

REDUCED VIBRATION TUBE BUNDLE DEVICE HAVING SLOTTED BAFFLES

FIELD OF THE INVENTION

[0001] This invention relates to tube bundle devices such as heat exchangers, condensers and similar fluid-handling equipment with collections of tubes or rod-like elements, for example, in devices such as nuclear reactors, electrical heaters, or any collection of parallel cylindrical shapes that has a fluid flow passing over the tubes or other elements. In particular, the present invention relates to a baffle structure for use in connection with the bundle to provide support to the individual tubes within the bundle and to direct the flow of fluids within the heat exchanger shell towards the heat transfer tubes of the bundle.

BACKGROUND OF THE INVENTION

[0002] Tube bundle equipment such as shell and tube heat exchangers and other similar fluid handling devices such as flow dampers and flow straighteners utilize tubes organized in bundles to conduct the fluids through the equipment. In such tube bundles, there is typically fluid flow both through the inside of the tubes and across the outside of the tubes. The configuration of the tubes in the bundle is set by the tubesheets into which the tubes are set. One common configuration for the tubes is the rectangular or square formation with the tubes set in aligned rows with tube lanes (the straight paths between the tubes) between each pair of rows, aligned orthogonally to one another. In this formation, each tube is adjacent to eight other tubes except at the periphery of the tube bundle and is directly opposite a corresponding tube across the tube lane separating its row from the two adjacent rows. In the triangular tube formation, the tubes in alternate rows are aligned with one another so that each tube is adjacent to six other tubes (the two adjacent tubes in the same row and four tubes in the two adjacent rows).

[0003] Increases in throughput in existing exchangers are often desired either to reduce capital cost by reducing equipment size or to increase productivity factors. A common limiting factor experienced when evaluating the increase of rates in a heat exchanger is the potential for flow-induced vibration damage of the tubes. Fluid flow patterns around the tubes may give rise to flow-induced vibrations of an organized or random oscillatory nature in the tube bundle and in the case of devices such as heat exchangers in which heat transfer takes place between the tubes and the surrounding fluid, the changes in the velocity, temperature and density of the fluid as it circulates and flows around the tubes may increase the likelihood of vibration. If these vibrations reach certain critical amplitudes, damage to the bundle may result. Tube vibration problems may be exacerbated if the heat exchanger equipment is retubed with tubes of a different material to the original tubes, for example, if relatively stiff materials are replaced with lighter weight tubes. Flow-induced vibration may also occur when equipment is put to more severe operating demands, for example, when other existing equipment is upgraded and a previously satisfactory heat exchanger, under new conditions, becomes subject to flow-induced vibrations. Vibration may even be encountered under certain conditions when a heat exchanger is still in the flow stream but without heat transfer taking place as well as in other bundle devices with collections of rods or rod-like elements in a flow stream with or without heat transfer.

[0004] A number of different equipment designs have evolved to deal with the problem of tube vibration. One example is the rod baffle design. Rod baffle heat exchangers are shell and tube type heat exchangers utilizing rod baffles to support the tubes and secure them against vibrations. The term "baffle" refers to the cages, placed every 15 cm or so along the length of the tube bundle, in which the ends of a plurality of support rods are connected to form a cage-like tube support structure; hence the term "rod baffle". Rod baffle exchangers, however, tend to be approximately 30 to 40% more expensive than

conventional shell-and-tube exchangers and there have been situations where tube bundle devices of this kind have failed owing to flow-induced vibrations. The rod baffles must have very precise dimensions. If the rods in rod baffles are slightly undersized, tube chatter will occur. If the rods are slightly oversized, tube loading will be very difficult and expensive. Rod baffle heat exchangers are described, for example, in U.S. Patents Nos. 4,342,360; 5,388,638; 5,553,665; and 5,642,778.

[0005] As described in U.S. Patent No. 5,553,665, certain applications of the rod baffle design such as gas-compression applications may benefit from longitudinal-flow, with shell-side pressure losses to be minimized. Reduction in shell-side pressure losses may be accomplished by increasing rod baffle spacing, thereby reducing the number of rod baffles, or by decreasing the number of tubes by increasing the tube pitch dimension, i.e., the distance between two adjacent rows of tubes as measured from the center of the tubes. Increasing baffle spacing is usually not an attractive option, since increased baffle spacing increases the likelihood of flow-induced tube vibration occurrence. The rod baffle design described in U.S. 5,553,665 represents an attempt to deal with the pressure drop problems of the rod baffle configuration.

[0006] An alternative design is the "Eggcrate" support design. This, however, is even more expensive than the rod baffle design. Like the rod baffle, the eggcrate is also susceptible to tube chatter that could lead to tube failure. Chatter is the motion of a tube hitting the tube supports because of a gap between the support and the tube outside diameter. The gap is required to allow for inserting the tubes through the eggcrate support when the bundle is being constructed.

[0007] Besides good equipment design, other measures may also be taken to reduce tube vibration. Tube support devices or tube stakes as these support devices are commonly known (and referred to in this specification) may be

installed in the tube bundle in order to control flow-induced vibration and to prevent excessive movement of the tubes. A number of tube supports or tube stakes have been proposed and are commercially available. U.S. Patent No. 4,648,442 to Williams, U.S. Patent No. 4,919,199 to Hahn, U.S. Patent No. 5,213,155 to Hahn and U.S. Patent No. 6,401,803 to Hahn, for example, describe different types of tube stake or tube support which can be inserted into the tube bundle to reduce vibration. Improved tube stakes are also shown in U.S. Patent No. 7,032,655 to Wanni et al., entitled "Anti-Vibration Tube Support", the disclosure of which is incorporated herein specifically by reference.

SUMMARY OF THE INVENTION

[0008] It is an aspect of the present invention to provide a tube bundle device (e.g., a heat exchanger) having at least one baffle which supports the tubes in the bundle device. The at least one baffle may consist of at least one slotted support baffle, which support the tubes within a tube bundle while also controlling the flow of fluid within the tube bundle device and at least one blocking baffle, which controls the flow of fluid within the tube bundle device.

[0009] The tube bundle device includes a housing or shell and a tube bundle located within the housing or shell. The tube bundle has a plurality of tubes arranged parallel to one another in tube rows. The tube bundle may include at least one partition lane that separates one group of tubes in the tube bundle from another group of tubes in the tube bundle. The number of partition lanes in the tube bundle is dependent on the number of passes the tubes make through the tube bundle. In the case of a single-pass tube bundle device, the partition lane may be omitted. When multiple passes through the tube bundle device are contemplated, the tube bundle device will include one or more partition lanes to divide the tube bundle into sections.

[0010] In accordance with an aspect of the present invention, the tube bundle device includes at least one slotted support baffle. The slotted support

baffles provide support for the individual tubes within the tube bundle. Each support baffle includes a plurality of spaced apart slots formed therein. Each of the slots being sized to receive at least one of the tubes of the tube bundle therethrough. The cross section of each slot is slightly larger than the outer diameter of the tubes for easy insertion of the tubes within the tube bundle device. Each slotted support baffle has an outer perimeter and a blocking area formed between the outer perimeter and the plurality of spaced apart slots. The blocking area prohibits the flow of fluid therethrough. As result, fluid flowing through the tube bundle device is directed inwardly towards the tube bundle when the fluid contacts the blocking area. The blocking area is sized to be located within a gap between the housing and outer tubes of the tube bundle device. Each slotted support baffle may also include at least one partition lane blocking area formed therein. The partition lane blocking area(s) being sized to be received within the partition lane or lanes of the tube bundle. The partition lane blocking areas prevent the flow of fluid through the partition lanes. As a result, fluid flowing through the partition lane is directed towards the tubes of the tube bundle when the fluid contacts the partition lane blocking area. It is contemplated that in the case of a single-pass tube bundle device, the partition lane will be omitted. Each slotted support baffle may contain a multitude of blocking areas which correspond to the partition lanes in the tube bundle.

[0011] In accordance with an aspect of the present invention, each support baffle may include a first group of the plurality of slots being located on one side of the partition lane blocking area between a portion of the blocking area and the partition lane blocking area and a second group of the plurality of slots being located on another side of the partition lane blocking area between another portion of the blocking area and the central blocking area. The slots may extend in a direction substantially parallel to the partition lane blocking area. Alternatively, the slots may extend in a direction substantially orthogonal to the partition lane blocking area. Support ribs extend between the slots. In some

circumstances (i.e., larger baffle sizes), the ribs may require reinforcement. In accordance with another aspect of the invention, each slotted support baffle may further include at least one reinforcement rib extending in a direction substantially orthogonal to the support ribs and the slots with each rib intersecting at least one rib and at least one slot.

[0012] In accordance with an aspect of the present invention, it is contemplated that the tube bundle device includes at least two slotted support baffles. In particular, it is contemplated that the tube bundle device includes at least one first oriented slotted support baffle and at least one second oriented slotted support baffle. Each of the first oriented slotted support baffles being spaced from an adjacent second oriented slotted support baffle. With such an arrangement, the plurality of spaced apart slots on the first oriented slotted support baffle have first orientation and the plurality of spaced apart slots on the second oriented slotted support baffle have a second orientation, which is different from the first orientation. The partition lane blocking areas for the first oriented slotted support baffle and the second oriented slotted support baffle may have the same orientation. Each of the first oriented slotted baffle and each of the at least one second oriented slotted support baffle includes a first group of slots being located on one side of the partition lane blocking area and a second group of slots being located on another side of the partition lane blocking area. Each slot of the first group and each slot of the second group for the first oriented slotted support baffle may extend in a direction substantially parallel to the partition lane blocking area. Each slot of the first group and each slot of the second group for the second oriented slotted support baffle extends in a direction substantially perpendicular to the partition lane blocking area.

[0013] In accordance with another aspect of the present invention, the tube bundle device includes at least one blocking baffle. Unlike the support baffle, the blocking baffle does not support the tubes. Instead, the blocking baffle functions to control the flow of fluid within the tube bundle device. Each

blocking baffle includes a blocking plate having an outer perimeter and at least one plate opening sized to receive the tubes of the tube bundle device therethrough. A blocking plate blocking area is formed between the outer perimeter of the blocking plate and the at least one plate opening. The blocking plate blocking area prevents the flow of fluid therethrough. As a result, fluid flowing through the tube bundle device is directed inwardly towards the tube bundle when the fluid contacts the blocking plate blocking area. The blocking plate blocking area is sized to be located within a gap between the housing and outer tubes of the tube bundle. The blocking plate baffle may further include at least one partition lane blocking plate blocking area formed therein. The number of partition lane blocking plate blocking areas is dependent upon the number of partition lanes within the tube bundle. As discussed above, the tube bundle may not include a partition lane (e.g., a single-pass heat exchanger typically does not include partition lanes). As such, the partition lane blocking plate blocking area may be omitted. Each partition lane blocking plate blocking area is sized to be received within a corresponding partition lane of the tube bundle device. The partition lane blocking plate blocking area may extend, for example, from opposing sides of the blocking plate blocking area between two openings in the plate when the blocking plate baffle is used in a U-bend tube bundle device having two passes therethrough. The partition lane plate blocking area prevents the flow of fluid therethrough. As a result, fluid flowing through the partition lane is directed towards the tubes of the tube bundle when the fluid contacts the partition lane blocking plate blocking area.

[0014] In accordance with another aspect of the present invention, a blocking baffle is located between adjacent slotted support baffles.

[0015] In accordance with another aspect of the present invention, at least one elongated tube support member is provided to support the tubes of the tube bundle to reduce vibration. Each elongated tube support member is selectively located in the space formed between adjacent rows of tubes. The elongated tube

supports may be inserted between the tubes between the blocking and slotted support baffles.

[0016] It is another aspect of the present invention to provide a method of controlling the flow of fluid within a tube bundle device. The method includes redirecting at least a portion of the flow of fluid in the gap to the tube bundle. The method further includes redirecting at least a portion of the flow of fluid in the partition lane to the tube bundle. The redirecting of the fluid flow is accomplished by locating the baffles at selected locations along the tube bundle. The blocking areas and blocking plate blocking areas on the slotted support baffles and the blocking baffles redirect the flow of fluid away from the gap between the housing or shell and the tube bundle into the tube bundle to improve heat transfer. The partition lane blocking areas redirect the flow of fluid away from the partition lane to improve heat transfer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The invention will now be described in conjunction with the accompanying drawings in which like reference numerals describe like elements and wherein:

Fig. 1 is a schematic view of a tube bundle having tubes supported using baffles in accordance with an embodiment of the present invention;

Fig. 2 is an end view of a slotted baffle having vertical slots in accordance with an embodiment of the present invention;

Fig. 3 is an end view of a slotted baffle having horizontal slots in accordance with an embodiment of the present invention;

Fig. 4 is an end view of a variation of the slotted baffle having horizontal slots as shown in Fig. 3;

Fig. 5 is an end view of a blocking baffle in accordance with an embodiment of the present invention;

Fig. 6 is a schematic view of a tube stake used in accordance with an embodiment of the present invention; and

Fig. 7 is a schematic view of another tube stake used in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] The present invention will now be described in greater detail in connection with the figures. Fig. 1 is a schematic view of a tube bundle 10 in accordance with an aspect of the present invention. The tube bundle 10 is part of a tube bundle device 1 (e.g., a heat exchanger or other suitable heat transfer component). The tube bundle 10 includes a plurality of parallel tubes 11. It is contemplated that the present invention is not limited to tubes; rather, it is contemplated that the rods and other heat transfer or fluid flow elements may be employed and are considered to be well within the scope of the present invention. As shown in Fig. 1, the parallel tubes 11 extend between a pair of tubes sheets 13 and 14. The tubesheet 13 may be a fixed tubesheet that is welded to the housing or shell 20. The tubesheet 13 may also be a stationary tubesheet that is secured, but not welded to the housing 20. The tubesheet 14 illustrated in Fig. 1 is a floating tubesheet. The tubes 11 may be arranged in a rectangular configuration. The present invention, however, is not intended to be limited to the parallel tubes extending between a pair of tubesheets 13 and 14; rather, it is contemplated that a single tubesheet may be used. With such an arrangement, the parallel tubes extend along one side of the bundle through a U-bend portion and returning along the opposing side of the bundle. It is contemplated that the tube bundle 10 will be fitted into the surrounding shell or housing 20 of the tube bundle device 1 in a conventional manner.

[0019] The tube bundle device 1 includes a shell or housing 20, which surrounds the tube bundle 10. There is typically fluid flow both through the inside of the tubes 11 and within the shell 20 across the outside of the tubes 11. As discussed above, there is a need to reduce flow-induced vibration within the tube bundle 10 to avoid damage to the bundle 10. It is also desirable to provide an assembly to reduce vibration in the tube bundle, which directs the flow of the fluid towards the tubes 11 away from the shell 20 of the tube bundle device inwardly towards to tube bundle 10. By directing the flow of fluid away from the shell 20 towards the tubes 11 of the tube bundle 10 and away from the partition lane(s) of the bundle, which do not contain any tubes towards the tubes 11, heat transfer is improved.

[0020] In accordance with an aspect of the present invention, the tube bundle 10 of the heat exchanger 1 is provided with at least one slotted baffle 30 having vertical slots. The slotted baffle 30 having vertical slots provides support for the tubes 11 in the bundle 10 to reduce vibration. The blocking region of the slotted baffle 30 is configured to redirect any bypass flow from between the outermost tubes 11 and the inside diameter of the shell 20 inwardly towards the tubes 11. A slotted baffle 30 having vertical slots in accordance with an embodiment of the present invention is illustrated in Fig. 2. The slotted baffle 30 having vertical slots is constructed from a plate having an outer diameter, which corresponds to the inner diameter of the shell 20 (The outer diameter of the plate is slightly smaller than the inner diameter of the shell). The plate includes a plurality of notches 32 and 33 formed therein. It is contemplated that the notches 32 and 33 may be formed by any one of several means that is capable of creating a notch in the plate including but not limited to cutting, laser cutting, grinding, water cutting, stamping and punching. The notches 32 are sized to receive a tie bar 5 therein. It is contemplated that the tie bar 5 may also contain complementary notches to receive the notches 32 therein. The notches 33 are sized to receive a skid bar 6 therein. The skid bar 6 is provided to ensure

support during insertion of the tube bundle 10 into the shell 20. The notches 32 and 33 ensure that the slotted baffle 30, the slotted baffle 40 or 50 having horizontal slots (described below) and the blocking baffles 60 (described below) are maintained in the proper orientation. The tie bars 5, the skid bars 6 and the baffles 30, 40 and 60 together form a rigid cage, which facilitates the insertion of the tubes 11 of the bundle 10. The tie bars 5 and the skid bars 6 are preferably welded or otherwise secured to the notches 32 and 33 in the baffles 30, 40, and 50. It is contemplated that the tie bars 5 are sized such that the tie bars 5 do not extend beyond the perimeter of the plate. The skid bars 6, however, preferably extend outwardly beyond the perimeter of the plate about 1/32 inches or 0.8 mm. The skid bars 6 form rails upon which the tube bundle 10 rides as it is slid into place within the shell 20.

[0021] Extending inwardly from the perimeter of the plate toward the center of the plate is a blocking area 34. The blocking area 34 is sized to approximately occupy the area between the tube bundle 10 and the inner surface of the shell 20. It is contemplated that a small gap will remain between the inner surface of the shell 20 and the outer perimeter of the baffle 30 to permit insertion of the bundle 10 into the shell or housing 20. The blocking area 34 is provided to block the flow of the fluid flowing within the space between the tube bundle 10 and the shell 20. The blocking area 34 redirects the flow within the tube bundle device 1 away from the shell 20 towards the tubes 11 of the tube bundle 10 to minimize the flow of fluid bypassing the bundle 10. This improves the efficiency of the heat exchanger by directing more fluid across the heat exchange surfaces of the tubes 11.

[0022] Typically, the tube bundle 10 includes at least one partition lane, which separates the tubes 11 within the tube bundle 10 into discrete groups. The partition lanes do not include any tubes 11. The partition lanes may have horizontal and vertical orientations. Fluid flowing through the partition lanes does not contact the heat transfer surfaces of the tubes 11. As such, it is

desirable to redirect the flow of fluid within the bundle 10 away from the partition lanes towards the tubes 11 to improve heat transfer. The baffle 30 includes at least one partition lane blocking area 35. The at least one partition lane blocking area 35 is sized to be received within the partition lanes of the tube bundle 10. Like the blocking area 34, the partition lane blocking areas 35 redirect the flow of fluid within the shell of the heat exchanger 1 towards the tubes 11 of the tube bundle 10. The partition lane blocking area 35 redirects the flow of fluid within the partition lane towards the tubes 11 of the bundle 10 to minimize the amount of fluid bypassing the tubes 11. This also improves the efficiency of the heat exchanger by directing more fluid across the heat exchange surfaces of the tubes 11. The presence of this crossflow component across tubes 11 in the bundle 10 improves heat transfer compared to the pure axial flow that would otherwise exist in this type of exchangers without the baffles in accordance with the present invention.

[0023] As shown in Fig. 2, the slotted baffle 30 includes a plurality of vertical slots 36 located on opposing sides of the partition lane blocking area 35. The slotted baffle 30 illustrated in Fig. 2 is configured for use in tube bundle having a central partition lane (i.e., for use in a U-bend tube bundle with two passes through the tube bundle device). In the case of a single-pass tube bundle device, the partition lane is omitted. As such, the slots 36 extend across the entire slotted baffle 30. The slots 36 are sized to receive and support the tubes 11 of the tube bundle 10. For purposes of illustration, several tubes 11 of the tube bundle 10 are illustrated in Fig. 2. As shown, the vertical slots 36 extend in a direction that is generally perpendicular to the partition lane blocking area 35. As discussed above, it is contemplated that the partition lanes may have horizontal orientations, vertical orientations and/or vertically oriented segments and horizontally oriented segments. As such, the partition lane blocking area 35 may have a horizontal orientation, a vertical orientation or vertically oriented segments with horizontally oriented segments. The vertical slots 36 are

perpendicular to the horizontal partition lanes or horizontal partition segments and parallel to the vertical partition lanes or vertical partition segments. The slots 36 are arranged to correspond to the rows of the tubes 11 in the bundle 10. A plurality of vertically extending ribs 37 are provided on the baffle 30. Each rib 37 extends vertically between the slots 36, as shown in Fig. 2. Each rib 37 preferably has a thickness that is slightly smaller than the spacing between adjacent tubes 11 in the tube bundle 10. This spacing aids in the assembly process because the tubes 11 can be easily loaded into the bundle, as described in greater detail below.

[0024] In accordance with the present invention, the slots 36 can be formed by cutting, laser or water cutting, drilling and stamping. It is contemplated that other fabrication techniques are considered to be well within the scope of the present invention provided such technique is capable of creating a slot 36 that is sized to receive at least one tube 11 therein. It is also preferable that the fabrication technique be suitable for the creation of multiple baffles 30.

[0025] The size of the baffle 30 is based upon the size of the exchanger 1. In some circumstances, the length of slot 36 may be sufficient such that the ribs 37 require additional reinforcement for stability and strength. This can be accomplished in one of several ways including increasing the thickness of the plate. It is also possible to include at least one reinforcement rib that extends generally orthogonal to the ribs 37. The ribs may interconnect the ribs 37 for stability. The reinforcement ribs would have a width similar to or greater than the width of the ribs 37. An example of a reinforcement rib is illustrated in Fig.4 as rib 48.

[0026] The tube bundle 10 of the heat exchanger 1 is provided with at least one slotted baffle 40 having horizontal slots. Fig. 3 illustrates the slotted baffle 40 having horizontal slots that provides support for the tubes 11 in the bundle 10 to reduce vibration. Like baffle 30, the baffle 40 is configured to

redirect the flow of fluid away from the gap between the outer tubes 11 of the tube bundle 10 and the inner surface of the shell 20 inwardly towards the tubes 11 in the bundle 10 away from the shell 20 and outwardly away from the partition lanes towards the tubes 11. The slotted baffle 40 is constructed from a plate having an outer circumference, which corresponds to the general circumference of the shell 20. The plate includes a plurality of notches 32 and 33 formed therein and described above in connection with baffle 30.

[0027] Extending inwardly from the perimeter of the plate toward the center of the plate is a blocking area 44. The blocking area 44 has a similar construction of the blocking area 34. The blocking area 44 is configured to direct the flow within the tube bundle device away from the shell 20 towards the tubes 11 of the tube bundle 10 to minimize the flow of fluid bypassing the bundle 10. This improves the efficiency of the heat exchanger by directing more fluid across the heat exchange surfaces. The baffle 40 may also include at least one partition lane blocking area 45. Like the partition lane blocking area 35, the partition lane blocking areas 45 are sized to be received within the partition lanes of the tube bundle 10. Like the blocking area 44, the partition lane blocking areas 45 redirects the flow of fluid within the tube bundle device 1 towards the tubes 11 of the tube bundle 10. The partition lane blocking areas 45 redirect the flow of fluid within the partition lane towards the tubes 11 of the bundle 10 to minimize the amount of fluid bypassing the tubes 11. In single-tube-pass exchangers, there may be no partition lanes.

[0028] As shown in Fig. 3, the slotted baffle 40 includes a plurality of horizontal slots 46. As shown in the two pass tube bundle device in Fig.3, the slots 46 are located on opposing sides of the partition lane blocking area 35. The slots 46 are sized to receive and support the tubes 11 of the tube bundle 10. For purposes of illustration, several tubes 11 of the tube bundle 10 are illustrated in Fig. 3. As shown, the horizontal slots 46 extend in a direction that is generally perpendicular to the partition lane blocking area 35. As discussed above, it is

contemplated that the partition lanes may have horizontal orientations, vertical orientations and/or vertically oriented segments and horizontally oriented segments. As such, the partition lane blocking area 35 may have a horizontal orientation, a vertical orientation or vertically oriented segments with horizontally oriented segments. The horizontal slots 37 are parallel to the horizontal partition lanes or horizontal partition segments and perpendicular to the vertical partition lanes or vertical partition segments. A plurality of horizontally extending ribs 47 are provided on the baffle 40. Each rib 47 extends between the slots 46, as shown in Fig. 3. Each rib 47 preferably has a thickness that is slightly smaller than the spacing between adjacent tubes 11 in the tube bundle 10.

[0029] In accordance with the present invention, like slots 36, the slots 46 can be formed by cutting, laser or water cutting, drilling and stamping. It is contemplated that other fabrication techniques are considered to be well within the scope of the present invention provided such technique is capable of creating a slot 46 that is sized to receive at least one tube 11 therein. It is also preferable that the fabrication technique be suitable for the creation of multiple baffles 40.

[0030] A variation of the baffle 40 is shown in Fig. 4. The slotted baffle 50 includes horizontal slots having at least one vertical rib 48. The vertical ribs 48 interconnect the ribs 47 to reinforce the ribs 47. The ribs 48 would have a width similar to or greater than the width of the ribs 47. While a single vertical rib 48 is shown, it is contemplated that additional ribs 47 may be provided to provide additional stability. This is especially useful for larger sized baffles, which are used in larger exchangers.

[0031] Applicants note that the terminology horizontal and vertical when used in connection with the present invention is intended as a point of reference to describe the orientation of the individual components of the baffles with respect to the other components of the baffles. The terminology is not intended

to describe the orientation of the baffles or components, which make up the baffles within the heat exchanger. It is contemplated that the tube bundle device 1 can have one of several orientations when in use. Thus the tube bundle device can be in general oriented horizontally, vertically or any angle relative to the horizontal.

[0032] The tube bundle 10 of the heat exchanger 1 is preferably provided with at least one blocking baffle 60. The blocking baffle 60 is configured to direct the flow of fluid inwardly towards the tubes 11 in the bundle 10 away from the shell 20 and outwardly away from the partition lane of the bundle. A blocking baffle 60 in accordance with an embodiment of the present invention is illustrated in Fig. 5. The blocking baffle 60 is constructed from a plate having an outer circumference, which corresponds to the general circumference of the shell 20. The plate includes a plurality of notches 32 and 33 formed.

[0033] Extending inwardly from the perimeter of the plate toward the center of the plate is a blocking area 64. The blocking area 64 is sized to approximately occupy the area between the tube bundle 10 and the inner surface of the shell 20. A small gap will remain between the baffle 60 and the inner surface of the shell 20 to permit insertion of the tube bundle 10 into the shell 20. The blocking area 64 is provided to redirect the flow of the fluid flowing within the gap between the outer tubes of the tube bundle 10 and the inner surface of the shell 20. The blocking area 64 redirects the flow within the heat exchanger away from the shell 20 towards tube bundle 10 to minimize the flow of fluid bypassing the bundle 10. This improves the efficiency of the heat exchanger by directing more fluid across the heat exchange surfaces.

[0034] As discussed above, the tube bundle 10 may include at least one partition lane. Like the baffles 30 and 40, the baffle 60 includes a partition lane blocking area 65. The partition lane blocking area 65 is sized to be received within the partition lane of the tube bundle 20 in the manner described above in

connection with blocking areas 35 and 45. Like the blocking area 64, the partition lane blocking area 65 redirects the flow of fluid within the heat exchanger 1 towards the tubes 11 of the tube bundle 10. Openings 66 and 67 are formed on opposing sides of the partition lane blocking area 35. The openings 66 and 67 are sized to receive the tubes 10 of the bundle 11 therethrough. In the event that the tube bundle 10 includes multiple partition lanes, the number of openings in the baffle 60 will increase to correspond to the groupings of the tubes 11 within the bundle 10. Also, in the event that the tube bundle device 1 is a single-pass device, in general, no partition lanes are present. In such a configuration, the baffle 60 will include a single opening.

[0035] The assembly of the tube bundle device 1 will now be described in greater detail. A rigid cage for the tube bundle 10 is constructed using the tie bars 5, skid bars 6 and the baffles 30, 40, and 60. The rigid cage is formed by securing the tie bars 5 and skid bars 6 within the respective slots 32 and 33 in the baffles 30, 40, and 60. As discussed above, the tie bars 5 and the skid bars 6 are preferably secured within the slots 32 and 33 by welding or other suitable attachment mechanism. The slotted baffles 30 and slotted baffles 40 or 50 are spaced between two (2) feet and five (5) feet apart with an alternating pattern as shown in Fig. 1. At least one blocking baffle 60 may be located between the vertical and horizontal baffles, as shown in Fig. 1.

[0036] Once the rigid cage has been assembled, the tubes 11 of the tube bundle 10 may be inserted into the cage. The tubes 11 are loaded into the bundle 10 by inserting the tubes 11 through the slots 36 and 46 in the baffles 30 and 40 and the openings 66 and 67 in the baffles 60. The ribs 37 and 47 of the baffles 30 and 40 cooperate to form a support structure for the tubes 11. The ribs 37 and 47 support the tubes 11 and prevent the tubes 11 from coming into contact with adjacent tubes 11. After the tubes 11 are located within the cage, the tubesheets 13 and 14 may be secured to the ends of the bundle 10. This is accomplished by welding or otherwise securing the end of each tube 11 to a tubesheet. As

discussed above, at least one of the tubesheets is stationary. It is contemplated that the ends of the tubes can be secured to a pair of tubesheets 13, one stationary tubesheet 13 and one floating tubesheet 14 or one stationary tubesheet 13 when the U-tubes are used such that both ends of the tubes are secured to the same tubesheet 13. The assembled tube bundle 10 is inserted into the shell 20 by sliding the bundle 10 along skid bars 6 into the shell. Once the bundle 10 is properly oriented within the shell 20, the tubes sheets 13 are secured to the shell 20.

[0037] As discussed above, a gap exists between the bundle 10 and the shell 20. As fluid flows within the shell 20, some fluid will migrate towards the gap and flow through the gap area of the exchanger. This effectively lowers the heat transfer efficiency of the exchanger. The slotted baffles 30, 40 and 60 are provided to redirect the flow of fluid inwardly towards the tubes 11 of the bundle 10. The fluid flowing within the gap comes in contact with the slotted baffles 30, 40 and 60. The blocking areas 34, 44, 54 and 64 block and redirect the flow of the fluid in the gaps areas. As such, the fluid is redirected inwardly to flow through the slots 36 and 46 and open areas 66 and 67. The flow of fluid through the slots 36 and 46 and the open areas 66 and 67 causes the fluid to flow pass the tubes 11, which contain heat transfer surfaces. The partition lane blocking areas 35, 45, 55, and 65 block or inhibit the flow of fluids within the partition lanes in the bundle 10. As fluid flows within the partition lanes, the partition lane blocking areas 35, 45 and 65 redirect the fluid flow away from the partition lane into the tube bundle 10 such that the fluid comes into contact with the tubes 11. The placement of the baffles 30, 40 and 60 at spaced locations along the tube bundle 20 is sufficient to redirect the flow of fluid away from the areas within the heat exchanger 1 that do not include heat transfer elements to those areas with heat transfer capabilities.

[0038] In addition to redirecting the flow of fluid within the shell 20, the baffles 30, 40 and 50 also function to reduce tube vibration. The ribs 37 and 47

on baffles 30 and 40 have different orientations with respect to each other. The ribs 37 and the surrounding blocking areas 34 and 35 on the baffle 30 limit the relative movement of the tubes 11. Depending on their location within the bundle 10, each tube 11 has either one rib 37 located on opposing sides of the tube 11, one rib 37 and the blocking area 34 located on opposing sides of the tube 11, or one rib and the partition lane blocking area 35 located on opposing side of the tube 11. The ribs 37 and the blocking areas 34 and 35 limit movement of the tubes 11 in a direction that is in the same plane as the plate 31 and substantially orthogonal to the ribs 37. In the event that tube 11 begins to vibrate, such vibration is curtailed through contact with the adjacent ribs 37 and/or blocking areas 34 and 35.

[0039] The ribs 47 and the surrounding blocking areas 44 or 54 and 45 or 55, as shown on Figs. 3 and 4, on baffle 40 limit the relative movement of the tubes 11. Depending on their location within the bundle 10, each tube 11 has either one rib 47 located on opposing sides of the tube 11, one rib 47 and the blocking area 44 or 54 located on opposing sides of the tube 11, or one rib and the partition lane blocking area 45 or 55 located on opposing side of the tube 11. The ribs 47 and the blocking areas 44 or 54 and 45 or 55 limit movement of the tubes 11 in a direction that is in the same plane as the plate 41 and substantially orthogonal to the ribs 47 and parallel to ribs 37. In the event that tubes 11 begin to vibrate, such vibration is curtailed through contact with the adjacent ribs 47 and/or blocking areas 44 or 54 and 45 or 55.

[0040] The use of baffles 30 and 40 or 30 and 50 in concert effectively reduce vibration of the tubes 11 within the bundle 10, but are not sufficient to prevent vibration. The tubes 11 may still be deflected by flow and for this reason, it may be desirable to use at least one tube support stake 70 and/or 80 between the tubes 11 of the bundle 10, resulting in greater axial strength and minimize vibration. The stakes 70 and/or 80 may be located at spaced locations between the baffles 30, 40, 50 and 60 within the tube bundle 10, as shown in Fig.

1. In addition, the use of tube supports deflects each tube in a sinusoidal fashion. This tends to disrupt the axial shell side flow that provides a cross-flow component, thus improving heat transfer. In other words, the tube supports that are mainly used for the purpose of ensuring a robust tube bundle would also lead to a heat-transfer enhancement.

[0041] The absence of complete support from the stakes 70 or 80 does not, however, diminish the effectiveness of the baffles 30, 40 and 60 to support the tubes 11 and direct the flow of fluid within the exchanger 1. In the rectangular tube arrangement, the alternating vertical/horizontal disposition of the ribs 37 and 47 will result in the stakes 70 in each set being parallel to the ribs 37 and 47 of one of the adjacent baffles 30 and 40 so that the tubes 11 are held by the stakes 70 firmly against the ribs to which they are parallel. Similarly, in the triangular tube arrangement, it is preferable for the orientation of the stakes at a given location to be parallel to the ribs of one of the baffles 30 and 40 in order to hold the tubes 11 firmly against the ribs of that baffle.

[0042] The tube stakes 70 or 80 which may be used may be of any type commonly used for that purpose, provided that they are dimensioned to impart the increased tube separation on insertion into the tube bundle to hold the tubes firmly against the support rods of the cages and have a mechanism for retaining their position in the bundle at all times. Thus, for example, the tube stakes described in U.S. Patent No. 4,648,442 to Williams, U.S. Patent No. 4,919,199 to Hahn, U.S. Patent No. 5,213,155 to Hahn and U.S. Patent No. 6,401,803 to Hahn might be used provided that their dimensions are satisfactory to the purpose. The preferred type of tube stakes are, however, shown in Figs. 6 and 7 and disclosed in U.S. Patent No. 7,032,655 to Wanni et al. and U.S. Patent Application No. 11/128,884 to Wanni et al., the disclosures of which are incorporated specifically herein by reference.

[0043] The tube stakes 70 are inserted to stiffen the tube bundle 10 with the stakes 70 being inserted into the bundle 10 around the midpoint between adjacent baffles 30 and 40. With such an arrangement, it is possible for the stakes 70 to be located in close proximity to the blocking baffles 60. Because the tubes 10 receive support from the baffles 30 and 40, as described above, it is not necessary to insert the stakes 70 into each tube lane (i.e., the lanes between adjacent rows of tubes 11). Although insertion of the tube support stakes into the same tube lanes at successive locations will make the bundle stronger, it is possible to insert the stakes only into alternate tube lanes with the insertion lane alternating at each successive location. For example, the stakes may be inserted into the odd-numbered tube lanes at the first location, into the even-numbered lanes at the second location and so on along the length of the tube bundle at successive stake set locations. The direction of insertion (alignment) for the stakes 70 is made to alternate in the same way as the baffles 30 and 40, namely, the stakes 70 are inserted in a different direction at each station or location where they are inserted into the bundle. It is also possible to insert additional stakes at bundle entrance or exit regions, or any other locations as necessary, to tighten up any loose tubes.

[0044] Fig. 6 illustrates an example of a tube stake or support 70. This type of tube stake or support includes corrugations along the inner portion (within the tube bundle) which deflect the tubes slightly to provide resilient support for the tubes while, at the same time, enabling the stakes to be readily inserted into the bundle; at its outer extremity, each stake has dimples which deflect the tubes slightly in the same way as the corrugations but which lock more securely onto the outermost tubes so as to minimize the likelihood of undesirable dislocation of the stakes strips during handling or in operation.

[0045] The tube support or stake 70 is formed from a strip of metal which extends in tube lane defined by the tubes 11 on the two sides of the lane. In the complete tube bundle, there will be additional tubes extending in the row formed

by a continuation of the tube rows, with other tube rows arranged in similar conventional manner making up the tube bundle. The tube lanes between these two adjacent rows and other adjacent rows of tubes will be similarly extensive across the tube bundle. Each tube stake 70 has transverse rows of raised tube-engaging zones. The tube-engaging zones may be formed as rows of alternating dimples 71 or corrugations 72 or combinations 73 thereof. With such an arrangement, dimples 71 and/or corrugations 72 and/or combinations 73 extend from opposing sides of the stake 70.

[0046] Fig. 7 illustrates another example of a tube support 80 for use in connection with the present invention. Tube support 80 comprises an elongated flat member made up of two flat strips of metal 81, 82 secured together. The tube support 80 includes at least one tube-engaging zone 83.

[0047] It will be apparent to those skilled in the art that various modifications and/or variations may be made without departing from the scope of the present invention. Thus, it is intended that the present invention covers the modifications and variations of the apparatus and methods herein, provided they come within the scope of the appended claims and their equivalents.

CLAIMS:

1. A tube bundle device comprising:

a housing;

a tube bundle located within the housing, wherein the tube bundle having a plurality of tubes arranged parallel to one another in tube rows; and

at least one slotted support baffle having a plurality of spaced apart slots formed therein, wherein each of the plurality of spaced apart slots being sized to receive at least one of the tubes therethrough,

wherein each slotted support baffle having an outer perimeter and a blocking area formed between the outer perimeter and the plurality of spaced apart slots,

wherein the blocking area being sized to be located within a gap between the housing and outer tubes of the tube bundle.

2. The tube bundle device according to 1, further comprising at least one blocking baffle, wherein each blocking baffle comprising:

a blocking plate having an outer perimeter;

at least one plate opening sized to receive the tubes of the tube bundle therethrough; and

a blocking plate blocking area formed between the outer perimeter of the blocking plate and the at least one plate opening,

wherein the blocking plate blocking area being sized to be substantially located within a gap between the housing and outer tubes of the tube bundle.

3. The tube bundle device according to claim 2, wherein the tube bundle having at least one partition lane separating a portion of the tubes of the tube bundle with another portion of the tubes of the tube bundle, wherein each of the at least one blocking baffle having at least one partition lane blocking plate blocking area formed therein, wherein each of the at least one partition lane blocking plate blocking area being sized to be received within a corresponding at least one partition lane of the tube bundle.

4. The tube bundle device according to claim 1, wherein the tube bundle having at least one partition lane separating a portion of the tubes of the tube bundle with another portion of the tubes of the tube bundle, wherein each of the at least one slotted support baffle having at least one partition lane blocking area formed therein, wherein each partition lane blocking area being sized to be received within the corresponding partition lane of the tube bundle.

5. The tube bundle device according to claim 4, wherein each support baffle comprising:

a first group of the plurality of slots being located on one side of the at least one partition lane blocking area between a portion of the blocking area and the partition lane blocking area; and

a second group of the plurality of slots being located on another side of the partition lane blocking area between another portion of the blocking area and the partition lane blocking area.

6. The tube bundle device according to claim 5, wherein each slotted support baffle further comprising:

a plurality of support ribs, wherein each support rib extends substantially parallel to the plurality of slots.

7. The tube bundle device according to claim 6, wherein each slotted support baffle further comprising:

at least one reinforcement rib extending in a direction substantially orthogonal to the support ribs and the slots, wherein each rib intersecting at least one rib and at least one slot.

8. The tube bundle device according to claim 1, comprising at least one first oriented slotted support baffle and at least one second oriented slotted support baffle,

wherein each of the first oriented slotted support baffles being spaced from an adjacent second oriented slotted support baffle,

wherein the plurality of spaced apart slots on the first oriented slotted support baffle having first orientation and the plurality of spaced apart slots on the second oriented slotted support baffle having a second orientation, which is different from the first orientation.

9. The tube bundle device according to claim 8, wherein the tube bundle having at least one partition lane separating a portion of the tubes of the tube bundle with another portion of the tubes of the tube bundle,

wherein each of the first oriented slotted support baffle and each of the at least one second oriented slotted support baffle having at least one partition lane blocking area formed therein,

and

wherein each of at least one partition lane blocking area being sized to be received within a corresponding partition lane of the tube bundle.

10. The tube bundle device according to claim 9, wherein each of the first oriented slotted baffle and each of the at least one second oriented slotted support baffle comprising:

a first group of slots and a second group of slots spaced from the first group of slots and separated by a partition lane blocking area therebetween.

11. The tube bundle device according to 8, further comprising at least one blocking baffle, wherein each blocking baffle comprising:

a blocking plate having an outer perimeter;

at least one plate opening sized to receive the tubes of the tube bundle therethrough; and

a blocking plate blocking area formed between the outer perimeter of the blocking plate and the at least one plate opening,

wherein the blocking plate blocking area being sized to be located substantially within a gap between the housing and outer tubes of the tube bundle.

12. The tube bundle device according to claim 11, wherein one of the at least one blocking baffle being located between adjacent first oriented slotted baffles and second oriented slotted baffles.

13. The tube bundle device according to claim 1, further comprising:

at least one elongated tube support member, wherein the at least one elongated tube support member being selectively located in the space formed between adjacent rows of tubes, wherein each elongated tube support member having a tube engaging zone for engaging an adjacent tube in the tube bundle.

14. The tube bundle device according to claim 8, further comprising:

at least one elongated tube support member, wherein the at least one elongated tube support member being selectively located in the space formed between adjacent rows of tubes, wherein each elongated tube support member having a tube engaging zone for engaging an adjacent tube in the tube bundle, wherein the at least one elongated tube support member being located between adjacent first oriented and second oriented support baffles.

15. The tube bundle device according to claim 12, further comprising:

at least one elongated tube support member, wherein the at least one elongated tube support member being selectively located in the space formed between adjacent rows of tubes, wherein each elongated tube support member having a tube engaging zone for engaging an adjacent tube in the tube bundle.

16. A slotted support baffle for use in supporting a plurality of tubes in a tube bundles, comprising:

a plate having an outer perimeter;

a plurality of spaced apart slots formed in the plate, wherein each of the plurality of spaced apart slots being sized to receive at least one of the tubes in the tube bundle therethrough; and

a blocking area formed between the outer perimeter and the plurality of spaced apart slots.

17. The slotted support baffle according to claim 16, further comprising:
- at least one partition lane blocking plate blocking area formed therein interconnecting one portion of the blocking area with another portion of the blocking area,
 - wherein a first group of the plurality of slots being located on one side of one of the at least one partition lane blocking area between a portion of the blocking area and the partition lane blocking area; and
 - a second group of the plurality of slots being located on another side of one of the at least one partition lane blocking area between another portion of the blocking area and the partition lane blocking area.
18. The slotted support baffle according to claim 17, further comprising:
- a plurality of support ribs, wherein each support rib extends substantially parallel to the plurality of slots.
19. The slotted support baffle according to claim 18, wherein each slotted support baffle further comprising:
- at least one reinforcement rib extending in a direction substantially orthogonal to the support ribs and the slots, wherein each rib intersecting at least one rib and at least one slot.
20. The slotted support baffle according to claim 19, further comprising a plurality of ribs, wherein each rib extends from a portion of the blocking area to another portion of the blocking area, wherein each rib extends substantially parallel to the plurality of slots and the partition lane blocking portion.

21. A blocking baffle for use with a tube bundle device having a plurality of tubes, comprising:

a plate having an outer perimeter;

a pair of openings formed in the plate, wherein each of the pair of openings being sized to receive a portion of the tubes of the tube bundle device; and

a blocking area formed between outer perimeter and the pair of openings.

22. A blocking baffle according to claim 21, further comprising:

at least one partition lane blocking plate blocking area formed therein interconnecting one portion of the blocking area with another portion of the blocking area.

23. A method of controlling the flow of fluid within a tube bundle device, wherein the tube bundle device having a housing and tube bundle located therein, wherein the tube bundle having a plurality of spaced parallel tubes, wherein a gap exists between the housing and the tube bundle, wherein the tube bundle having a partition lane separating a first group of the spaced parallel tubes from a second group of the spaced parallel tubes, the method comprising:

redirecting at least a portion of the flow of fluid in the gap to the tube bundle; and

redirecting at least a portion of the flow of fluid in the partition lane to the tube bundle.

24. The method according to claim 23, wherein redirecting at least a portion of the flow of fluid in the gap to the tube bundle comprising:

providing at least one slotted support baffle at a predetermined locations on the tube bundle having a plurality of spaced apart slots formed therein, wherein each of the plurality of spaced apart slots being sized to receive at least one of the tubes therethrough, wherein each slotted support baffle having an outer perimeter and a blocking area formed between the outer perimeter and the plurality of spaced apart slots, wherein the blocking area being sized to be substantially located within a gap between the housing and outer tubes of the tube bundle device, wherein the blocking area redirecting the flow of fluid from the gap towards the plurality of spaced apart slots.

25. The method according to claim 24, wherein redirecting at least a portion of the flow of fluid in the gap to the tube bundle comprising:

providing at least one blocking baffle at predetermined locations along the tube bundle, wherein each blocking baffle having a blocking plate with an outer perimeter and at least one plate opening sized to receive the tubes of the tube bundle device therethrough, and a blocking plate blocking area formed between the outer perimeter of the blocking plate and the at least one plate opening, wherein the blocking plate blocking area being sized to be located within a gap between the housing and outer tubes of the tube bundle device, wherein the blocking plate blocking area directing the flow of fluid from the gap towards the plurality of spaced apart slots.