HEAT TRANSFER UNIT FOR PROCESS FLUIDS

A heat transfer unit includes an inlet manifold; an outlet manifold spaced from the inlet manifold; and a plurality of conduits coupling the inlet manifold to the outlet manifold, wherein at least one conduit is coupled to the outlet manifold at an oblique angle. In one form, the conduit includes a L-Coil. In another form, the conduit includes a D-Coil. Each conduit includes a section arranged in an interior space of a heater box, and at least one heater is arranged in the interior space of the heater box.
Published: with international search report (Art. 21(3))
HEAT TRANSFER UNIT FOR PROCESS FLUIDS

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application No. 14/014,475 which was filed August 30, 2013, the contents of which are hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The disclosure relates to a low pressure drop heat transfer unit for process fluids.

2. Description of the Related Art

[0003] Various catalytic conversion processes are known in the petrochemical industry. For example, the catalytic reforming of a hydrocarbon feedstream (e.g., a naphtha feedstream) to produce aromatics (e.g., benzene, toluene, and xylenes) is described in U.S. Patent Application Publication Nos. 2012/0277501, 2012/0277502, 2012/0277503, 2012/0277504, and 2012/0277505. The catalytic dehydrogenation of a paraffin stream to yield olefins is described in U.S. Patent No. 8,282,887.

[0004] Catalytic reforming and catalytic dehydrogenation processes are endothermic and therefore, heat must be added to maintain the temperature of the reactions. U.S. Patent Application Publication No. 2012/0275974 describes the use of interbed heaters to maintain the temperature of reaction in the catalytic reactor of a reforming process. Example heaters for process fluids can also be found in U.S. Patent Nos. 8,176,974 and 7,954,544.

[0005] Aromatics yield from a catalytic reforming unit and olefin yield from a catalytic dehydrogenation unit increase, while yield of undesirable products from competing cracking reactions decreases, with lessening operating pressure. Thus, it may be advantageous to minimize reaction zone operating pressure.

[0006] The hot residence time of a process stream before the product stream leaves a reactor (also known as hot volume) can also be critical to the catalytic selectivity to desired products for thermally sensitive processes such as catalytic
reforming and catalytic dehydrogenation. Hot residence time reduction can be critical in reactor circuit non-catalyst volumes in order to prevent yield loss (aromatics or olefins) from competing thermal cracking reactions.

[0007] Thus, the design of heaters used in catalytic reforming and catalytic dehydrogenation processes to heat the feed upstream of each reactor can be guided by two criteria, pressure drop and hot residence time. While the overall low operating pressure benefits the yields from the processes, it is more beneficial to use the available pressure drop diligently in a reactor circuit. The use of the available pressure drop further upstream in the reactor circuit is least detrimental. The use of higher pressure drop further upstream in the reactor circuit reduces yields to a lesser extent. However, it reduces the hot residence time (thus thermal cracking) in the upstream heaters where the process streams are often more susceptible to thermal cracking than in the downstream heaters.

[0008] Thermal expansion and contraction in heater coils is yet another design consideration. Specifically, the heater coils must be able to withstand high process temperatures and metallurgical changes and mechanical stress.

[0009] Therefore, what is needed is an improved heat transfer unit for process fluids wherein the heat transfer unit provides low pressure drop but also the flexibility to withstand thermal expansion/contraction in the heater coils.

SUMMARY OF THE INVENTION

[0010] The foregoing needs are met by a heat transfer unit for process fluids. The heat transfer unit includes an inlet manifold; an outlet manifold spaced from the inlet manifold; and a plurality of conduits coupling the inlet manifold to the outlet manifold, wherein at least one of the conduits is coupled to the outlet manifold at an oblique angle.

[0011] In one version of the heat transfer unit, at least one of the conduits includes a L-Coil.

[0012] In another version of the heat transfer unit, at least one of the conduits includes a D-Coil.

[0013] In another version of the heat transfer unit, at least one of the conduits includes a coil having a plurality of generally C-shaped sections.
[0014] In another version of the heat transfer unit, at least one of the conduits is coupled to the outlet manifold at an angle between five and eighty-five degrees.

[0015] In another version of the heat transfer unit, at least one of the conduits is coupled to the outlet manifold at an angle between thirty and sixty degrees.

[0016] In another version of the heat transfer unit, each of the conduits is coupled to the outlet manifold at an oblique angle.

[0017] In another version of the heat transfer unit, each conduit includes a section arranged in an interior space of a heater box and wherein at least one heater is arranged in the interior space of the heater box.

[0018] In another aspect, the invention provides an L-Coil heat transfer unit for process fluids. The L-Coil heat transfer unit includes an inlet manifold; an outlet manifold spaced from the inlet manifold; and an L-Coil coupled between the inlet manifold and the outlet manifold. The L-Coil includes a horizontal leg and a vertical leg, wherein the horizontal leg is coupled to the outlet manifold at an oblique angle such that a flow aperture formed therebetween defines an oblong profile.

[0019] In one version of the L-Coil heat transfer unit, a plurality of L-Coils are coupled to the outlet manifold at an oblique angle.

[0020] In another version of the L-Coil heat transfer unit, the L-Coil is arranged at between a thirty and sixty degree angle relative to the outlet manifold.

[0021] In another version of the L-Coil heat transfer unit, the L-Coil is arranged at between a five and eighty-five degree angle relative to the outlet manifold.

[0022] The L-Coil heat transfer unit can further comprise a heater arranged substantially adjacent a bottom of the L-Coil heat transfer unit.

[0023] The L-Coil heat transfer unit can include a section arranged in an interior space of a heater box.

[0024] In another aspect, the invention provides a D-Coil heat transfer unit for process fluids. The D-Coil heat transfer unit includes an inlet manifold; an outlet manifold spaced from the inlet manifold; and a D-Coil coupled between the inlet manifold and the outlet manifold, The D-Coil includes an inlet section and an outlet section, and the inlet section is coupled to the inlet manifold at an oblique angle, and the outlet section is coupled to the outlet manifold at an oblique angle.
In one version of the D-Coil heat transfer unit, a flow aperture formed between the outlet section and the outlet manifold defines an oblong profile.

In another version of the D-Coil heat transfer unit, a plurality of D-Coils are coupled to the inlet manifold at an oblique angle and are coupled to the outlet manifold at an oblique angle.

In another version of the D-Coil heat transfer unit, the inlet section is arranged at between a thirty and sixty degree angle relative to the inlet manifold, and the outlet section is arranged at between a thirty and sixty degree angle relative to the outlet manifold.

In another version of the D-Coil heat transfer unit, the D-Coil includes a section arranged in an interior space of a heater box. At least one heater can be arranged in the interior space of the heater box.

In a low pressure drop heater design, the heater manifold may account for close to 50% of the total pressure heater pressure drop. The manifold pressure drop is mainly due to the entrance and exit frictional losses from heater tubes to the heater outlet and inlet.

The invention provides a heat transfer unit with an L-coil design that decreases pressure drop. In one non-limiting example of the heat transfer unit, an angled entrance to the heater outlet manifold is used with the L-coil design. An angled entrance results in an elliptical opening into the manifold. This lowers the inlet velocity and the velocity is in the same direction as the process fluid flow resulting in an additional decrease in a pressure drop. An angled inlet into the heater outlet manifold also provides a longer horizontal arm in an L-heater coil. This in turn gives more flexibility to the heater coil for vertical compression and tension. A longer horizontal arm of the L-Coil can provide better flexibility in vertical movements.

The invention also provides a heat transfer unit with a D-Coil to integrate the benefits for low pressure drop design with an improved flexibility. A D-coil achieves an added reduction in pressure drop by having an angled entry into and exit from, inlet and outlet manifolds, respectively. In addition, a D-Coil provides a better flexibility for vertical movements in a heater coil.

The invention demonstrates that an angled connection from heater conduits to the manifold is preferably used and more preferably, an angled
connection is used at an outlet manifold connection. This provides pressure drop reduction due to a bigger opening at the connection (thus lower frictional loss) and less turbulence (via same flow direction) with more flexibility for vertical movements. The pressure drop reduction by angled connection may be more at the outlet manifold connection than the inlet connection due to higher designed velocity at the outlet. The pressure reduction benefit can be more prominent in the low pressure drop heater design. The design can also be used for higher pressure drop heater designs. However, yield benefits from reduced heater drop may be less.

[0033] It is therefore an advantage of the invention to provide a low pressure drop heat transfer unit for process fluids.

[0034] It is another advantage of the invention to provide a heat transfer unit for process fluids in a process where pressure drop affects product yields.

[0035] These and other features, aspects, and advantages of the present invention will become better understood upon consideration of the following detailed description, drawings, and appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] Figure 1 is an end view of a prior art U-Coil heat transfer unit.
[0037] Figure 2 is a perspective view of the U-Coil heat transfer unit of Figure 1.
[0038] Figure 3 is a perspective view of a prior art L-Coil heat transfer unit.
[0039] Figure 4 is a side view of the L-Coil heat transfer unit of Figure 3.
[0040] Figure 5 is an end view of the L-Coil heat transfer unit of Figure 3.
[0041] Figure 6 is a top view of the L-Coil heat transfer unit of Figure 3.
[0042] Figure 7 is a side view of an outlet manifold of the L-Coil heat transfer unit of Figure 3.
[0043] Figure 8 is a perspective view of an L-Coil heat transfer unit according to one embodiment of the invention.
[0044] Figure 9 is a side view of the L-Coil heat transfer unit of Figure 8.
[0045] Figure 10 is an end view of the L-Coil heat transfer unit of Figure 8.
[0046] Figure 11 is a top view of the L-Coil heat transfer unit of Figure 8.
[0047] Figure 12 is a side view of an outlet manifold of the L-Coil heat transfer unit of Figure 8.
[0048] Figure 13 is a perspective view of an L-Coil heat transfer unit according to one embodiment of the invention.

[0049] Figure 14 is a side view of the L-Coil heat transfer unit of Figure 13.

[0050] Figure 15 is an end view of the L-Coil heat transfer unit of Figure 13.

[0051] Figure 16 is a top view of the L-Coil heat transfer unit of Figure 13.

[0052] Figure 17 is a perspective view of an L-Coil heat transfer unit according to one embodiment of the invention.

[0053] Figure 18 is a side view of the L-Coil heat transfer unit of Figure 17.

[0054] Figure 19 is an end view of the L-Coil heat transfer unit of Figure 17.

[0055] Figure 20 is a top view of the L-Coil heat transfer unit of Figure 17.

[0056] Figure 21 is a perspective view of a D-Coil heat transfer unit according to one embodiment of the invention.

[0057] Figure 22 is a side view of the D-Coil heat transfer unit of Figure 21.

[0058] Figure 23 is an end view of the D-Coil heat transfer unit of Figure 21.

[0059] Figure 24 is a top view of the L-Coil heat transfer unit of Figure 21.

[0060] Figure 25 is a perspective view of a D-Coil heat transfer unit according to one embodiment of the invention.

[0061] Figure 26 is a side view of the D-Coil heat transfer unit of Figure 25.

[0062] Figure 27 is an end view of the D-Coil heat transfer unit of Figure 25.

[0063] Figure 28 is a top view of the L-Coil heat transfer unit of Figure 25.

[0064] Figure 29 is a side view of a Triple C-Coil heat transfer unit according to one embodiment of the invention.

[0065] Like reference numerals will be used to refer to like parts from Figure to Figure in the following description of the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0066] Catalytic reactor systems may use U-Coil heaters for heating fresh feed and reheating feed between reactors. A U-Coil style heater may be desirable due to low process side pressure drop. An example U-Coil style heat transfer unit 10 is shown in Figures 1 and 2 and includes an inlet manifold 14, an outlet manifold 18, a heater box 19, and a plurality of U-coils 22 arranged for fluid communication therebetween. A number of burners or heaters 26 are arranged adjacent the axial
ends of the manifolds 14, 18. The coils in this embodiment and the other
e embodiments described herein may be formed from a stainless steel (e.g., an
austenitic 300 series stainless steel such as 347) or a steel such as 9-Chrome-Moly
Steel.

Alternatively, catalytic reactor systems may use L-Coil heaters for heating
fresh feed and reheating feed between reactors. An example L-Coil style heat
transfer unit 30 is shown in Figures 3-7 and includes an inlet manifold 34, an outlet
manifold 38, a heater box 39, and a plurality of L-coils 42 arranged for fluid
communication therebetween. Figure 7 shows apertures 46 arranged in the outlet
manifold 38 where the outlet manifold 38 couples with the L-Coils 42. As clearly
shown in Figure 7, in this arrangement the apertures 46 are substantially circular.

Figures 8-12 show an L-Coil heat transfer unit 50 according to one aspect
of the invention. The L-Coil heat transfer unit 50 includes an inlet manifold 54
arranged to receive a process fluid, an outlet manifold 58 arranged to provide the
process fluid to a downstream location, a heater box 59, and a plurality of L-Coils 62
arranged therebetween.

The L-Coils 62 are preferably welded to the inlet manifold 54 and the outlet
manifold 58 to provide a hermetic seal. As is clearly visible in Figure 11, the L-Coils
62 are arranged at an oblique angle relative to a longitudinal axis A of the outlet
manifold 58. As shown in Figures 3-7, the current state-of-the-art is to have L-Coils
arranged perpendicular to an outlet manifold (i.e., arranged at a ninety-degree angle
(90°)). In a preferred embodiment, the L-Coils 62 are rotated relative to the
longitudinal axis A by forty-five degrees (45°). In other embodiments, the L-Coils 62
are rotated relative to the longitudinal axis A by between thirty and sixty degrees
(30-60°). In still other embodiments, the L-Coils 62 are rotated relative to the
longitudinal axis A by between twenty and seventy degrees (20-70°). In still other
embodiments, the L-Coils 62 are rotated relative to the longitudinal axis A by
between five and eighty-five degrees (5-85°).

As shown in Figure 10, the inlet manifold 54 is horizontally spaced from
the outlet manifold 58 by a horizontal distance. Additionally, each L-Coil 62 includes
a horizontal leg 66 and a vertical leg 70. Non-limiting example length ranges for the
horizontal leg 66 are 0.30 to 7.62 meters (1-25 feet), or 0.61 to 6.10 meters (2-20
feet), or 1.52 to 4.57 meters (5-15 feet). Non-limiting example length ranges for the vertical leg 70 are 6.10 to 24.38 meters (20-80 feet), or 9.14 to 21.34 meters (30-70 feet), or 12.19 to 18.29 meters (40-60 feet), or 13.72 to 16.76 meters (45-55 feet). The oblique arrangement of the L-Coils 62 provides a longer horizontal leg 66 relative to the horizontal distance between the inlet manifold 54 and the outlet manifold 58 as compared with a perpendicular arrangement. This longer horizontal leg 66 allows for more flexibility in the system for better response to thermal and mechanical stresses.

[0071] Turning to Figure 12, the outlet manifold 58 is shown removed from the L-Coil heat transfer unit 50. L-Coil outlet apertures 74 are clearly visible and provide an oval or oblong or elliptical communication pathway between the L-Coils 62 and the outlet manifold 58. The L-Coil outlet apertures 74 have a larger sectional area as compared to the apertures 46 shown in Figure 7.

[0072] In one embodiment, the length of the inlet manifold 54 and outlet manifold 58 in the longitudinal direction is fifteen meters (50 feet) or more. In other embodiments, the installation may be smaller or larger, as desired. The L-Coils 62 may be spaced apart by fifty centimeters (10 feet). In other embodiments, more or less spacing may be desirable. The L-Coil heat transfer unit 50 may include up to eighteen-hundred (1800) L-Coils 62. In other embodiments, the L-Coil heat transfer unit 50 may include more or less L-Coils 62, as desired.

[0073] An additional feature of the L-Coil heat transfer unit 50 is the ability to position a burner 78 in a variety of locations and arrangements. As shown in Fig. 10, the burner 78 may be arranged near the inlet manifold 54 at the bottom of the heater box 59 and arranged under the L-Coils 62. The burner 78 may extend the full longitudinal length of the L-Coil heat transfer unit 50. In other arrangements, two or more burners 78 may be used (see Figure 15) and may be arranged elevated above the inlet manifold 54, arranged only at one or two ends of the L-Coil heat transfer unit 50, or arranged differently, as desired. The L-Coil heat transfer unit 50 provides a significant advantage in the flexibility of how the L-Coils 62 are heated as compared to prior art U-Coil designs wherein hot spots are a significant concern and inhibit the use of burners arranged near the floor or inlet manifold 54. This flexibility will be readily appreciated by those skilled in the art.
[0074] The L-Coil heat transfer unit 50 provides an advantageous fluid flow pattern (shown in dash lines in Figure 8) that reduces the fluid friction and therefore reduces the pressure drop through the L-Coil heat transfer unit 50 compared to other heat transfer solutions. In other embodiments, other flow patterns are feasible. For example, the inlet manifold 54 flow may originate on the left (as shown in Figure 8), or the outlet manifold 58 and the inlet manifold 54 may be switched such that fluid flow is substantially reversed from what is shown.

[0075] Turning now to Figures 13-16, another L-Coil heat transfer unit 50' is shown. The L-Coil heat transfer unit 50' is substantially similar to the L-Coil heat transfer unit 50 but includes a larger horizontal spacing between an inlet manifold 54' and an outlet manifold 58' and a correspondingly longer horizontal leg 66' on each L-Coil 62'. All components of the L-Coil heat transfer unit 50' have been numbered similar to the L-Coil heat transfer unit 50 with prime numbers. An increased horizontal leg 66' length provides an L-Coil 62' with more flexibility with respect to thermal and mechanical stresses.

[0076] Turning now to Figures 17-20, another L-Coil heat transfer unit 50" is shown. The L-Coil heat transfer unit 50" is substantially similar to the L-Coil heat transfer unit 50 but includes a larger horizontal spacing between an inlet manifold 54" and an outlet manifold 58"", and a correspondingly longer horizontal leg 66" on each L-Coil 62". All components of the L-Coil heat transfer unit 50" have been numbered similar to the L-Coil heat transfer unit 50 with prime numbers. An increased horizontal leg 66" length provides an L-Coil 62" with more flexibility with respect to thermal and mechanical stresses.

[0077] Turning to Figures 21-24, a D-Coil heat transfer unit 100 includes an inlet manifold 104, and outlet manifold 108, a heater box 109, and a plurality of D-Coils 112 arranged therebetween. The distance between the inlet manifold 104 and the outlet manifold 108 may be in the range of 6.10 to 24.38 meters (20-80 feet), or 9.14 to 21.34 meters (30-70 feet), or 12.19 to 18.29 meters (40-60 feet), or 13.72 to 16.76 meters (45-55 feet). Each D-Coil 112 includes an oblique inlet section 116, an outlet section 122, and a transfer section 124 therebetween. Non-limiting example length ranges for the inlet section 116 and the outlet section 122 are 0.30 to 7.62 meters (1-25 feet), or 0.61 to 6.10 meters (2-20 feet), or 1.52 to 4.57 meters (5-15 feet).
Non-limiting example length ranges for the transfer section 124 are 9.14 to 13.72 meters (30-45 feet), or 12.19 to 14.68 meters (40-48 feet).

[0078] The illustrated inlet section 116 is arranged at an oblique angle relative to a longitudinal axis of the inlet manifold 104. In the illustrated embodiment, the inlet section 116 is arranged at a forty-five degree angle (45°) relative to the longitudinal axis of the inlet manifold 104. In other embodiments, the inlet section 116 is arranged at between thirty and sixty degrees (30-60°) relative to the longitudinal axis of the inlet manifold 104. In still other embodiments, the inlet section 116 is arranged at between twenty and seventy degrees (20-70°) relative to the longitudinal axis of the inlet manifold 104. In still other embodiments, the inlet section 116 is arranged at between five and eighty-five degrees (5-85°) relative to the longitudinal axis of the inlet manifold 104.

[0079] The outlet section 122 is arranged at an oblique angle relative to a longitudinal axis of the outlet manifold 108. In the illustrated embodiment, the outlet section 122 is arranged at a forty-five degree angle (45°) relative to the longitudinal axis of the outlet manifold 108. In other embodiments, the outlet section 122 is arranged at between thirty and sixty degrees (30-60°) relative to the longitudinal axis of the outlet manifold 108. In other embodiments, the outlet section 122 is arranged at between twenty and seventy degrees (20-70°) relative to the longitudinal axis of the outlet manifold 108. In still other embodiments, the outlet section 122 is arranged at between five and eighty-five degrees (5-85°) relative to the longitudinal axis of the outlet manifold 108.

[0080] As a result of the oblique relation between the D-Coils 112 and the inlet and outlet manifolds 104, 108, the flow apertures formed at the junction between the D-Coils 112 and the inlet and outlet manifolds 104, 108 are oval or oblong or elliptical as described above with respect to apertures 74.

[0081] The D-Coil heat transfer unit 100 provides an advantageous fluid flow pattern (shown in dash lines in Figure 22) that reduces the fluid friction and therefore reduces the pressure drop through the D-Coil heat transfer unit 100 compared to other heat transfer solutions. In other embodiments, other flow patterns are feasible.

[0082] Figures 25-28 show a D-Coil heat transfer unit 100' similar to the D-Coil heat transfer unit 100 and is labeled with prime numbers. The inlet sections 116' and
the outlet sections 122' are of decreased length compared to the inlet sections 116 and the outlet sections 122 in the embodiment of Figures 21-24.

[0083] Turning to Figure 29, a Triple C-Coil heat transfer unit 200 includes an inlet manifold 204, an outlet manifold 208, a heater box, and a plurality of Triple C-Coils 210 arranged therebetween. The distance between the inlet manifold 204 and the outlet manifold 208 may be in the range of 6.10 to 24.38 meters (20-80 feet), or 9.14 to 21.34 meters (30-70 feet), or 12.19 to 18.29 meters (40-60 feet), or 13.72 to 16.76 meters (45-55 feet). Each Triple C-Coil 210 includes a generally C-shaped inlet section 216, a generally C-shaped outlet section 222, and a generally C-shaped transfer section 212 therebetween.

[0084] The illustrated inlet section 216 is arranged at an oblique angle relative to a longitudinal axis of the inlet manifold 204. In the illustrated embodiment, the junction of the inlet section 216 is arranged at a forty-five degree angle (45°) relative to the longitudinal axis of the inlet manifold 204. See angle C in Figure 29. In other embodiments, the junction of the inlet section 216 is arranged at between thirty and sixty degrees (30-60°) relative to the longitudinal axis of the inlet manifold 204. In still other embodiments, the junction of the inlet section 216 is arranged at between twenty and seventy degrees (20-70°) relative to the longitudinal axis of the inlet manifold 204. In still other embodiments, the junction of the inlet section 216 is arranged at between five and eighty-five degrees (5-85°) relative to the longitudinal axis of the inlet manifold 204.

[0085] The outlet section 222 is arranged at an oblique angle relative to a longitudinal axis of the outlet manifold 208. In the illustrated embodiment, the junction of the outlet section 222 is arranged at a forty-five degree angle (45°) relative to the longitudinal axis of the outlet manifold 208. See angle D in Figure 29. In other embodiments, the junction of the outlet section 222 is arranged at between thirty and sixty degrees (30-60°) relative to the longitudinal axis of the outlet manifold 208. In other embodiments, the junction of the outlet section 222 is arranged at between twenty and seventy degrees (20-70°) relative to the longitudinal axis of the outlet manifold 208. In still other embodiments, the junction of the outlet section 222 is arranged at between five and eighty-five degrees (5-85°) relative to the longitudinal axis of the outlet manifold 208.
[0086] As a result of the oblique relation between the Triple C-Coils 210 and the inlet and outlet manifolds 204, 208, the flow apertures formed at the junction between the Triple C-Coils 210 and the inlet and outlet manifolds 204, 208 are oval or oblong or elliptical as described above with respect to apertures 74.

[0087] The Triple C-Coil heat transfer unit 200 provides an advantageous fluid flow pattern that reduces the fluid friction and therefore reduces the pressure drop through the Triple C-Coil heat transfer unit 200 compared to other heat transfer solutions. In other embodiments, other flow patterns are feasible.

[0088] In one aspect, the invention provides a catalytic dehydrogenation process that includes passing a hydrocarbon feed stream through any of heat transfer units 10, 30, 50, 50', 50", 100, 100', 200, and then passing the heated hydrocarbon feed stream and a catalyst into a reactor thereby creating a product stream.

[0089] In another aspect, the invention provides, a catalytic reforming process that includes passing a hydrocarbon feed stream through any of heat transfer units 10, 30, 50, 50', 50", 100, 100', 200, and then passing the heated hydrocarbon feed stream and a catalyst into a reactor thereby creating a product stream.

[0090] Thus, the invention provides a heat transfer unit for process fluids. While use of the heat transfer unit is not limited to any process, the heat transfer unit can be particularly beneficial in heating process fluids in: (i) the catalytic reforming of a hydrocarbon feedstream (e.g., a naphtha feedstream) to produce aromatics (e.g., benzene, toluene and xylenes) (see, e.g., U.S. Patent Application Publication Nos. 2012/0277501, 201 2/0277502, 2012/0277503, 201 2/0277504, and 201 2/0277505); and (ii) the catalytic dehydrogenation of a paraffin stream to yield olefins (see, e.g., U.S. Patent No. 8,282,887).

SPECIFIC EMBODIMENTS

[0091] While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

[0092] A first embodiment of the invention is a heat transfer unit for process fluids, the heat transfer unit comprising: an inlet manifold; an outlet manifold spaced from the inlet manifold; and a plurality of conduits coupling the inlet manifold to the
outlet manifold, wherein at least one of the conduits is coupled to the outlet manifold at an oblique angle. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein at least one of the conduits includes a L-Coil. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein at least one of the conduits includes a D-Coil. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein at least one of the conduits includes a coil having a plurality of generally C-shaped sections.

An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein at least one of the conduits is coupled to the outlet manifold at an angle between five and eighty-five degrees. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein each of the conduits is coupled to the outlet manifold at an oblique angle. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph, wherein each conduit includes a section arranged in an interior space of a heater box and wherein at least one heater is arranged in the interior space of the heater box.

[0093] A second embodiment of the invention is a L-Coil heat transfer unit for process fluids, the L-Coil heat transfer unit comprising an inlet manifold; an outlet manifold spaced from the inlet manifold; and a L-Coil coupled between the inlet manifold and the outlet manifold, the L-Coil including a horizontal leg and a vertical leg, the horizontal leg coupled to the outlet manifold at an oblique angle such that a flow aperture formed there between defines an oblong profile. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein a plurality of L-Coils are coupled to the outlet manifold at an oblique angle. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in
this paragraph, wherein the L-Coil is arranged at between a thirty and sixty degree angle relative to the outlet manifold. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the L-Coil is arranged at between a five and eighty-five degree angle relative to the outlet manifold. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, further comprising a heater arranged substantially adjacent a bottom of the L-Coil heat transfer unit. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph, wherein the L-Coil includes a section arranged in an interior space of a heater box.  

[0094] A third embodiment of the invention is a D-Coil heat transfer unit for process fluids, the D-Coil heat transfer unit comprising an inlet manifold; an outlet manifold spaced from the inlet manifold; and a D-Coil coupled between the inlet manifold and the outlet manifold, the D-Coil including an inlet section and an outlet section, the inlet section coupled to the inlet manifold at an oblique angle, the outlet section coupled to the outlet manifold at an oblique angle. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein a flow aperture formed between the outlet section and the outlet manifold defines an oblong profile. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein a plurality of D-Coils are coupled to the inlet manifold at an oblique angle and are coupled to the outlet manifold at an oblique angle. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein the inlet section is arranged at between a thirty and sixty degree angle relative to the inlet manifold, and wherein the outlet section is arranged at between a thirty and sixty degree angle relative to the outlet manifold. 19 An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein the D-Coil includes a section arranged in an interior space of a heater box. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the third embodiment in this paragraph, wherein the outlet section is arranged at between a thirty and sixty degree angle relative to the outlet manifold.
paragraph, wherein at least one heater is arranged in the interior space of the heater box.

[0095] Although the invention has been described in considerable detail with reference to certain embodiments, one skilled in the art will appreciate that the present invention can be practiced by other than the described embodiments, which have been presented for purposes of illustration and not of limitation. Therefore, the scope of the appended claims should not be limited to the description of the embodiments contained herein.
CLAIMS:

1. A heat transfer unit for process fluids, the heat transfer unit comprising:
an inlet manifold;
an outlet manifold spaced from the inlet manifold; and
a plurality of conduits coupling the inlet manifold to the outlet manifold,
wherein at least one of the conduits is coupled to the outlet manifold at an oblique angle.

2. The heat transfer unit of claim 1, wherein at least one of the conduits includes a L-Coil.

3. The heat transfer unit of claim 1, wherein at least one of the conduits includes a D-Coil.

4. The heat transfer unit of claim 1, wherein at least one of the conduits includes a coil having a plurality of generally C-shaped sections.

5. The heat transfer unit of claim 1, wherein at least one of the conduits is coupled to the outlet manifold at an angle between five and eighty-five degrees.

6. The heat transfer unit of claim 1, wherein at least one of the conduits is coupled to the outlet manifold at an angle between thirty and sixty degrees.

7. The heat transfer unit of claim 1, wherein each of the conduits is coupled to the outlet manifold at an oblique angle.

8. The heat transfer unit of claim 1, wherein each conduit includes a section arranged in an interior space of a heater box and wherein at least one heater is arranged in the interior space of the heater box.
9. The heat transfer unit of claim 2 wherein the L-Coil comprises a horizontal leg and a vertical leg, the horizontal leg coupled to the outlet manifold at an oblique angle such that a flow aperture formed therebetween defines an oblong profile.

10. The heat transfer unit of claim 3 wherein the D-Coil comprises an inlet section and an outlet section, the inlet section coupled to the inlet manifold at an oblique angle, the outlet section coupled to the outlet manifold at an oblique angle.
INTERNATIONAL SEARCH REPORT

International application No. PCT/US2014/050814

A. CLASSIFICATION OF SUBJECT MATTER

CIOG ll/00(2006.01)i

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)

CIOG 11/00; B01J 8/02; F22B 1/00; C10J 3/26; C07C 4/04; B01J 8/06; B01J 19/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic database consulted during the international search (name of database and, where practical, search terms used)
eKOMPASS(KIPO internal) & Keywords: heat transfer, inlet, outlet, manifold, conduits, oblique angle, L-coil, D-coil, C-shaped

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<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 US 4811696 A (LACQUEMENT, R. G. et a1.) 14 March 1989 See abstr act; column 3, line 26 - column 5, line 34; claims 7, 12; and figures 2, 3</td>
<td>1-7, 9, 10</td>
</tr>
<tr>
<td>Y US 2002-004302A1 (WARREN, D. F.,) 18 April 2002 See abstr act; paragraphs [0032], [0040] - [0044]; claim 1; and figure 1</td>
<td>8</td>
</tr>
<tr>
<td>A US 2011-0257455 A (SPICER, D. B. et a1.) 20 October 2011 See abstr act; paragraphs [0012], [0015], [0032], [0048], [0067]; claims 12, 24; and figure 1</td>
<td>1-7, 9, 10</td>
</tr>
<tr>
<td>A WO 2007-104952 A2 (HELISWIRL TECHNOLOGIES LIMITED) 20 September 2007 See abstr act; page 1, line 4 - 28, page 6, line 5 - 17, page 9, line 20 - page 10, line 11; and figure 2</td>
<td>1-10</td>
</tr>
<tr>
<td>A US 2012-0020852 A (HE, XIOU et a1.) 26 January 2012 See abstr act; paragraphs [0058], [0062]; claims 1, 6 - 9; and figure 2</td>
<td>1-10</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* 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
"A" document member of the same patent family

Date of the actual completion of the international search
25 November 2014 (25.11.2014)

Date of mailing of the international search report
25 November 2014 (25.11.2014)

Name and mailing address of the ISA/KR

Authorized officer

International Application Division
Korean Intellectual Property Office
189 Cheongna-ro, Seo-gu, Daejeon Metropolitan City, 302-781, Republic of Korea

Telephone No. +82-42-481-8163

LEE, Dong Woek

Facsimile No. +82-42-472-7140
INTERNATIONAL SEARCH REPORT
Information on patent family members

<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 4811696 A</td>
<td>14/03/1989</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>US 2002-0043022 Al</td>
<td>18/04/2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AT 478729 T</td>
<td>15/09/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AU 2002-11742 Al</td>
<td>29/04/2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA 2425524 Al</td>
<td>25/04/2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA 2425524 C</td>
<td>12/12/2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DE 60142923 D1</td>
<td>07/10/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 1341600 B4</td>
<td>09/11/2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 1341600 T4</td>
<td>25/08/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ES 2348769 T3</td>
<td>14/12/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 6423279 Al</td>
<td>23/07/2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WO 02-32566 Al</td>
<td>25/04/2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2011-0257455 Al</td>
<td>20/10/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA 2794432 Al</td>
<td>27/10/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 103189707 A</td>
<td>03/07/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2561296 A2</td>
<td>27/02/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP 2013-540249 A</td>
<td>31/10/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KR 10-1454527 Bl</td>
<td>23/10/2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KR 10-2012-0139813 A</td>
<td>27/12/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG 184052 Al</td>
<td>30/10/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 8747765 B2</td>
<td>10/06/2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WO 2011-133283 A2</td>
<td>27/10/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WO 2011-133283 A3</td>
<td>10/10/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AU 2005-286233 Al</td>
<td>30/03/2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA 2589956 Al</td>
<td>03/07/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA 2580955 C</td>
<td>30/04/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101061321 A</td>
<td>24/10/2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101454075 A</td>
<td>10/06/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101454075 B</td>
<td>08/05/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101556047 A</td>
<td>14/10/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EA 014787 Bl</td>
<td>28/02/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EA 200801966 Al</td>
<td>27/02/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 1802872 Al</td>
<td>04/07/2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 1802872 Bl</td>
<td>22/04/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2004320 A2</td>
<td>24/12/2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2004320 B2</td>
<td>20/08/2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2082796 Al</td>
<td>29/07/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2082796 Bl</td>
<td>19/05/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2107258 Al</td>
<td>07/10/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EP 2206930 Al</td>
<td>14/07/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GB 0604895 D</td>
<td>19/04/2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP 05252684 B2</td>
<td>31/07/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP 05401099 B2</td>
<td>29/01/2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP 2008-513709 A</td>
<td>01/05/2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP 2009-138943 A</td>
<td>25/06/2009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Form PCT/ISA/210 (patent family annex) (July 2009)
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP 2009-529406 A</td>
<td>20/08/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KR 10-1072978 Bl</td>
<td>12/10/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KR 10-1335479 Bl</td>
<td>02/12/2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KR 10-2009-0013754 A</td>
<td>05/02/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2008-0017550 Al</td>
<td>24/01/2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2008-0257436 Al</td>
<td>23/10/2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2009-0095594 Al</td>
<td>16/04/2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 7749462 B2</td>
<td>06/07/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 8029749 B2</td>
<td>04/10/2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 8088345 B2</td>
<td>03/01/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPO 2006-032877 Al</td>
<td>30/03/2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JPO 2007-104952 A</td>
<td>13/03/2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 2012-0020852 Al</td>
<td>26/01/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101723784 A</td>
<td>09/06/2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN 101723784 B</td>
<td>26/12/2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WO 2010-043116 Al</td>
<td>22/04/2010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>