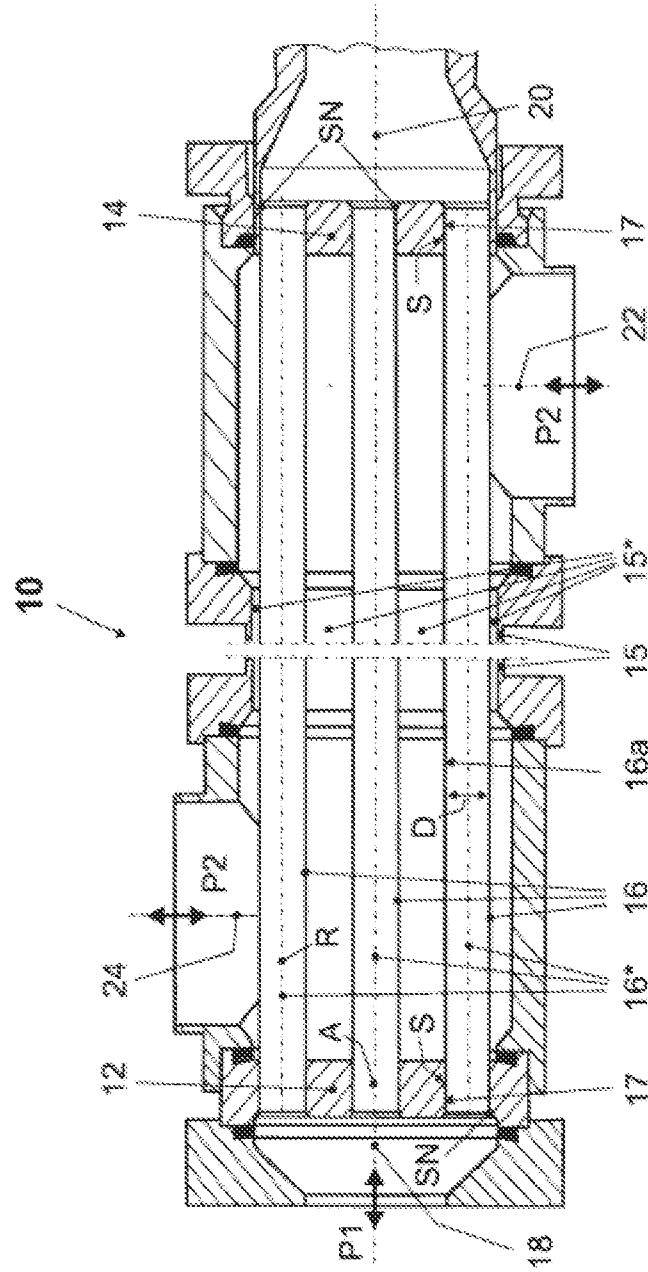


Fig. 3
(Prior art)

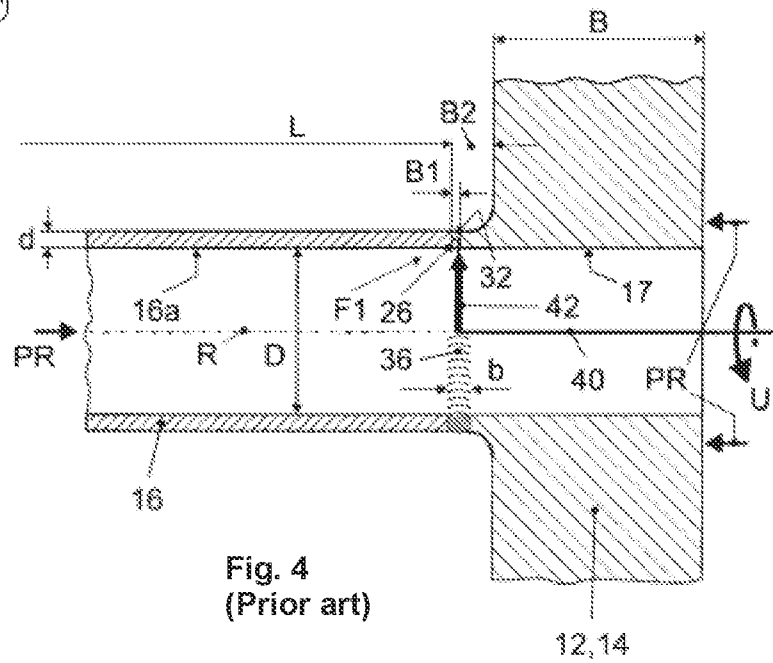


Fig. 4
(Prior art)

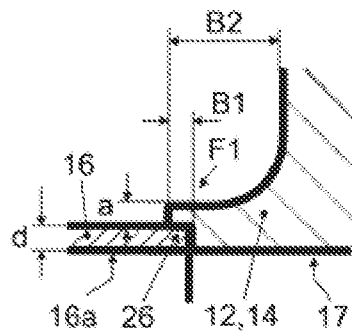


Fig. 4b
(Prior art)

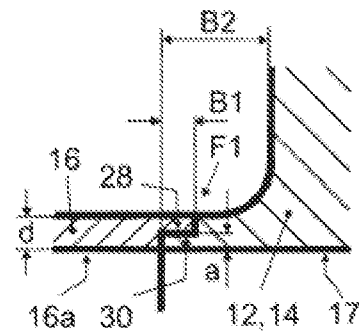


Fig. 4a
(Prior art)

