



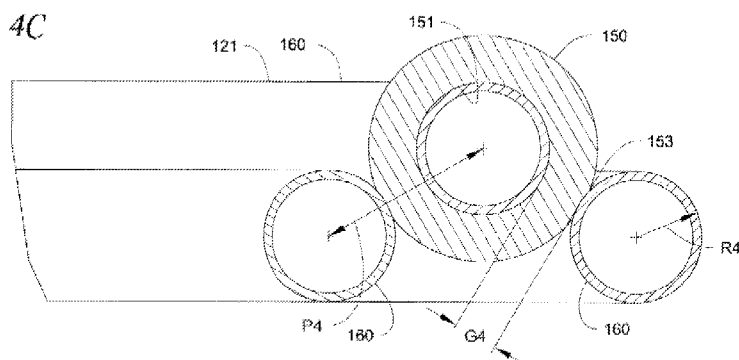
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(54) **Title:** SHELL AND TUBE HEAT EXCHANGER

Fig. 4C



(57) **Abstract:** Disclosed is a shell and tube heat exchanger (100) in which heat-exchanging tubes (120) have "U" bend sections (121). The "U" bend sections (121) of the heat-exchanging tubes (120) may have stabilizing members (150) which are configured to stabilize the "U" bend sections (121) of the heat-exchanging tubes (120). The stabilizing members (150) may be configured to be made of an elastic material, such as rubber. The stabilizing members (150) may have a circular cross-section so that the stabilizing members (150) can be slid onto the heat-exchanging tubes (120) easily. The cross-section of the stabilizing members (150) may be larger than a gap (G4) between neighboring heat-exchanging tubes (150) so that the stabilizing members (150) can form an interference fit with an outer surface (160) of the heat-exchanging tubes (120). The stabilizing members (150) can help to prevent the neighboring heat-exchanging tubes (120) from colliding with each other.

SHELL AND TUBE HEAT EXCHANGER

Field

The disclosure herein relates to a heating, ventilation, and air-conditioning (“HVAC”) system, and more particularly to a shell and tube type heat exchanger used in a HVAC chiller system. Generally, systems and methods are described to help stabilize a “U” bend section of heat-exchanging tubes in a shell and tube type heat exchangers.

Background

A chiller, such as used in a HVAC system, may generally include a compressor and heat exchangers (e.g. a condenser and an evaporator) to form a refrigeration loop. The heat exchangers can be used as a condenser and/or an evaporator. In a shell and tube type heat exchanger, the heat exchanger generally includes heat-exchanging tubes running across a shell. The heat-exchanging tube is typically configured to carry a first fluid (such as refrigerant or water) forming a tube side; and the shell is configured to carry a second fluid (such as refrigerant or water) forming a shell side. The tube side and the shell side can form a heat exchanging relationship in the heat exchanger. The heat exchanger can help exchange heat between the first fluid in the tube side with the second fluid in the shell side.

Summary

Embodiments disclosed herein can help stabilize “U” bend sections of heat-exchanging tubes in a shell and tube type heat exchanger. Embodiments disclosed herein can help prevent the “U” bend section from colliding with each other, so as to help reduce damages to the heat-exchanging tubes due to heat-exchanging tubes collision. Embodiments disclosed herein may also be applicable to other relatively long unsupported sections of the heat-exchanging tubes.

In some embodiments, in a shell and tube type of heat exchanger, each of a plurality of heat-exchanging tubes may have a “U” bend section. A peak portion of each of the “U” bend section of the plurality of heat-exchanging tubes may be equipped with a stabilizing member. The stabilizing member can be configured to engage an outer surface of an neighboring one of the

heat-exchanging tubes.

In some embodiments, the stabilizing member may be configured to have an “O” ring shape including an opening configured to receive one of the heat-exchanging tubes through the opening of the “O” ring shaped stabilizing member. In some embodiments, a cross-section of the stabilizing member has a circular profile so that the stabilizing member can be slid on the heat-exchanging tube easily.

In some embodiments, the cross-section of the stabilizing member has a diameter. The diameter can be configured to be larger, such as 3% to 100% larger, than a difference between a tube pitch of the heat-exchanging tubes and two times a radius of the outer surface of the heat-exchanging tube.

In some embodiments, the stabilizing member can be configured to form an interference fit with the outer surface of the neighboring one of the plurality of heat-exchanging tubes. In some embodiments, the stabilizing member of one of the heat-exchanging tubes is configured to be positioned off-set with the stabilizing member of the neighboring heat-exchanging tube(s).

In some embodiments, a method to prevent “U” bend sections of a plurality of heat-exchanging tubes from colliding with each other in a shell and tube type heat exchanger may include providing a stabilizing member to at least some of the “U” bend sections of the plurality of heat-exchanging tubes; and positioning the stabilizing member on the at least some of the “U” bend sections so that the stabilizing members on the neighboring “U” bend sections are off-set from each other. In some embodiments, each of the plurality of “U” bend sections may be provided with the stabilizing member. In some embodiments, the stabilizing member may be configured to form an interference fit with the neighboring heat-exchanging tube(s). The stabilizing members can hold the tube bundle and stabilize the “U” bend sections of the heat-exchanging tubes.

Other features and aspects of the embodiments will become apparent by consideration of the following detailed description and accompanying drawings.

Brief Description of the Drawings

Reference is now made to the drawings in which like reference numbers represent

corresponding parts throughout.

Fig. 1 illustrates a perspective and partial cut-out view of a shell and tube type heat exchanger, according to one embodiment.

Fig. 2 illustrates a perspective view of the shell and tube type heat exchanger of Fig. 1, with a shell of the heat exchanger removed.

Fig. 3 illustrates an enlarged perspective view of “U” bend sections of the heat-exchanging tubes of Fig. 2.

Figs. 4A to 4E illustrate different aspects of heat-exchanging tubes of the heat exchanger of Fig. 1. Fig. 4A illustrates three neighboring heat-exchanging tubes of the heat exchanger. Fig. 4B is an enlarged view of an area 4B of Fig. 4A. Fig. 4C is a sectional view along the line 4C-4C in Fig. 4B. Fig. 4D illustrates a top view of a stabilizing member. Fig. 4E illustrates a cross-section view along the line 4E-4E in Fig. 4D.

Detailed Description

Various shell and tube types of heat exchangers have been developed. Typically, a shell and tube type of heat exchanger has a structure of heating exchanging tubes extending in a shell. The heat-exchanging tubes form a tube side configured to carry a first fluid, and the shell forms a shell side configured to carry a second fluid. The tube side and the shell side form a heat exchanging relationship in the heat exchangers.

Typically, the heat-exchanging tube is a tube with a constant diameter with a first open end and a second open end. The first open end is configured to receive a fluid, and the second open end is configured to allow the fluid to flow out of the heat-exchanging tube. In some embodiments, the first open end and the second open end of the heat-exchanging tubes are positioned at a first end of the shell side. In these embodiments, the heat exchange tube may have a “U” bend section inside the shell around a second end of the shell side. The “U” bend section may be a relatively long section without any supports. During operation, a fluid flow in the shell side may cause the “U” bend section to wobble or vibrate, and the neighboring “U” bend sections may collide with each other causing damages to the “U” bend sections of the heat-exchanging tubes. Over a long period of time, the colliding of the neighboring “U” bend

sections may cause leakage on the heat-exchanging tubes. Relatively long unsupported straight sections of heat-exchanging tube may also collide with each other, causing damages.

Embodiments disclosed herein are directed to methods and apparatuses to help stabilize “U” bend sections of heat-exchanging tubes in a shell and tube type of heat exchanger. In some

5 embodiments, a stabilizing member can be positioned at the “U” bend section of the heat-exchanging tube. The stabilizing member can be configured to form an interference fit with an outer surface of the neighboring heat-exchanging tube so as to help prevent the “U” bend sections from colliding with each other. In some embodiments, the stabilizing members may be made of an elastic material, such as rubber. In some embodiments, the stabilizing member may
10 have a circular cross-section so that the stabilizing member can be slid onto the heat-exchanging tube easily. In some embodiments, the stabilizing member can be positioned close to a peak section of the “U” bend, and the neighboring “U” bends can be positioned off-set with each other so that each stabilizing member forms an interference fit with the outer surface of the neighboring heat-exchanging tube.

15 References are made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration of the embodiments in which the embodiments may be practiced. The term “interference fit” generally means “friction fit,” which generally refers to a situation that two parts forming the interference fit are pressed against each other and the two parts have friction between them. It is to be understood that the terms used herein are for the purpose of
20 describing the figures and embodiments and should not be regarded as limiting the scope of the present application.

Fig. 1 illustrates a partial cut-out and exploded view of a shell and tube type heat exchanger 100 according to one embodiment, which can be configured to work as an evaporator of a chiller. The heat exchanger 100 includes a shell 110 having a first end 112 and a second end
25 114. The shell 110 includes a process fluid inlet 116 and a process fluid outlet 118. The process fluid inlet 116 is configured to receive a process fluid, such as water; and the process fluid outlet 118 is configured to direct the conditioned process fluid out of the shell 110. Typically, the process fluid inlet 116 is located closer to the first end 112 and the process fluid outlet 118 is located closer to the second end 114, with the appreciation that the process fluid inlet can be

closer to the second end 114 and the process fluid outlet can be closer to the first end 112.

It is noted that the embodiment as illustrated in Fig. 1 is exemplary. In some other embodiments, the shell can be configured to carry refrigerant, while the heat-exchanging tubes can be configured to carry a process fluid. In some embodiments, the process fluid inlet may be positioned close to the first end 112 and the process fluid outlet may be positioned close to the second end 114.

Heat-exchanging tubes 120 extend in the shell 110 between the first end 112 and the second end 114 in a longitudinal direction defined by a length L of the shell 110. Open ends 122 of the heat-exchanging tubes 120 are attached to a tube sheet 140 close to the first end 112 of the shell 110. The open ends 122 form an inlet region 122a and an outlet region 122b on the tube sheet 140. The inlet region 122a is typically configured to receive refrigerant and distribute the refrigerant to the heat-exchanging tubes 120. The outlet region 122b is typically configured to direct the refrigerant out of the heat-exchanging tubes 120. The heat exchanger 100 also includes a head 130 that is configured to be attached to the tube sheet 140. Each of the heat-exchanging tubes has a “U” bend section 121 close to the second end 114 of the shell 110.

Referring to Fig. 2, a perspective view of the heat exchanger 100 of Fig. 1 with the shell 110 removed is shown. Generally, each of the heat-exchanging tubes 120 starts at the inlet region 122a (as shown in Fig. 1) of the tube sheet 140, runs across the shell 110 in the longitudinal direction defined by the length L, and then makes a “U” turn at the “U” bend section 121 close to the second end 114 of the shell 110. The heat-exchanging tube 120 then runs across the shell 110 in the longitudinal direction defined by the length L again, then ends at the outlet region 122b (as shown in Fig. 2) of the tube sheet 140. A stabilizing member 150 is installed on the “U” bend section 121 of the heat-exchanging tube 120.

Referring to Figs. 1 and 2, in operation, the process fluid may be directed into the shell 110 through the process fluid inlet 116, then flow in the longitudinal direction defined by the length L, and be directed out of the shell from the process fluid outlet 118. The process fluid flow in the shell 110 may cause wobbling or vibrations of the “U” bend sections 121 of the heat-exchanging tubes 120, which may cause the “U” bend sections 121 of the neighboring heat-exchanging tubes 120 to collide with each other. The stabilizing member 150 may help prevent

the “U” bend sections 121 of the heat-exchanging tubes 120 from colliding with each other.

Fig. 3 illustrates an enlarged view of the “U” bend sections 121. The heat-exchanging tubes 120 pass through and are supported by a plurality of baffles 152 from the first end 112 to the second 114. After an end baffle 152a of the plurality of baffles 152, the heat-exchanging tubes 120 are configured to have the “U” bend section 121. The end baffle 152a is usually the baffle 152 that is closest to the second end 114 in the longitudinal direction defined by the length L compared to other baffles 152.

As illustrated, at least some of the “U” bend sections 121 of the heat-exchanging tubes 121 have a stabilizing member 150. In some embodiments, each of the “U” bend sections 121 of the heat-exchanging tubes 121 can be configured to have the stabilizing member 150. The stabilizing members 150 are generally positioned at a peak portion 121a of the “U” bend section 121. The peak portion 121a is generally where the heat-exchanging tube 121 makes a turn back toward the first end 112 (as shown in Fig. 1).

The “U” bend sections 121 of the heat-exchanging tubes 121 may have different arc lengths. As illustrated in Fig. 2, relative to the end baffle 152a, arcs of some of the “U” bend sections 121 travel further away from the end baffle 152a than some other “U” bend sections 121. Generally, the “U” bend sections 121 with longer arc lengths are more prone to the wobbling and/or vibrations.

It is appreciated that in some embodiments, it may be the case that not every one of the “U” bend sections 121 may be equipped with the stabilizing members 150. It is preferred that the “U” bend sections 150 with relatively longer arc lengths are equipped with the stabilizing members 150.

As illustrated, the neighboring stabilizing members 150 are positioned off-set with each other, so that each of the stabilizing members 150 can engage the neighboring heat-exchanging tube 121 directly. And the stabilizing members 150 do not interfere with each other.

More details of the stabilizing members 150 and configurations of the “U” bend sections 121 are illustrated in Figs. 4A to 4E.

Fig. 4A illustrates a side view of heat-exchanging tubes 120 of the heat exchanger 100 (as shown in Fig. 1). Only three neighboring heat-exchanging tubes 120 are shown. Each of the

heat-exchanging tubes 120 includes two straight sections 120a and 120b, which extend inside the shell 110 of the heat exchanger 100 in the longitudinal direction defined by the length L (as shown in Fig. 1).

The two straight sections 120a and 120b pass through the end baffle 152a, and the two
5 straight sections 120a and 120b are connected by the “U” bend section 121.

An enlarged view of an area 4B in Fig. 4A is shown in Fig. 4B, which includes the end baffle 152a, the “U” bend sections 121, and a part of the straight sections 120a and 120b.

As illustrated, the straight sections 120a and 120b extend beyond the end baffle 152a, forming straight ends 123a and 123b respectively. The straight ends 123a and 123b are
10 connected by the “U” bend section 121. The straight ends 123a and 123b has a length L2 from the end baffle 152a to a starting (and/or ending) point of the “U” bend sections 121.

It may be desirable to minimize the length L2 so as to reduce the wobbling or vibrations of the “U” bend sections 121. In some embodiments, the length L2 is configured to be no more than 2.5 times of a radius (i.e. the radius R4 in Fig. 4C) of an outer surface (i.e. the outer surface
15 160 in Fig. 4C) of the heat-exchanging tubes 120.

Heat transfer efficiency between the refrigerant carried in the heat-exchanging tubes 120 and the process fluid carried in the shell 110 (as shown in Fig. 1) is relatively low in the “U” bend section 121 compared to other portions of the heat-exchanging tubes 120. Reducing the length L2 of straight ends 123a and 123b can save manufacturing costs without sacrificing much
20 of the heat transfer efficiency.

The peak portion 121a of the “U” bend section 121 may be equipped with the stabilizing members 150. The stabilizing members 150 are configured to surround an outer surface 160 of the heat-exchanging tube 120. As illustrated in Fig. 4B, the stabilizing members 150 located on the neighboring heat-exchanging tubes 120 are positioned off-set with each other, so that the
25 stabilizing members 150 can engage the outer surface 160 of the neighboring heat-exchanging tube(s) 120, and the neighboring stabilizing members 150 do not interfere with each other.

A cross-section along the line 4C-4C is shown in Fig. 4C. The stabilizing member 150 is configured to have an “O” ring shape with an opening 151. The opening 151 is configured to allow the “U” bend section 121 to pass through.

The stabilizing member 150 is also configured to engage the outer surface 160 of the neighboring heat-exchanging tube(s) 120. The stabilizing member 150 can be configured to form an interference fit 153 between the stabilizing member 150 and the outer surface 160 of the neighboring heat-exchanging tube(s) 120.

5 Figs. 4D and 4E illustrate one embodiment of the stabilizing member 150. The stabilizing member 150 generally has an “O” ring shape with the opening 151. A cross-section along the line 4E-4E in Fig. 4D is illustrated in Fig. 4E.

As shown in Fig. 4E, the cross section of the stabilizing member 150 generally has a circular profile, which has a diameter D4. The circular profile allows the stabilizing member 150
10 to be slid onto the heat-exchanging tubes 120 easily. The stabilizing member 150 can be made of an elastic material, such as rubber.

Referring to Figs. 4C, 4D and 4E, the diameter D4 of the stabilizing member 150 can be configured based on a tube pitch P4 and/or a radius R4 of the outer surface 160 of the heat-exchanging tube 120. The tube pitch P4 generally means a distance between center-lines of two
15 neighboring heat-exchanging tubes. The radius R4 refers to the radius of the outer surface 160 of the heat-exchanging tube 120 relative to the center line of the heat exchanging tube 120. In some embodiments, the diameter D4 is configured to be larger, for example about 3% to 100% larger than the difference between the pitch P4 and two times the radius R4 ($D4 = (1.03 \text{ to } 2) * (P4 - 2 * R4)$). In other words, the diameter D4 is larger than (about 3% to 100% larger than) a gap G4
20 between the outer surfaces 160 of the neighboring heat-exchanging tubes 120. In some embodiments, when a 3/8” heat-exchanging tubes are used and the gap G4 is about 3mm, the diameter D4 for example is about 3.1-3.6mm, which is about 0.1 to 0.6mm larger than the gap G4.

Since the stabilizing member 150 can be made of an elastic material, the diameter D4
25 allows the stabilizing member 150 to be pressed against the outer surface 160 of the neighboring heat-exchanging tube 120, forming the interference fit 153. The interference fit 153 can help hold the tube bundles 119 together and stabilize the “U” bend sections 121 of the heat-exchanging tubes 120. The interference fit 153 can also help retain a position of the stabilizing member 150 relative to the “U” bend section 121 so as to help prevent the stabilizing member

150 from sliding along the heat-exchanging tube 120.

In the embodiment as illustrated, each of the heat-exchanging tubes 120 is configured to have one stabilizing member 150. This is one preferred example. It is appreciated that each of the heat-exchanging tubes 120 can be configured to have more than one stabilizing members

5 150. It is to be appreciated that the stabilizing members 150 may be positioned at places along the “U” bend sections 121 other than the peak portion 121a of the “U” bend section 121.

Positioning one stabilizing member 150 at the peak portion 121a of each of the “U” bend section 121 is typically effective for preventing the “U” section from colliding with each other, and can save manufacturing costs and time than applying more than one stabilizing member 150 for each
10 of the “U” bend section 121.

Embodiments as disclosed herein can be generally used in a shell and tube type heat exchanger that includes heat-exchanging tubes with “U” bend sections, where wobbling or vibrations of the “U” bend sections can cause collision in the “U” bend sections. The embodiments as disclosed herein may also be used in a heat exchanger that includes heat-
15 exchanging tubes with relatively long unsupported sections, where collision among the relatively long unsupported sections may cause damages to the heat-exchanging tubes.

With regard to the foregoing description, it is to be understood that changes may be made in detail, without departing from the scope of the present invention. It is intended that the specification and depicted embodiments are to be considered exemplary only, with a true scope
20 and spirit of the invention being indicated by the broad meaning of the claims.

Claims

What claimed is:

1. A heat exchanger, comprising:

a shell;

5 a plurality of heat-exchanging tubes extending in the shell, each of the plurality of heat-exchanging tubes having a “U” bend section; and

the “U” bend section having a peak portion, wherein the peak portion of the “U” bend section of one of the plurality of heat-exchanging tubes has a stabilizing member configured to engage an outer surface of an adjoining one of the plurality of heat-exchanging tubes.

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2. The heat exchanger of claim 1, wherein the stabilizing member has an “O” ring shape including an opening configured to receive the heat-exchanging tubes.

15 3. The heat exchanger of claim 1, wherein a cross-section of the stabilizing member has a circular profile.

4. The heat exchanger of claim 3, wherein the cross-section of the stabilizing member has a diameter, the plurality of the heat-exchanging tubes have a tube pitch, the outer surfaces of the plurality of the heat-exchanging tubes have a radius, and the diameter is larger than the
20 difference between the tube pitch and two times the radius.

5. The heat exchanger of claim 4, wherein the diameter is 3% to 100% larger than the difference between the tube pitch and two times the radius.

25 6. The heat exchanger of claim 1, wherein the stabilizing member of one of the plurality of heat-exchanging tubes is configured to form an interference fit with the outer surface of the adjoining one of the plurality of heat-exchanging tubes.

7. The heat exchanger of claim 1, wherein the stabilizing member of one of the plurality of heat-

exchanging tubes is configured to be positioned off-set with the stabilizing member of the neighboring one of the plurality of heat-exchanging tubes.

8. The heat exchanger of claim 1, further comprising:

- 5 an end baffle, wherein the heat-exchanging tubes have straight sections between the end baffle and a starting point of the “U” bend section, the straight sections have a length that is no more than 2.5 times of a radius of a radius of outer surfaces of the heat-exchanging tubes.

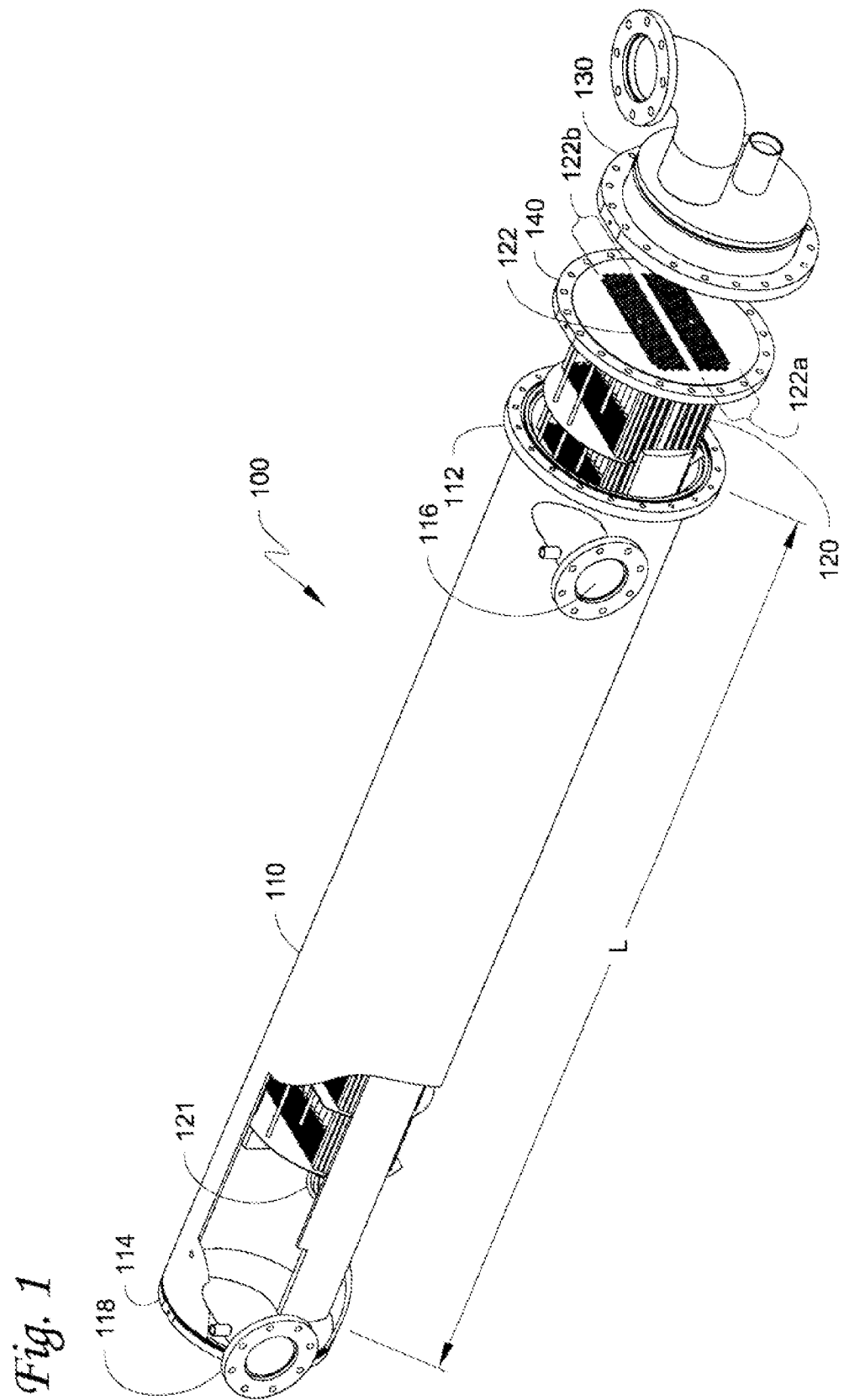
9. A method to prevent “U” bend sections of a plurality of heat-exchanging tubes from colliding
10 with each other in a shell and tube type heat exchanger, comprising:

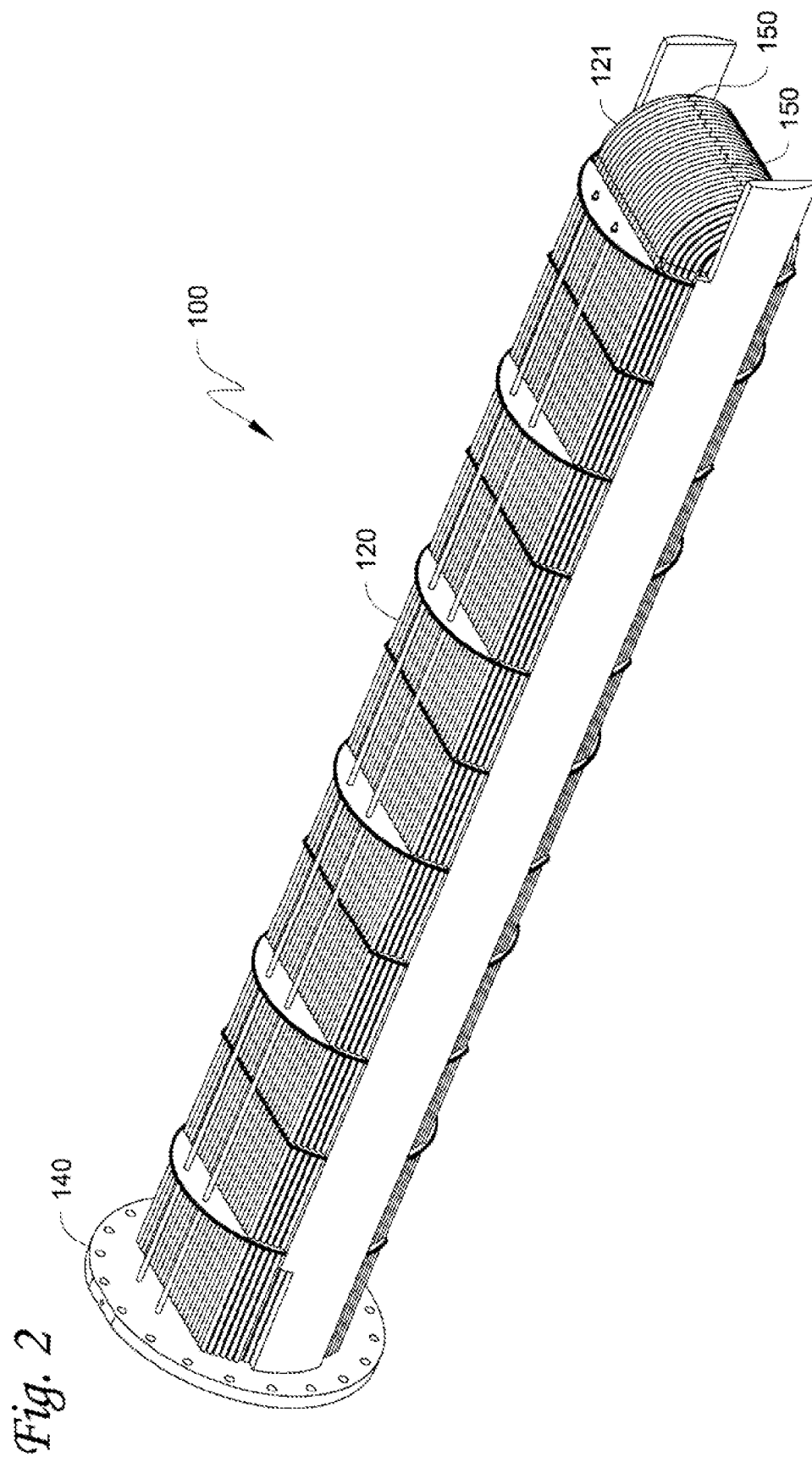
 providing a stabilizing member to the “U” bend sections of the plurality of heat-exchanging tubes, the stabilizing member configured to surround the heat-exchanging tube;

- positioning the stabilizing member on the “U” bend sections so that the stabilizing members on a neighboring “U” bend section are off-set from each other along the “U” bend
15 sections, wherein the stabilizing member configured to form an interference fit with the neighboring heat-exchanging tube.

10. The method of claim 9, further comprising:

- installing the heat-exchanging tubes to a plurality of baffles; and
20 limiting a straight section of the heat-exchanging tube between an end baffle and the “U” bend section to no more than 2.5 times of an radius of an outer surface of the heat-exchanging tube.





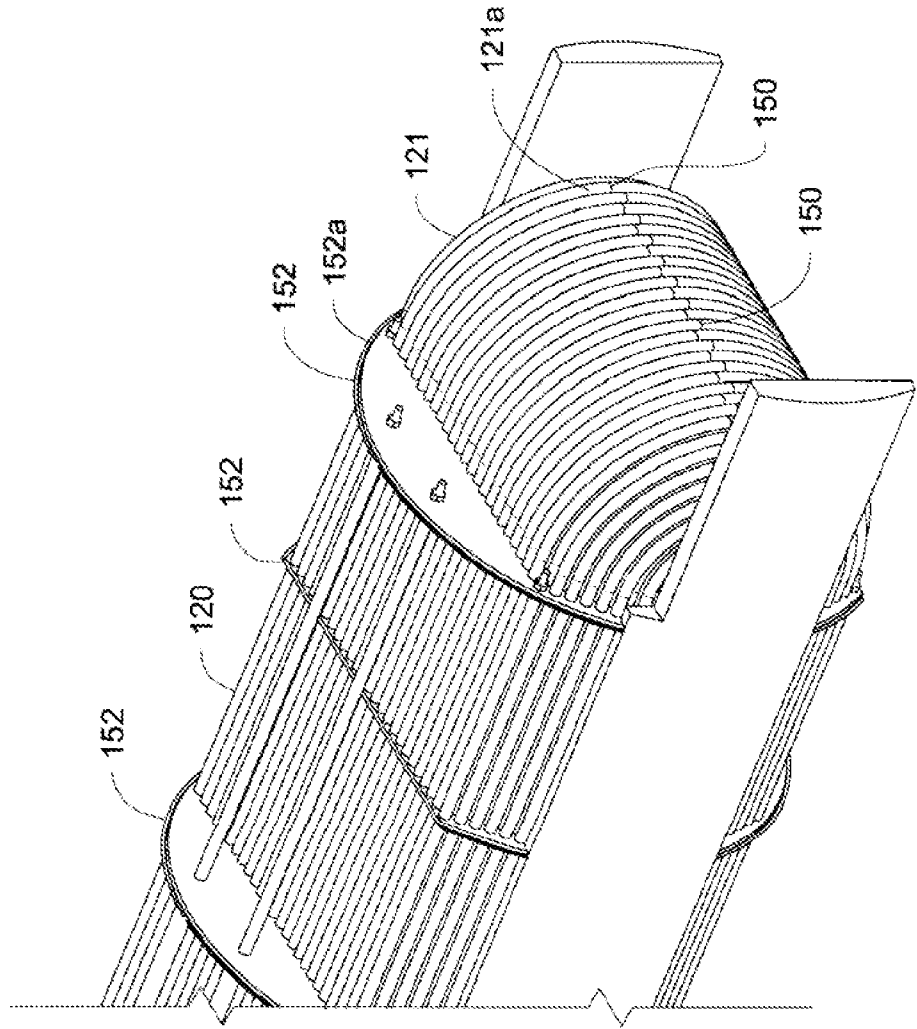


Fig. 3

Fig. 4A

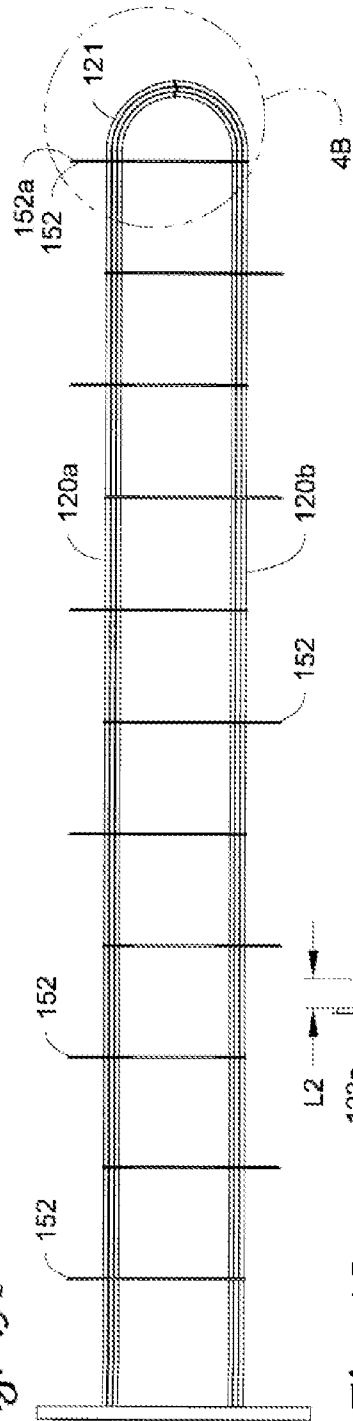
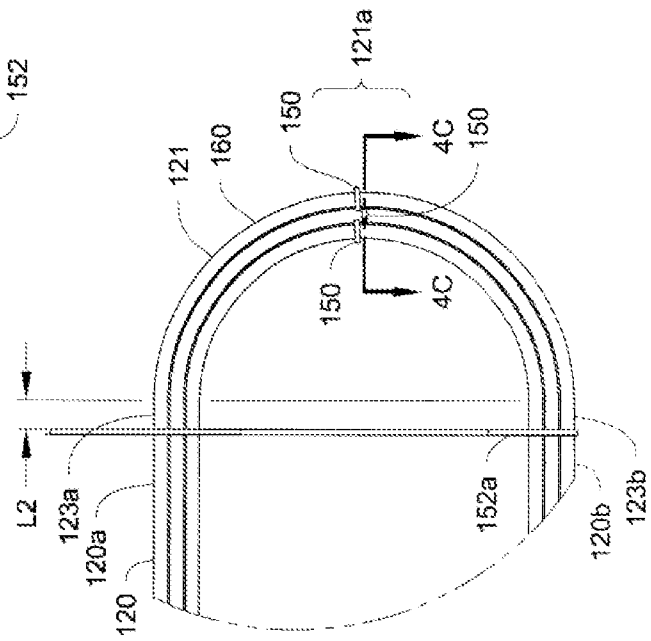
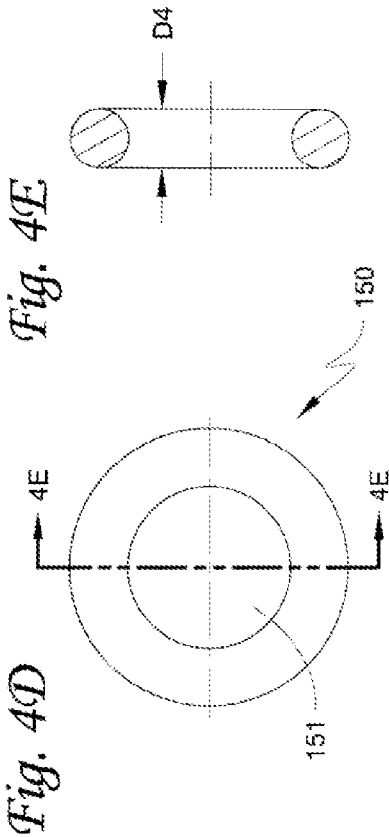
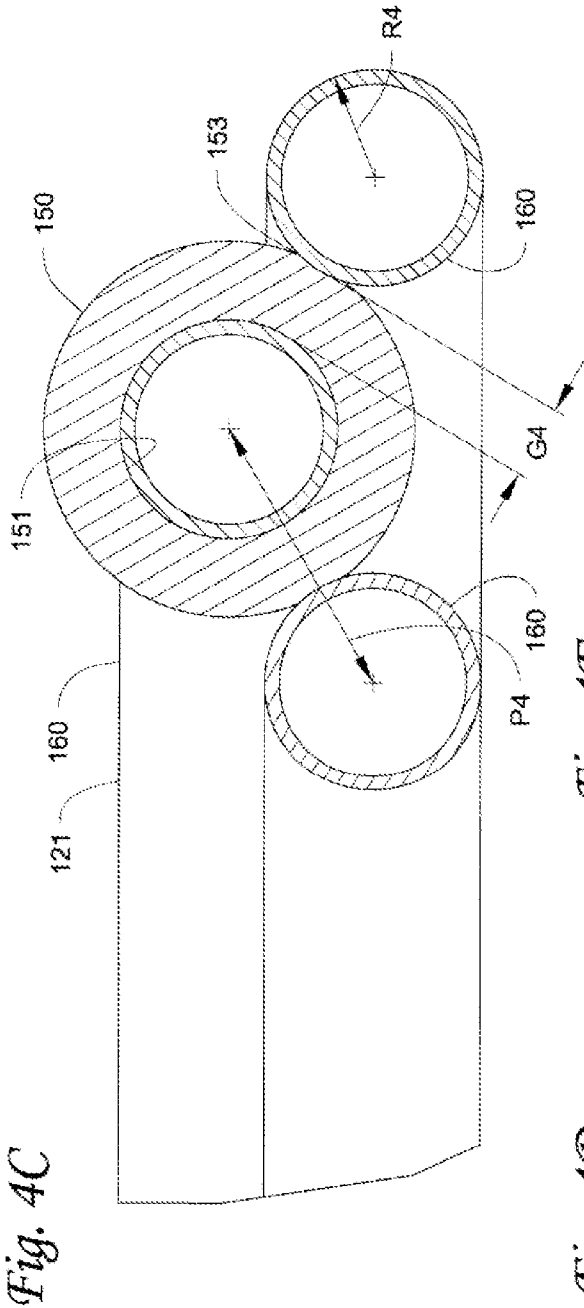


Fig. 4B





INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/087167

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F28F 9, F28D 7, F28F 1, F25B 39, F25B 40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, CNKI, WPI, EPODOC: u w shape?, return+, bend+, ring?, spacer, o w shape?, wob+, stabiliz+, vibrat+, impact+, collid+, collision, pipe?, tube?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 55167093 U (HITACHI SHIPBUILDING ENG CO) 01 December 1980 (01.12.1980) description, page 1, line 11 to page 3, line 17 and figures 1 to 5	1-10
X	CN 101603446 A (VISTEON GLOBAL TECH INC) 16 December 2009 (16.12.2009) description, page 12, line 9 to page 13, line 1 and figures 14 to 17	1
X	CN 201016612 Y (HU, Jie) 06 February 2008 (06.02.2008) description, page 2, lines 7 to 9 and figures 1 to 3	1
A	CN 202254960 U (WUXI CHEMEQUIP CO LTD) 30 May 2012 (30.05.2012) the whole document	1-10
A	EP 0268147 A2 (PHILLIPS PETROLEUM CO) 25 May 1988 (25.05.1988) the whole document	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 20 March 2013 (20.03.2013)	Date of mailing of the international search report 19 Sep. 2013 (19.09.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer GU, Xiaoyan Telephone No. (86-10)62084873

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/087167

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
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CLASSIFICATION OF SUBJECT MATTER

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