One

Abstract:

Title: CORE-IN-SHELL EXCHANGER REFRIGERANT INLET FLOW DISTRIBUTOR

Apparatuses and systems for introducing two-phase refrigerant into a shell of a core-in-shell exchanger are disclosed. One system includes: an exchanger shell; a heat-exchanging core disposed inside the exchanger shell; and an inlet flow distributor for directing incoming fluid comprising: a baffle plate with an array of orifice holes, wherein the orifice holes are off-set from the heat-exchanging core.
The present invention relates generally to equipment utilized during liquefaction of natural gas. More particularly, but not by way of limitation, embodiments of the present invention include a refrigerant inlet flow distributor used to introduce two-phase refrigerant into a shell of a heat-exchanging apparatus.

Natural gas is an important resource widely used as energy source or as industrial feedstock used in, for example, manufacture of plastics. Comprising primarily of methane, natural gas is a mixture of naturally occurring hydrocarbon gases and is typically found in deep underground natural rock formations or other hydrocarbon reservoirs. Other components of natural gas include, but are not limited to, ethane, propane, carbon dioxide, nitrogen, and hydrogen sulfide.

Typically, natural gas is transported from source to consumers through pipelines that physically connect a reservoir to a market. Because natural gas is sometimes found in remote areas devoid of necessary infrastructure (i.e., pipelines), alternative methods for transporting natural gas must be used. This situation commonly arises when the source of natural gas and the market are separated by great distances, for example a large body of water. Bringing this natural gas from remote areas to market can have significant commercial value if the cost of transporting natural gas is minimized.

One alternative method of transporting natural gas involves converting natural gas into a liquefied form through a liquefaction process. Because natural gas exists in vapor phase under standard atmospheric conditions, it must be subjected to certain thermodynamic processes in order to be liquefied to produce liquefied natural gas (LNG). In its liquefied form, natural gas has a specific volume that is significantly lower than its specific volume in its vapor form. Thus, the liquefaction process greatly increases the ease of transporting and storing natural gas, particularly in cases where pipelines are not available. For example, ocean liners carrying LNG tanks can effectively link a natural
gas source with a distant market when the source and market are separated by large bodies of water.

[0005] Converting natural gas to its liquefied form can have other economic benefits. For example, storing LNG can help balance out periodic fluctuations in natural gas supply and demand. In particular, LNG can be more easily "stockpiled" for later use when natural gas demand is low and/or supply is high. As a result, future demand peaks can be met with LNG from storage, which can be vaporized as demand requires.

[0006] In order to store and transport natural gas in the liquid state, the natural gas is typically cooled to -160°C at near-atmospheric vapor pressure. Liquefaction of natural gas can be achieved by sequentially passing the gas at an elevated pressure through a plurality of cooling stages whereupon the gas is cooled to successively lower temperatures until the liquefaction temperature is reached. Cooling is generally accomplished by indirect heat exchange with one or more refrigerants such as propane, propylene, ethane, ethylene, methane, nitrogen, carbon dioxide, or combinations of the preceding refrigerants (e.g., mixed refrigerant systems).

[0007] Cryogenic exchangers (e.g., shell-and-tube exchanger, brazed aluminum heat exchanger, core-in-shell exchanger, etc.) are often installed in LNG facilities to facilitate indirect heat exchange. Cryogenic exchangers may be used, for example, to transfer heat from a natural gas stream to a refrigerant stream. Some conventional core-in-shell heat exchangers feature a brazed aluminum heat exchanger (BAHX) core inserted in a horizontally-oriented, cylindrical pressure vessel shell. These shells tend to be long in length to ensure that the BAHX core is submerged in a pool of evenly distributed refrigerant.

[0008] A BAHX exchanger is typically compact, rigid, and constructed of several different aluminum alloys. Aluminum has no endurance limit, or stress value below which the material will withstand infinite load cycles. As such, BAHX's are susceptible to fatigue failure when subjected to repeated thermal cycles, high internal temperature gradients, or excessive thermal transients. Erosion damage to the core can result when liquid refrigerant repeatedly impinges on the BAHX core directly inside the shell. Consequently, flow control that results in good distribution of fluid may be particularly important when introducing a two-phase refrigerant into a core-in-shell exchanger as
two-phase fluids can rapidly change BAHX metal temperature. A conventional LNG facility typically features a two-phase expander that can at least partially expand a refrigerant into the vapor phase to produce a two-phase refrigerant. Piping arrangements used to transfer fluids in LNG facilities are typically elaborate and asymmetrically configured which can lead to momentum-induced flow maldistribution of a two-phase refrigerant as it enters core-in-shell exchangers.
BRIEF SUMMARY OF THE DISCLOSURE

[0009] The present invention relates generally to equipment utilized during liquefaction of natural gas. More particularly, but not by way of limitation, embodiments of the present invention include a refrigerant inlet flow distributor used to introduce two-phase refrigerant into a shell of a heat-exchanging apparatus.

[0010] One example of a heat-exchanging apparatus comprises: an exchanger shell; a heat-exchanging core disposed inside the exchanger shell; and an inlet flow distributor for directing incoming fluid comprising: a baffle plate with an array of orifice holes, wherein the orifice holes are off-set from the heat-exchanging core.

[0011] Another example of a heat-exchanging apparatus comprises: a hollow horizontally-oriented exchanger shell; a heat-exchanging core disposed inside the hollow horizontally-oriented exchanger shell; an inlet flow distributor comprising: a baffle plate with an array of orifice holes and a wall plate, wherein the orifice holes are off-set from the heat-exchanging core and the wall plate directs an incoming fluid through at least one orifice hole; and an inlet configured to introduce the incoming fluid into the hollow horizontally-oriented exchanger shell through the inlet flow distributor.
BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more complete understanding of the present invention and benefits thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings in which:

[0013] **FIG. 1** is a schematic illustrating a core-in-shell exchanger equipped with a refrigerant inlet flow distributor according to one or more embodiments.

[0014] **FIG. 2** is a cross-sectional view of the core-in-shell exchanger from **FIG. 1**.
DETAILED DESCRIPTION

[0015] Reference will now be made in detail to embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. Each example is provided by way of explanation of the invention, not as a limitation of the invention. It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modifications and variations that come within the scope of the invention.

[0016] The present invention disclosed herein is directed to an inlet flow distributor designed to improve flow of a fluid entering a relatively large cross-sectional area (e.g., shell of a core-in-shell exchanger) from a relatively small cross-sectional area (e.g., conduit). The inlet flow distributor is designed to impart a predetermined and/or desired pressure drop on the entering fluid (e.g., refrigerant in an LNG liquefaction process) for the purpose of improving flow distribution. In another aspect, this device can also counteract momentum-induced refrigerant flow maldistribution problems resulting from non-symmetrical external piping arrangement in a core-in-shell exchanger. Furthermore, the inlet flow distributor can prevent or impede erosion damage to certain components (e.g., BAHX cores) by reducing or preventing liquid refrigerants from impinging directly onto the certain components installed inside the exchanger shell.

Core-in-Shell Exchanger

[0017] Some conventional core-in-shell exchangers address flow distribution and erosion protection issues by, for example, utilizing an internal flow distributor having large slots in the bottom or employing an internal flow distributor open at both ends. These conventional core-in-shell exchangers may be hampered by certain design issues. For example, the large slots in the former design typically do not impart sufficient pressure drop to provide good refrigerant flow distribution inside the shell. Moreover, core-in-shell exchangers employing these internal flow distributors can allow refrigerants to impinge directly on the BAHX core.
[0018] In some embodiments, the inlet flow distributor may be integrated or otherwise utilized in a compatible system to control fluid flow. While references herein are made to a core-in-shell exchanger as an example compatible system, this is not intended to be limiting. Other compatible systems (e.g., shell and tube exchanger comprising tube bundle as the heat-exchanging core), including core-in-shell exchanger configurations not disclosed herein, may be used in conjunction with the inlet flow distributor of the present invention. While at least one embodiment described herein relates to a core-in-shell exchanger featuring an inlet flow distributor of the present invention installed in a liquefied natural gas facility for use during an LNG process, this is not intended to be limiting. Other compatible facilities/processes may include, but are not limited to, gas plants, NGL processing plants, ammonia processing plants, ammonia refrigeration systems, ethylene plants and the like.

[0019] FIGS. 1-2 are schematics only and, therefore, many items of equipment that would be needed in a commercial core-in-shell exchanger for successful operation have been omitted for sake of clarity. Such items may include, for example, nozzles, inlets, outlets, header tanks, spacer bars, and the like.

[0020] Core-in-shell exchangers (sometimes referred to as "core-in-drum" or a commercially available version called Core-in-Kettle® from Chart E & C located in La Crosse, WI) are well-known heat exchangers often used in lieu of shell-and-tube cryogenic exchangers during liquefaction of natural gas ("LNG process"). Some core-in-shell exchangers can contain up to 10 times more heat transfer surface per unit volume than a shell-and-tube unit despite being as little as about half in size and about a fifth in weight.

[0021] Referring initially to FIG. 1, a core-in-shell exchanger 5 equipped with an example inlet flow distributor 30 in accordance with the concepts described herein is illustrated. The core-in-shell heat exchanger 5 includes a BAHX core 20 housed in a hollow exchanger shell 10. As shown, the exchanger shell 10 is cylindrical and horizontally-oriented such that its dimension along the horizontal axis is substantially longer than its dimension along the vertical axis. The illustrated BAHX (sometimes referred to as "plate-fin exchanger") core 20 can be constructed from alternating layers of corrugated fins and flat separator sheets. The stacked arrangement is then vacuum brazed
to yield the BAHX core 20. The resulting core is made up of finned chambers separated by flat plates that route fluid through alternating hot and cold passages. Heat can be transferred via fins in the passageways, through the separator plate, and into the cold fluids via fins again. Nozzles and headers (not illustrated) may be attached to the BAHX core 20 to route fluid in and out of the core. The exchanger shell 10 may also be connected to nozzles and headers to route fluid in and out of the shell (not illustrated). Due to the narrow flow channels between the fins and sheets, even distribution of fluid can be important for successful operations. FIG. 2 is a cross-sectional view of the core-in-shell exchanger illustrated in FIG. 1. For clarity, same reference numbers are used in FIGS. 1 and 2.

**Inlet Flow Distributor**

[0022] In the embodiment illustrated in FIGS. 1-2, the inlet flow distributor 30 is installed near or at the top portion of the core-in-shell exchanger 5 such that fluid injected horizontally into the exchanger through inlet nozzles 50 is discharged vertically down through the orifice holes 40. The arrows in FIG. 2 indicate the direction of fluid flow. The inlet flow distributor 5 comprises of a two perpendicular plates joined along an edge to form an "L" shaped structure as illustrated in FIG. 2. The vertical plate 35 is solid while round orifice holes 40 have been drilled on the horizontal baffle plate 60. Plate dimensions and orifice hole diameters will vary depending on a number of factors including, but not limited to, physical size of the shell, amount of refrigerant flow entering the shell, and physical properties of the refrigerant.

[0023] The orifice holes 40 are strategically-sized, -shaped and located to provide a preselected and/or desired distribution of refrigerant flow. Referring to FIG. 1, the inlet flow distributor 30 includes an array of orifice holes comprising two rows of orifice holes 40, each row extending out to the lateral ends of the inlet flow distributor 30. The rows are defined by the orifice holes that have been drilled and/or fashioned onto the horizontal baffle plate 60. As illustrated in FIG. 1, the top row comprises a non-interrupted row of orifice holes while the bottom row is interrupted by a non-drilled area such that the array of orifice holes are off-set or misaligned vertically to the BAHX core to ensure that the two-phase refrigerant mixture does not jet out of the orifice holes and impinge directly on the BAHX core (see FIG. 2).
While the first row has a greater number of orifice holes compared to the number of orifice holes on the second row, in some embodiments, the horizontal baffle plate 60 may contain any arrangement of orifice holes, including any number of rows, columns, non-drilled area, etc. The specific dimensions and arrangement of the orifice holes depend a number of factors including, but not limited to, BAHX core dimensions, shell length and width, refrigerant inlet weight fraction vapor, refrigerant inlet liquid density, refrigerant inlet vapor density, number of orifice holes, orifice hole diameter, and orifice hole discharge coefficient. In some embodiments, the total area of the orifice holes can be about 5% to about 25% of total area of the baffle plate. In some embodiments, the orifice holes may have non-round shapes. Suitable examples of non-round shapes may include, but are not limited to, squares, rectangles, hexagons, stars, crosses, and the like. Optionally, the inlet flow distributor 30 may include one or more lateral solid plates that flank the lateral sides of the inlet flow distributor 30. In some embodiments, the inlet flow distributor may be made from a material selected from the group consisting of: stainless steels, austenitic stainless steels, carbon steel alloys, aluminum, aluminum alloys, and combinations thereof.

In some embodiments, the core-in-shell exchanger 5 can be integrated in a refrigeration system such that a two-phase refrigerant stream enters through inlet nozzles 50. The inlet flow distributor 30 is used to control the flow of the two-phase refrigerant to the exchanger shell 10. In such embodiments, the two-phase refrigerant is injected into the inlet flow distributor 30 where it flows laterally, away from the inlet nozzles 50 before exiting through the array of orifice holes 40 such that the refrigerant does not directly impinge the BAHX core 20 and collecting evenly at the bottom of the exchanger shell 10. Over time, the BAHX core 20 becomes submerged in a pool of liquid refrigerant. The cold refrigerant boils and partially vaporizes as a warm process stream flowing through the BAHX core 20 is simultaneously cooled as described above. The inlet flow distributor 30 resists flow maldistribution that can result from non-symmetric refrigerant piping external to the core-in-shell exchanger. The round orifice holes are located such that a refrigerant entering the exchanger shell 10 does not impinge directly on the BAHX core and thus prevents erosion damage to the brazed aluminum core.
The following example of a certain embodiment of the invention is given. The example is provided by way of explanation of the invention, one of many embodiments of the invention, and the following example should not be read to limit, or define, the scope of the invention.

**Example 1**

This example calculates a sample pressure drop (i.e., decrease in pressure from one point in a tube to another point downstream) that can occur on a two-phase refrigerant as it is introduced through a refrigerant inlet flow distributor according to one or more embodiments.

Equations (1) and (2) show different forms of a separated flow two-phase pressure loss model where \(\Delta P_{sp}\) is a single phase pressure drop through a tube, \(f\) is friction factor, \(L\) is orifice hole length, \(D\) is orifice hole diameter, \(v\) is velocity, \(g_c\) is gravitational constant (1.00), \(p\) is density, and \(K\) is orifice discharge coefficient (\(f = \frac{L}{D_{orifice}} = 0.779\)).

\[
\Delta P_{sp} = f \frac{L}{D_{orifice}} \frac{v^2}{2g_c} \cdot p \quad (1)
\]

\[
\Delta P_{sp} = K \frac{v^2}{2g_c} \cdot p \quad (2)
\]

Equation (3) describes the relationship between total mass velocity \((G_t)\), total mass flow rate and total area \((A_{total})\) of orifice holes, where \(D_{orifice}\) is orifice hole diameter.

\[
G_t = \frac{m_{total}}{A_{total}} \quad (3)
\]

where \(m_{total} = 74.39\) kg/s (empirically measured)

and \(A_{total} = \frac{\pi}{4} (D_{orifice})^2 \times \text{(# of orifice holes)} = \frac{\pi}{4} (0.009\) m\(^2\) \times 3800 = 0.24175\) m\(^2\)
Substituting $m_{\text{mal}}$ and $A_{\text{total}}$ into (3):

$$G_i = \frac{74.39^\circ}{0.24175m^2} = 307.715 \frac{k_i}{m^2 \cdot s}$$

Velocity ($v$) is equal to the total mass flow rate divided by density and total area as shown in equation (4). Rearranging and substituting for $G_i$ yields equation (5).

$$v = \frac{m_{\text{total}}}{\rho A_{\text{total}}} = \frac{G_i}{P} \quad (4)$$

$$v^2 = \frac{G_i^2}{\rho^2} \quad (5)$$

Substituting equation (5) into equation (2) yields equation (6) which describes the single-phase pressure drop in general form. Single-phase vapor pressure drop ($\Delta P_v$) can be calculated by multiplying the general form pressure drop with the inlet vapor fraction by weight ($y = 0.3570$) as shown in equation (8). Single-phase liquid pressure drop ($\Delta P_l$) can be calculated by multiplying the general form pressure drop with $(1-y)$ as shown in equation (7) below.

$$\Delta P_{\text{vp}} = K \frac{G_i^2}{\rho \cdot 2g_c} \cdot \rho = \frac{KG_i^2}{2 \rho g_c} \quad (6)$$

$$\Delta P_l = KG_i^2(1-y)^2\left(\frac{1}{2\rho_l g_c}\right) \quad (7)$$

$$\Delta P_v = KG_i^2(y)^2\left(\frac{1}{2\rho_v g_c}\right) \quad (8)$$

Equation (9) expands the pressure loss model to two-phase pressure drop ($\Delta P_{\psi f}$):

$$\Delta P_{\psi f} = \Delta P_l + C\sqrt{\Delta P_l \Delta P_v} + \Delta P_v \quad (9)$$
Where:

\[ C = \text{Correlating Factor For Two-Phase Friction} \]

For \( G < 339 \), \( C = C_0 \left(1 - \frac{5}{\nu \cdot \rho} \right)^5 \).

For both liquid & gas phases turbulent, \( C_0 = 20 \).

Substituting:

\[ C = 20 \left(1 - \frac{9.428 \text{ kg/m}^3}{671.3 \text{ kg/m}^3} \right)^5 = 19.58 \]

[SOLVING FOR \( A_P \)] Solving for \( A_P \) in equation (7) where density of liquid is \( 671.3 \text{ kg/m}^3 \) yields:

\[ A_P = (0.779)(307.715 \text{ kg/m}^3 \cdot s)^2 \left(1 - 0.3570 \right)^2 \left( \frac{1}{(2)(671.30 - 0.3570)} \right) = 22.715 \text{ kg/m}^3 \cdot s \]

[SOLVING FOR \( A_P \)] Solving for \( A_P \) in equation (8) where density of vapor is \( 9.428 \text{ kg/m}^3 \) yields:

\[ A_P = (0.779)(307.715 \text{ kg/m}^3 \cdot s)^2 (0.3570)^2 \left( \frac{1}{(2)(9.43 \text{ kg/m}^3)(1.00)} \right) = 498.56 \text{ kg/m}^3 \cdot s \]

[SOLVING FOR \( A_P \)] Solving for \( A_P \) in equation (9) yields:

\[ A_P = 22.715(19.58)^2 \sqrt{(22.715 \cdot 498.56)} + 498.56 = 2,604.94 \text{ kg/m}^3 \cdot s = 2.61 \text{ kPa} \]
Table 1 summarizes process conditions of Example 1.

<table>
<thead>
<tr>
<th>Process Conditions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mass flowrate (m&lt;sub&gt;total&lt;/sub&gt;)</td>
<td>74.39 kg/s</td>
</tr>
<tr>
<td>Orifice discharge coeff (K)</td>
<td>0.779</td>
</tr>
<tr>
<td>Inlet weight fraction vapor (Y)</td>
<td>0.3579</td>
</tr>
<tr>
<td>Liquid phase density (ρ&lt;sub&gt;L&lt;/sub&gt;)</td>
<td>671.30 kg/m³</td>
</tr>
<tr>
<td>Vapor Phase Density (ρ&lt;sub&gt;v&lt;/sub&gt;)</td>
<td>9.43 kg/m³</td>
</tr>
<tr>
<td>Gravitational Constant (g&lt;sub&gt;c&lt;/sub&gt;)</td>
<td>1.00</td>
</tr>
<tr>
<td>Total Mass Velocity (G&lt;sub&gt;g&lt;/sub&gt;)</td>
<td>307.72 kg/m²·s</td>
</tr>
<tr>
<td>Two-Phase Friction Correlation (C)</td>
<td>19.58</td>
</tr>
</tbody>
</table>

Table 2 summarizes geometry of the inlet flow distributor of Example 1.

<table>
<thead>
<tr>
<th>Orifice Plate Geometry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole Diameter</td>
<td>9.00 mm</td>
</tr>
<tr>
<td>Number of Holes</td>
<td>3800</td>
</tr>
<tr>
<td>Total Hole Area</td>
<td>0.24 m²</td>
</tr>
</tbody>
</table>

Table 3 summarizes calculated pressure drop of Example 1.

<table>
<thead>
<tr>
<th>Pressure Drop</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Phase (ΔP&lt;sub&gt;i&lt;/sub&gt;)</td>
<td>22.715 kg/m·s²</td>
</tr>
<tr>
<td>Vapor Phase (ΔP&lt;sub&gt;i&lt;/sub&gt;)</td>
<td>498.56 kg/m·s²</td>
</tr>
<tr>
<td>Two-Phase (ΔP&lt;sub&gt;off&lt;/sub&gt;)</td>
<td>2605 kg/m·s²</td>
</tr>
</tbody>
</table>
[0040] In closing, it should be noted that the discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication date after the priority date of this application. At the same time, each and every claim below is hereby incorporated into this detailed description or specification as additional embodiments of the present invention.

[0041] Although the systems and processes described herein have been described in detail, it should be understood that various changes, substitutions, and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. Those skilled in the art may be able to study the preferred embodiments and identify other ways to practice the invention that are not exactly as described herein. It is the intent of the inventors that variations and equivalents of the invention are within the scope of the claims while the description, abstract and drawings are not to be used to limit the scope of the invention. The invention is specifically intended to be as broad as the claims below and their equivalents.
REFERENCES

[0042] All of the references cited herein are expressly incorporated by reference. The discussion of any reference is not an admission that it is prior art to the present invention, especially any reference that may have a publication data after the priority date of this application. Incorporated references are listed again here for convenience:

1. US 8,257,508
2. US 5,651,270
CLAIMS

1. A heat-exchanging apparatus comprising:
   an exchanger shell;
   a heat-exchanging core disposed inside the exchanger shell; and
   an inlet flow distributor, e.g. for directing incoming fluid, comprising: a baffle plate with an array of orifice holes, wherein the orifice holes are off-set from the heat-exchanging core.

2. The heat-exchanging apparatus of claim 1, wherein:
   the exchanger shell is a hollow horizontally-oriented exchanger shell;
   the baffle plate further comprises a wall plate, wherein the wall plate directs an incoming fluid through at least one orifice hole; and wherein the apparatus further comprises
   an inlet configured to introduce the incoming fluid into the hollow horizontally-oriented exchanger shell through the inlet flow distributor.

3. The heat-exchanging apparatus of claim 1 or claim 2, wherein the heat-exchanging core is selected from the group consisting of: a brazed aluminum heat exchanger, a plate-fin heat exchanger, a tube bundle, and any combination thereof.

4. The heat-exchanging apparatus of claim 1 or claim 2, wherein the array of orifice holes comprises one or more rows of the orifice holes fashioned on the baffle plate.

5. The heat-exchanging apparatus of claim 4, wherein the array of orifice holes comprises two or more rows of orifice holes, wherein the two or more rows of orifice holes are different in length.

6. The heat-exchanging apparatus of claim 1 or claim 2, wherein the inlet flow distributor is configured to prevent direct impinging of the fluid onto the heat-exchanging core.

7. The heat-exchanging apparatus of claim 1 or claim 2, wherein the at least one inlet nozzle is installed directly over the array of orifice holes.

8. The heat-exchanging apparatus of claim 1 or claim 2, wherein the array of orifice holes has a total area that ranges from about 5% to about 25% of the total area of the baffle plate.
9. The heat-exchanging apparatus of claim 1 or claim 2, wherein the orifice holes have a shape selected from the group consisting of: a circle, a square, a rectangle, a hexagon, a star, a cross, and a combination thereof.

10. The heat-exchanging apparatus of claim 1 or claim 2, wherein the core-in-shell exchanger is installed in a liquefied natural gas plant, a gas plant, an NGL processing plant, an ammonia processing plant, an ammonia refrigeration system, or an ethylene plant.

11. The heat-exchanging apparatus of claim 1 or claim 2, wherein the baffle plate is made from a material selected from the group consisting of: stainless steel, austenitic stainless steel, carbon steel alloy, aluminum, aluminum alloy, and a combination thereof.

12. A heat-exchanging apparatus comprising:
   a hollow horizontally-oriented exchanger shell;
   a heat-exchanging core disposed inside the hollow horizontally-oriented exchanger shell;
   an inlet flow distributor comprising: a baffle plate with an array of orifice holes and a wall plate, wherein the orifice holes are off-set from the heat-exchanging core and the wall plate directs an incoming fluid through at least one orifice hole; and
   an inlet configured to introduce the incoming fluid into the hollow horizontally-oriented exchanger shell through the inlet flow distributor.
FIG. 2
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F28D 7/00 (2014.01)
USPC - 165/160

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(8) - F28B 9/00; F28D 7/00; F28F 9/22 (2014.01)
USPC - 165/11.114,134.1,144,145,157,158,159,160,161 .913

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

CPC - F28B 9/00; F28D 7/00; F28F 9/22 (2014.02)

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

PatBase, Google Patents, Google, YouTube

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 4,550,775 (EDWARDS et al) 05 November 1985 (05.11.1985) entire document</td>
<td>1,3-11</td>
</tr>
<tr>
<td>Y</td>
<td>US 2,830,797 (GARLAND) 15 April 1958 (15.04.1958) entire document</td>
<td>1,2,12</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "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)
- "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

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
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
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
O& document member of the same patent family

Date of the actual completion of the international search: 15 June 2014

Date of mailing of the international search report: 27 JUN 2014

Name and mailing address of the ISA/US

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