



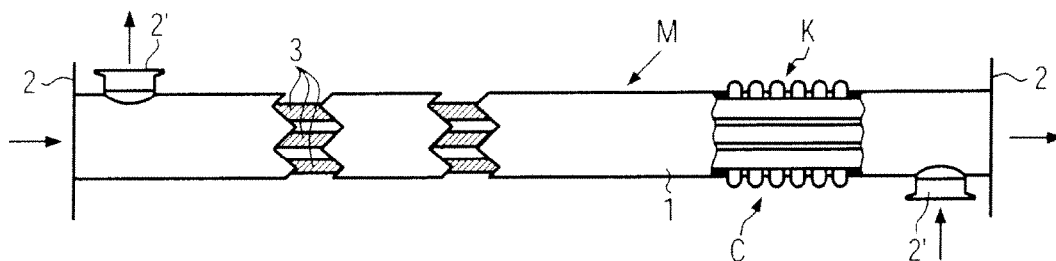
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(19) **United States**(12) **Patent Application Publication**  
**Zacharias**(10) **Pub. No.: US 2011/0056653 A1**(43) **Pub. Date: Mar. 10, 2011**(54) **SHELL-AND-TUBE HEAT EXCHANGER**(52) **U.S. Cl. .... 165/83; 165/158**(75) **Inventor: Jörg Zacharias, Kofering (DE)**(73) **Assignee: KRONES AG, Neutraubling (DE)**(21) **Appl. No.: 12/875,341**(22) **Filed: Sep. 3, 2010**(30) **Foreign Application Priority Data**

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**F28D 1/053** (2006.01)  
**F28F 7/00** (2006.01)(57) **ABSTRACT**

A shell-and-tube heat exchanger including a casing tube and at least one inner tube for treating liquid food products, optionally also with a product/product flow guidance, and having at least one thermal-expansion compensating device for the casing and/or inner tube, with the compensating device having a surface which can be contacted by the product to be treated, where the surface is provided on a bellows integrated into the casing and/or inner tube, with a plurality of relatively wide folds which extend around the tube axis and are of rounded cross-section, with the respective fold being configured with a radial depth and an axial width with a ratio of B:T of about 1 or more and to be cleanable on the product side in a hygienically irreproachable way.



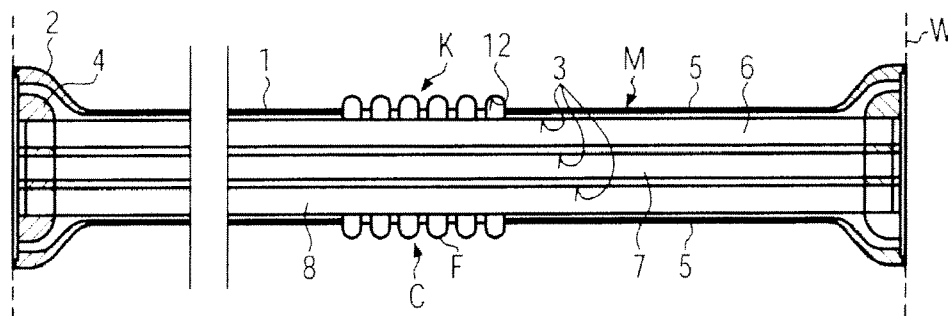


FIG. 1

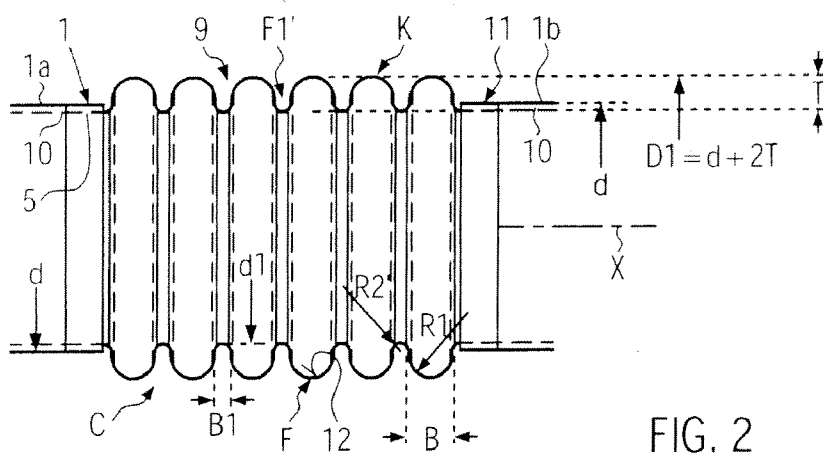


FIG. 2

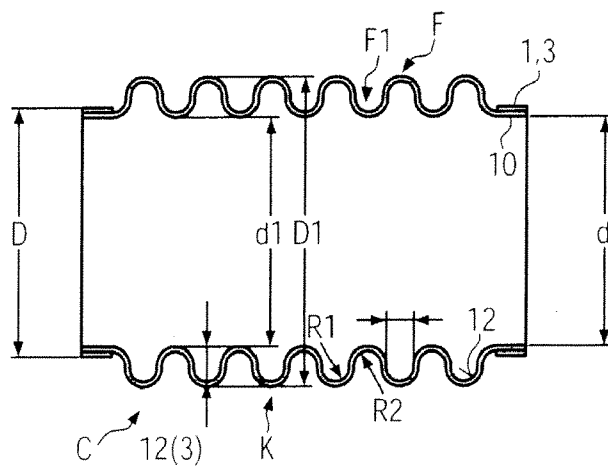


FIG. 3

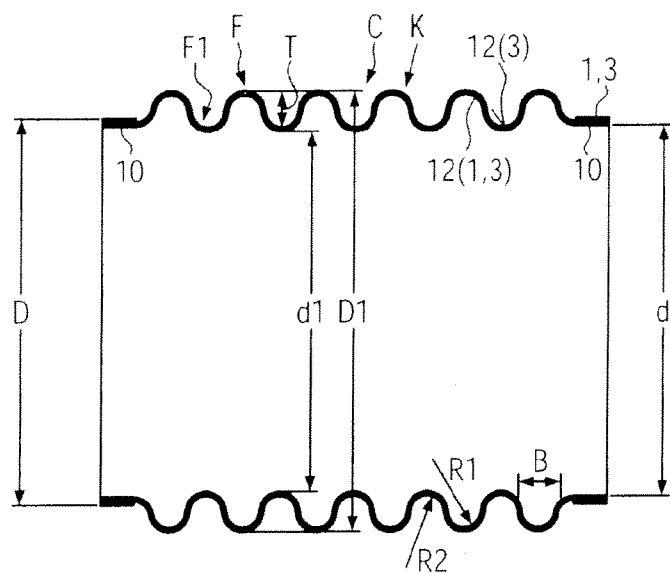


FIG. 4

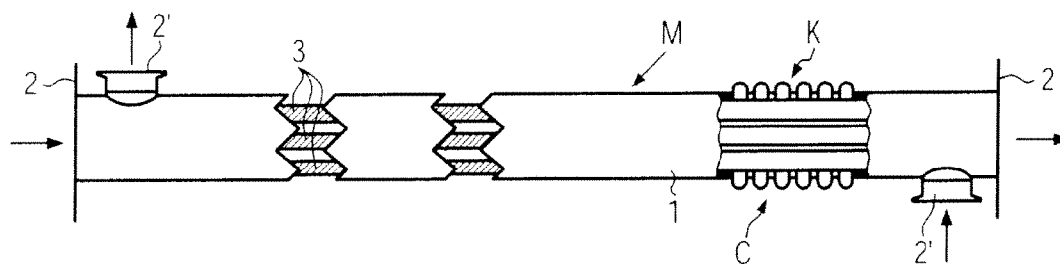


FIG. 5

## SHELL-AND-TUBE HEAT EXCHANGER

### CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of priority of German Application No. 102009040560.7, filed Sep. 8, 2009. The entire text of the priority application is incorporated herein by reference in its entirety.

### FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to a shell-and-tube heat exchanger of the type used for treating liquid foods.

### BACKGROUND

[0003] Shell-and-tube heat exchangers e.g. for product/product flow guidance are known from DE 600 19 635 T2 and DE 102 56 232 B4. The heat-expansion compensating device is here a slide connection with seals or a floating or moveable bearing permitting thermally caused relative movements, but creating dead spaces in which the product can settle in such a way that despite intensive cleaning it cannot be removed any more, or requires a dismantling operation for hygienically irreproachable cleaning. Under hygienic aspects such compensating devices are not recommended by the authorities in charge, but have so far been common as a compromise solution for the product/product flow guidance.

[0004] By contrast, in shell-and-tube heat exchangers in the food industry, in which flow guidance of product/heat carrier medium (e.g. water) takes place, it is known that at least one bellows is installed as a thermal-expansion compensating device in such a way that it is exclusively contacted by the heat-carrier medium, but definitely not by the product. After specific periods of use of the shell-and-tube heat exchanger, or during product change, the bellows will not be cleaned because it has only been in contact with the heat carrier medium at any rate. The bellows is deliberately configured with a ratio of B:T of very much less than 1, optionally with straight flanks and very small radii of curvatures between the flanks, because it is in this way that the compensatory action per fold is strong and the number of folds that is needed is thus as small as possible. On account of the ratio of B:T of very much less than 1, which is of advantage to compensation, this bellows could no longer be cleaned to obtain a hygienically irreproachable condition because inevitably firmly sticking product deposits would arise upon contact with a product e.g. due to swirl formations and dead zones.

### SUMMARY OF THE DISCLOSURE

[0005] One aspect of the present disclosure to configure a shell-and-tube heat exchanger of the aforementioned type for product/product flow guidance in a way that it can be cleaned in a hygienically irreproachable way.

[0006] The deliberate turning away from a fold B:T ratio that is usually standard for an optimum heat expansion compensation and the adoption of a ratio of B:T of about 1 or more, which is less advantageous for compensation, at least on the surface of the fold that can be contacted by the product, makes it possible that the surface that can be contacted by the product can be cleaned for achieving a hygienically irreproachable state of the product because there are relatively moderate directional changes in the rounded folds and relatively weakly curved surfaces and there are no critical dead spaces. Hence, the product is less prone to sticking, but is

always swiftly flushed out of the fold. Cleaning media can efficiently eliminate product residues and the media themselves can be flushed out easily and/or removed without any residues. To accomplish the compensatory action required on the whole, one need only provide a corresponding additional number of folds. This, however, is certainly acceptable with respect to the achievable, hygienically irreproachable conditions for the product/product flow guidance and hermetic tightness in the shell-and-tube heat exchanger. Due to the accepted deterioration of the compensatory action of each fold, which contacts the product e.g. with its inside and is provided as such for the technical purpose of compensating heat expansions, it is only now that the bellows is given the hygienic qualification for the product/product flow guidance in the shell-and-tube heat exchanger, also for the reason that a harmonious surface extension achieves very advantageous flow conditions that drastically improve the cleaning efficiency in particular. Hence, a shell-and-tube heat exchanger with hygienic bellows is accomplished.

[0007] In an expedient embodiment the ratio of B:T may e.g. be about 1 up to about 2. The greater the ratio, the more advantageous is the fold during cleaning after predetermined operating periods or with respect to a product change.

[0008] In an expedient embodiment, several folds are provided in the bellows; these folds are directly successive in axial direction, they are formed alternately inwards and outwards and they are at least substantially similar and relatively wide. Whenever this bellows is arranged in the casing tube, the surface which can be contacted by the product is only present on the inside. By contrast, if the bellows is arranged in an inner tube, the inner or the outer surface or both surfaces can be contacted by the product, with optimum conditions being each time provided for the cleaning action.

[0009] In an alternative embodiment, a plurality of folds that are axially successive with interspaces and substantially similar are provided inwards or outwards; the folds are formed with the ratio of B:T of about 1 or more on the surface which can be contacted by the product, and folds which are given a ratio of  $B1:T < 1$  are provided in the interspaces. It is recommended in this embodiment that the convexly curved surfaces of the folds should be arranged with the ratio of  $B1:T < 1$  on the bellows surface which can be contacted by the product, because these convex surface sections can also be cleaned easily. This constitutes a hybrid configuration of the bellows, on the one hand to be able to clean the concave surface sections of the relatively wide folds with the ratio of B:T of about 1 or more without difficulty, but also to achieve a smaller compensatory action per length unit, and on the other hand to be able to achieve an adequately good cleaning action also on the convex surface portions of the folds with the ratio of  $B1:T1 < 1$ , but to obtain a stronger compensatory action per length unit at said place. As has been stated, this hybrid form of the bellows is specifically recommended for the casing tube if said tube is contacted by the product on the inner surface.

[0010] In another embodiment, the inner diameter of the bellows has a size which lies between approximately the inner diameter of the inner or casing tube comprising the bellows and said inner diameter less the depth of the folds. Depending on the specific application of the bellows in the casing tube or in an inner tube, undesired constrictions within said bellows/inner diameter region can be avoided or minimized in the respective flow channels.

[0011] In one embodiment the bellows comprises substantially circular cylindrical tube sockets welded to the inner or casing tube, which are inserted in or over section ends of the inner or casing tube. Integrating the bellows into the respective tube can be easily mastered by way of production technology. The welds are tight and can withstand high pressure differences without any problems. The bellows can be arranged at the respectively optimum position of the tube.

[0012] In an alternative embodiment, the bellows is integrally formed in the circular cylindrical wall of the respective tube, e.g. by roller treatment or by hydraulic formation. Weld joints are thereby no longer needed.

[0013] In an expedient embodiment a casing tube forms a shell-and-tube heat exchanger module with a plurality of inner tubes. The bellows, at least one bellows, can be arranged approximately in the longitudinal center of the heat-exchanger module so as to develop its compensatory action in an optimum way. Preferably, the bellows is positioned in the casing tube in such a way that the surface of the bellows which can be contacted by the product is oriented towards the inner tubes which are accommodated in the casing tube and may be smooth.

[0014] It is important for an efficient cleaning when at least on the surface which can be contacted by the product the fold has such a harmonious surface extension that essentially turbulent flow conditions are promoted there, such flow conditions completely encompassing all recesses of the bellows. Essentially turbulent flow conditions offer the advantage that no zones are formed where it must be feared that not only the product will deposit, but a cleaning medium is also not in a position to develop an efficient cleaning action.

[0015] Particularly expediently, each fold is formed in an axial section of the inner and/or casing tube which is equipped with the bellows and consists of curvature sections continuously passed into one another. Preferably, this regards circular-arc sections with a radius of curvature corresponding approximately to half the depth and/or width of the respective fold.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Embodiments of the subject matter of the disclosure shall now be explained in more detail with reference to the drawings, in which:

[0017] FIG. 1 is a schematic longitudinal section through a module of an exemplary shell-and-tube heat exchanger;

[0018] FIG. 2 shows, on an enlarged scale, a detail of FIG. 1 with a bellows in a casing tube of the shell-and-tube heat exchanger module;

[0019] FIG. 3 is an axial section of another embodiment, e.g. a casing tube or an inner tube of a module;

[0020] FIG. 4 is an axial section of another embodiment of a casing tube or an inner tube of a module; and

[0021] FIG. 5 is a partial section of a specific embodiment of a module.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] Each of FIGS. 1 and 5 illustrates an individual module M of a shell-and-tube heat exchanger W shown in broken line, as is e.g. used in the bottling or filling industry for liquid food products (e.g. water, juices, milk) for a product/product flow guidance in the heat treatment (heating or cooling) of a food product. In the shell-and-tube heat exchanger W it is

possible to install a plurality of modules so as to obtain flow paths for the product that are as long as possible. Module M may here have a length of e.g. 3.0 m, 6.0 m, or even more.

[0023] In FIG. 1 the module M comprises a casing tube 1, e.g. of stainless steel, which comprises end-sided fastening flanges 2 for installation in the shell-and-tube heat exchanger W. In the casing tube 1 at least one inner tube 3 is provided that extends substantially axially parallel with respect to the casing tube 1 between fastening flanges 4. In the embodiment in FIG. 1, several inner tubes 3 are provided that are combined to form a tube bundle, so that at least the flow channels 5, 6, 7 and 8 are defined between the casing tube 1 and the inner tubes 3 and also in the inner tubes 3, with the channels 6, 7 and 8 pertaining to a primary flow and the channel 5 belonging to a secondary flow channel. In these flow channels the food product is circulating, and at least one flow path is here optionally also used for a heat carrier medium (in FIG. 1 e.g. the flow path 5). To be able to compensate for unavoidable thermal expansions between the tubes 1, 3, which are caused by different temperatures prevailing in the flow paths, a compensating device K, which is configured as a bellows C with a plurality of folds F, is integrated in the casing tube 1 in the embodiment in FIG. 1. It would certainly be possible to provide a plurality of bellows C over the length of the module M (e.g. 6.0 m or more). The bellows C shown in FIG. 1 is provided on the inside with a surface 12 which can be contacted by the product in the flow path 5, and the bellows compensates for the different axial heat expansions of the casing tube 1 in relation to the axial heat expansions of the inner tubes 3 by way of predominantly axial operation. In FIG. 5 open end flanges 2 are provided on the casing tube 1 for the connection of e.g. the inner tubes 3, and lateral connections 2' are provided in the casing tube 1.

[0024] The inner tubes 3 could also be equipped with bellows C in addition, or only the inner tubes 3; in this case a bellows C in an inner tube 3 presents, optionally on the inside and/or outside, a surface 12 which can be contacted by the product.

[0025] FIG. 2 shows the bellows C of FIG. 1 on an enlarged scale. The bellows C is welded with end-sided, e.g. circular cylindrical, tube sockets 10 to the casing tube 1, i.e. here inserted into casing tube section ends 1a, 1b on the inside and welded at 11. Alternatively, the tube sockets 10 could also be attached on the outside onto the casing-tube section ends 1a, 1b and welded. The bellows C is prefabricated and installed in the casing tube 1 at a later time.

[0026] The bellows C in FIG. 2 is distinguished in that it comprises a plurality of relatively wide folds F that are arranged axially with interspaces one after the other and extend around the tube axis X and have a radial depth T and an axial width B and are similar to one another. The ratio of B:T is about 1 or is even greater, up to preferably about 2 at the most. The surface 12 that can be contacted by the product is mainly concavely rounded and extends relatively harmoniously with e.g. a radius of curvature R1, which may be about half the depth T or the width B.

[0027] Opposite folds F1' are provided in the interspaces between the axially spaced-apart folds F; on the surface 12 which can be contacted by the product, the folds F1' have each a convex surface section with a radius of curvature R2' which is smaller than half the depth T or the width B and may be about half the width B1 of the fold F1'.

[0028] The inner diameter of the bellows C is designated with d and approximately corresponds to the inner diameter D

of the casing tube 1. The outer diameter D1 of the bellows C corresponds approximately to the inner diameter d plus two times the depth T and plus the material thickness of the bellows C. Like the casing tube 1, the bellows C consists preferably of stainless steel. The inner tubes 3 are not shown in FIG. 2. The exterior surface 9 of the bellows C does not get into contact with the product in module M.

[0029] In the embodiment in FIG. 3, the bellows C is integrated either into the casing tube 1 or into the respective inner tube 3. When the bellows C is positioned in the inner tube 3, the inner and outer surfaces 12 can then be contacted by the product in this instance. In the bellows C, a plurality of axially directly successive, alternately inwardly and outwardly shaped folds F, F1 are formed; these may be similar and have successively convex and concave curvatures, expediently with radii of curvature R1, R2 corresponding to about half the depth T. Expediently, these are circular sections, preferably semicircles, continuously passed into one another. The inner diameter d1 of the bellows C corresponds to about the inner diameter d of the casing or inner tube 1, 3 or the outer diameter D thereof whereas the outer diameter D1 of the bellows corresponds approximately to the outer diameter D plus two times the depth T and the material thickness. In the illustrated embodiment for an inner or casing tube 1, 3 with an outer diameter D of about 70.0 mm, the width B of each fold is just below 10.0 mm; the depth T of each fold is also about 10.0 mm, and six folds F and five folds F1 are provided over the length of the bellows C.

[0030] In the embodiment in FIG. 4, the inner diameter d1 of the bellows C is smaller than the inner diameter d of the casing or inner tube 1, 3, smaller preferably up to not more than about the depth T, and the outer diameter D1 of the bellows C is slightly larger than the outer diameter D or almost as large as the outer diameter D. Likewise in the bellows C in FIG. 4, a plurality of folds F, F1 are provided in axially direct succession alternately inwardly and outwardly; these folds may be similar.

[0031] In the embodiment of FIG. 4, the outer diameter D is about 114.0 mm, the length of the bellows C is about 146.0 mm, the depth T is about 12.0 mm and the width B is about 11.0 mm.

[0032] In each embodiment the ratio B:T of the fold F, F1 is chosen to be about 1.0 or greater, preferably up to not more than about 2.0.

[0033] The ratio may here be slightly smaller than 1, but preferably always more than 0.9.

[0034] Preferred embodiments have casing diameters of up to 250 mm. There may however also be shapes with larger diameters.

1. A shell-and-tube heat exchanger, comprising a casing tube, at least one inner tube for treating liquid food products, particularly low-viscosity products, such as juices or milk, also with a product/product flow guidance, at least one thermal-expansion compensating device for the casing and/or inner tube, with the compensating device having disposed therein at least one surface which can be contacted by the product to be treated, on at least one bellows integrated into the casing and/or inner tube the surface which can be contacted by the product is provided with a plurality of relatively wide folds which extend around the tube axis and are of rounded cross-section, and that the respective fold is configured on the surface which can be contacted by the product

with a radial depth and an axial width with a ratio of B:T of about 1 or more and can thereby be cleaned in a hygienically irreproachable way.

2. The shell-and-tube heat exchanger according to claim 1, wherein the ratio of B:T, at least on the surface which can be contacted by the product, ranges from about 1 to about 2.

3. The shell-and-tube heat exchanger according to claim 1, and a plurality of axially directly successive, alternately inwardly and outwardly shaped, at least substantially similar folds are provided with the ratio of B:T of about 1 or more.

4. The shell-and-tube heat exchanger according to claim 1, and a plurality of relatively wide folds which are axially successive with interspaces and substantially of a similar kind are provided inwards or outwards and are formed on the surface which can be contacted by the product with the ratio B:T of about 1 or more, and that narrower folds are provided in the interspaces, the narrower folds being configured with a ratio of B1:T of less than 1.

5. The shell-and-tube heat exchanger according to claim 1, wherein the inner diameter of the bellows has a size that is between approximately the inner diameter of the inner or casing tube including the bellows and the inner diameter less the depth.

6. The shell-and-tube heat exchanger according to claim 1, wherein the bellows comprises substantially circular cylindrical tube sockets which are welded to the inner or casing tube and which are inserted in or over inner-tube or casing-tube section ends.

7. The shell-and-tube heat exchanger according to claim 1, wherein the bellows is formed by a roller treatment or by hydraulic formation integrally in the per se circular cylindrical wall of the inner and/or casing tube.

8. The shell-and-tube heat exchanger according to claim 1, wherein the casing tube forms a heat-exchanger module with a plurality of inner tubes, and that the bellows is arranged approximately in the longitudinal center of the heat-exchanger module on relatively wide folds with the ratio of B:T of about 1 or more.

9. The shell-and-tube heat exchanger according claim 1, and wherein on the surface which can be contacted by the product the fold has a harmonious surface extension that promotes substantially turbulent flow conditions such that the flow encompasses all depths of the bellows.

10. The shell-and-tube heat exchanger according to claim 1, wherein each fold is formed in an axial section of the inner or casing tube of curvature sections continuously passed into one another.

11. The shell-and-tube heat exchanger according to claim 3, wherein the plurality of at least substantially similar folds is up to six or more folds.

12. The shell-and-tube heat exchanger according to claim 3, wherein the plurality of at least substantially similar folds are convexly rounded to the outside.

13. The shell-and-tube heat exchanger according to claim 1, wherein the bellows is arranged in the casing tube and with the surface which is oriented towards the inner tubes and can be contacted by the product.

14. The shell-and-tube heat exchanger according to claim 10, wherein the curvature sections have circular-arc sections with a radius of curvature corresponding to about half the depth and/or width.

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