A shell and tube heat exchanger is described. The shell and tube heat exchanger includes a shell side having a separation plate dividing the shell into at least two compartments, each of the compartments having a feed inlet and a feed outlet; and a tube side comprising a plurality of tubes in the shell, at least one tube in each compartment, and the tube side having an effluent inlet and an effluent outlet. A method of heating a feed stream for a reaction zone using reactor effluent using the shell and tube heat exchanger is also described.
FIG. 4
SHELL AND TUBE HEAT EXCHANGER
WITH SPLIT SHELL AND METHOD OF USING

BACKGROUND OF THE INVENTION

[0001] Traditionally, in hydroprocessing units such as kerosene, diesel, gas oil, resid hydrotreating and hydrocracking units, hydrogen rich recycle gas and fresh hydrocarbon feed are preheated in a series of heat exchangers utilizing heat available from the reactor effluent. The hot hydrocarbon feed and recycle gas are mixed together to form a combined feed stream at the inlet of the charge heater. The charge heater provides the necessary heat to the combined stream to obtain the desired reactor inlet temperature. This particular flow scheme is known as a separate heat exchanger scheme. The separate heat exchanger flow scheme is used for units that require more than two passes for the charge heater. This flow scheme increases the equipment count and required plot space.

[0002] FIG. 1 is an illustration of one embodiment of an arrangement for pre-heating a fresh hydrocarbon feed and hydrogen rich recycle gas using the reactor effluent.

[0003] The hydrocarbon feed 105 is pre-heated in first reactor effluent-feed heat exchanger 110 and second reactor effluent-feed heat exchanger 115 to form pre-heated hydrocarbon feed stream 120.

[0004] The hydrogen rich recycle gas 125 is pre-heated in first reactor effluent-recycle gas heat exchanger 130, second reactor effluent-recycle gas heat exchanger 135, and third reactor effluent-recycle gas heat exchanger 140 to form pre-heated recycle gas stream 145.

[0005] Pre-heated hydrocarbon feed stream 120 and pre-heated recycle gas stream 145 are combined to form pre-heated combined feed stream 150. Pre-heated combined feed stream 150 is heated in charge heater 155 to form heated feed stream 160.

[0006] Heated feed stream 160 is sent to reactor 165. The reactor effluent stream 170 from reactor 165 is successively sent to second reactor effluent-recycle gas heat exchanger 140, second reactor effluent-feed heat exchanger 115, second reactor effluent-recycle gas heat exchanger 135, first reactor effluent-feed heat exchanger 110, and first reactor effluent-recycle gas heat exchanger 130.

[0007] The cooled reactor effluent stream 175 can then be sent for separation between the gas and the liquid (not shown).

[0008] The multiple heat exchangers (five in this example) increase the equipment cost and the space required. Therefore, there is a need for a heat exchanger design which allows the use of a single exchanger train for the scheme which requires more than two heater passes.

SUMMARY OF THE INVENTION

[0009] One aspect of the invention is a shell and tube heat exchanger which reduces the equipment count, capital cost, and plot space requirement significantly. In one embodiment, the shell and tube heat exchanger includes a shell side having a separation plate dividing the shell into at least two compartments, each of the compartments having a feed inlet and a feed outlet; and a tube side comprising a plurality of tubes in the shell, at least one tube in each compartment, and the tube side having an effluent inlet and an effluent outlet.

[0010] Another aspect of the invention is method of heating a feed and gas stream for a reaction zone using reactor effluent. In one embodiment, the method includes providing a shell and tube heat exchanger as described. The feed stream is divided into at least two portions. The two portions of the feed stream are passed from the feed inlets to the feed outlets of each compartment, and the reactor effluent is passed from the effluent inlet to the effluent outlet to pre-heat the two portions of the feed stream. The two pre-heated portions of the feed stream are heated in a charge heater. The two heated portions of the feed stream from the charge heater are introduced into the reaction zone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is an illustration of a prior art separate heat exchanger configuration for pre-heating a feed and hydrogen rich recycle gas using reactor effluent.

[0012] FIG. 2 is an illustration of one embodiment of a shell and tube heat exchanger of the present invention.

[0013] FIG. 3 is an illustration of one embodiment of a configuration for pre-heating a combined feed stream using reactor effluent and employing the shell and tube heat exchanger of the present invention for a two charge heater pass configuration.

[0014] FIG. 4 is an illustration of another embodiment of a configuration for pre-heating a combined feed stream using reactor effluent and employing the shell and tube heat exchanger of the present invention for a four charge heater pass configuration.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The shell and tube heat exchanger has a split shell design. The shell side has a separation plate dividing the shell into at least two separate compartments. Each of the compartments has a feed inlet and a feed outlet. The tube side has a plurality of tubes, and there is at least one tube in each compartment. The tube side has an effluent inlet and an effluent outlet. The feed inlet, feed outlet, effluent inlet, and effluent outlet are typically nozzles.

[0016] Typically, the compartments are substantially equal in size (for example, within ±10%).

[0017] In some embodiments, the shell includes at least one baffle. Typically, each compartment contains at least one baffle. There are typically two or more baffles in each compartment. The baffles are typically arranged to create turbulence for efficient indirect heat transfer between the tube side reactor effluent stream and the shell side combined feed stream. For example, one baffle could contact the bottom (or one side) of the compartment leaving an opening at the top (or opposite side) of the compartment, and the next baffle could contact the top (or the opposite side) leaving an opening at the bottom (or the first side).

[0018] The shell, tubes, separation plate, and baffles can be made of any suitable material.

[0019] In some embodiments, the shell side inlet and outlet are at opposite ends of the shell. In some embodiments, the tube side inlet and outlet are at the same end of the exchanger.

[0020] In some embodiments, the tube side inlet and outlet are at the same end of the exchanger as the feed outlet. The tubes in this arrangement are U-shaped tubes.

[0021] Alternatively, the tube side inlet and outlet are at opposite ends of the exchanger. In this arrangement, the tubes are straight tubes.
Other arrangements of feed inlets and outlets, effluent inlet and outlet, and tube shape could be used, as would be understood by those of skill in the art.

Typically, there are the same numbers of tubes in each compartment so that the heat exchange is uniform in the compartments.

The split shell and tube heat exchanger can be used to heat the feed stream entering a reaction zone, for example, a hydrotreating or hydrocracking zone. The feed stream can be heated using the effluent from the same reaction zone. Alternatively, the effluent from one reaction zone could be used to heat the feed for another reaction zone.

In some embodiments, the feed stream can be a mixture of liquid hydrocarbons and hydrogen rich gaseous hydrocarbons. For example, the liquid hydrocarbon stream could be a fresh hydrocarbon feed stream, and the gaseous hydrocarbon feed stream could be a hydrogen rich recycle hydrocarbon stream.

In these embodiments, the combined feed stream is split into two (or more) streams which enter the two (or more) compartments of the shell side of the heat exchanger through the feed stream inlets. The effluent from the reaction zone enters the tube side of the heat exchanger. The effluent can be a two phase mixture of liquid and gaseous hydrocarbons. The heat from the effluent is used to pre-heat the combined feed stream in the two compartments of the shell side. The pre-heated combined feed streams exit the two compartments of the shell side through the shell side outlet nozzles for each compartment.

The two pre-heated streams are sent to a charge heater to be further heated to the inlet temperature of the reaction zone. The heated streams are sent from the charge heater to the reaction zone where the reaction occurs.

The combined heat exchanger scheme is more energy efficient and requires fewer heat exchangers than the separate heat exchanger scheme. The split shell and tube heat exchanger allows a combined feed heat exchanger scheme when the number of charge exchanger passes is two or more.

In some embodiments, a hydrogen rich gaseous hydrocarbon stream can be mixed with the feed stream after the feed stream is divided. Alternatively, it could be mixed with the feed stream after the feed stream is divided.

The heated streams from the charge heater can be combined before they are introduced into the reaction zone. Alternatively, they can be introduced into the reaction zone separately.

More than one split shell and tube heat exchanger could be used in the process. For example, two or more heat exchangers could be used. The feed stream will be divided into two (or more) streams for each heat exchanger. The number of feed streams per heat exchanger depends on the number of compartments in each heat exchanger.

FIG. 2 illustrates one embodiment of a shell and tube heat exchanger 200. The shell and tube heat exchanger 200 includes a shell 205 and tubes 210. The shell 205 has a separation plate 215 which divides the shell 205 into two separate compartments 220, 225.

There is a feed inlet 230 and a feed outlet 235 for compartment 220, and a feed inlet 240 and a feed outlet 245 for compartment 225. One portion of the feed flows through compartment 220 from the feed inlet 230 to the feed outlet 235, and another portion flows through compartment 225 from the feed inlet 240 to the feed outlet 245.

There is a reactor effluent inlet 250 and a reactor effluent outlet 255. The reactor effluent inlet 250 is in fluid communication with the tube inlets 260. The reactor effluent outlet 255 is in fluid communication with the tube outlets 265. The reactor effluent flows from the reactor effluent inlet 250 into the tube inlets 260 through the tubes 210 to the tube outlets 265 and out through the reactor effluent outlet 255. A plate 270 separates the tube inlets 260 from the tube outlets 265.

As illustrated, the tubes 210 are U-shaped, and the reactor effluent inlet 250 and reactor effluent outlet 255 are at the same end of the shell. However, if straight tubes were used, the reactor effluent inlet 250 would be at one end of the shell 205, and the reactor effluent outlet 255 would be at the opposite end of the shell 205.

Also as illustrated, the reactor effluent inlet 250 and reactor effluent outlet 255 are at the same end of the shell 205 as the feed outlets 235, 245 for compartments 220, 225.

Compartment 220, 225 have at least one baffle 275. Typically, there are at least two baffles 275 in each compartment 220, 225. The baffles 275 fill the space around the tubes 210 with an opening 280 for the feed to flow around the baffles 275. The baffles 275 are typically arranged so that the feed flows over one baffle 275 and under the next in an S-shaped path to provide maximum heat exchange of the feed with the effluent from the reaction zone flowing through the tubes 210.

FIG. 3 is an illustration of a process 300 for heating a feed 305. The feed stream 305 is split into two portions 305A and 305B. A gas stream 310 is also split into two portions 310A and 310B. The feed portions 305A and 305B are mixed with the gas portions 310A and 310B to form combined feeds 315A and 315B.

Combined feeds 315A and 315B are sent to a shell and tube heat exchanger 320 with a split shell such as the one illustrated in FIG. 2. The effluent 325 from reaction zone 330 is used to pre-heat the combined feeds 315A and 315B.

Pre-heated combined feeds 335A and 335B are sent to the same charge heater 340 for further heating. Heated combined feeds 345A and 345B are then combined into stream 350 and sent to the reaction zone 330, such as a hydprocessing reaction zone. The effluent 325 from the reaction zone 330 is sent to the split shell heat exchanger 320 to heat the combined feeds 315A and 315B. The effluent 355 from the shell and tube heat exchanger 320 with the split shell can be sent to a downstream separator (not shown) for further separation between the gas and the liquid.

FIG. 4 is another illustration of a process 400 in which two shell and tube heat exchangers 420A and 420B with split shells are used to heat a feed 405. The feed 405 is split into four portions 405A, 405B, 405C, and 405D. A gas 410 is also split into four portions 410A, 410B, 410C, and 410D. The feed portions 405A, 405B, 405C, and 405D are mixed with the gas portions 410A, 410B, 410C, and 410D to form combined feed 415A, 415B, 415C, and 415D.

Combined feeds 415A, 415B, 415C, and 415D are sent to the shell and tube heat exchangers 420A and 420B with the split shells. The effluent 425 from reaction zone 430 is used to pre-heat the combined feeds 415A, 415B, 415C, and 415D in the shell and tube heat exchangers 420A and 420B with the split shells.

Pre-heated combined feeds 435A, 435B, 435C, and 435D are sent to the same charge heater 440 for further heating. Heated combined feeds 445A, 445B, 445C, and
The effluent 425 from reaction zone 430 is sent to the split shell heat exchangers 420A and 420B to heat the combined feeds 415A, 415B, 415C, and 415D. The effluent 455 from the shell and tube heat exchangers 420A and 420B with the split shells can be sent to a downstream separator (not shown) for further separation between the gas and the liquid.

As used herein, the term about means within 10% of the value, or within 5%, or within 1%.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

1. A shell and tube heat exchanger comprising:
   - a shell side having a separation plate dividing the shell into at least two compartments, each of the compartments having a feed inlet and a feed outlet; and
   - a tube side comprising a plurality of tubes in the shell, at least one tube in each compartment, the tube side having an effluent inlet and an effluent outlet.

2. The shell and tube heat exchanger of claim 1 further comprising at least one baffle in the shell.

3. The shell and tube heat exchanger of claim 1 wherein there are at least two baffles in each compartment.

4. The shell and tube heat exchanger of claim 3 wherein the at least two baffles in at least one compartment are arranged with an opening at a first end of one baffle followed by an opening at an opposite end of the next baffle.

5. The shell and tube heat exchanger of claim 1 wherein at least one of: the feed inlet of at least one compartment comprises a nozzle; the feed outlet of at least one compartment comprises a nozzle; the effluent inlet of the tube side comprises a nozzle; and the effluent outlet of the tube side comprises a nozzle.

6. The shell and tube heat exchanger of claim 1 wherein the feed inlets of each compartment are at a first end of the shell and the feed outlets of each compartment are at a second end of the shell.

7. The shell and tube heat exchanger of claim 1 wherein the effluent inlet and the effluent outlet are at the same end of the shell.

8. The shell and tube heat exchanger of claim 7 wherein the feed outlets of each compartment are at the same end of the shell as the effluent inlet and the effluent outlet.

9. The shell and tube heat exchanger of claim 7 wherein the plurality of tubes are U-shaped tubes.

10. The shell and tube heat exchanger of claim 1 wherein the plurality of tubes are straight tubes.

11. The shell and tube heat exchanger of claim 1 wherein each compartment has the same number of tubes.

12. A method of heating a feed stream for a reaction zone using reactor effluent comprising:
   - providing a shell and tube heat exchanger comprising:
     - a shell side having a separation plate dividing the shell into at least two compartments, each of the compartments having a feed inlet and a feed outlet; and
     - a tube side comprising a plurality of tubes in the shell, at least one tube in each compartment, the tube side having an effluent inlet and an effluent outlet;
   - dividing the feed stream into at least two portions;
   - passing the two portions of the feed stream from the feed inlets to the feed outlets of each compartment and passing the reactor effluent from the effluent inlet to the effluent outlet to preheat the two portions of the feed stream;
   - heating the two preheated portions of the feed stream in a charge heater; and
   - introducing the two heated portions of the feed stream from the charge heater into the reaction zone.

13. The method of claim 12 further comprising mixing a hydrogen rich gaseous hydrocarbon stream with the feed stream.

14. The method of claim 13 wherein the hydrogen rich gaseous hydrocarbon stream is introduced into the feed stream after the feed stream is divided into the two portions.

15. The method of claim 12 wherein the reactor effluent comprises a liquid hydrocarbon phase and a gaseous hydrocarbon phase.

16. The method of claim 12 wherein the two heated portions of the feed stream from the charge heater are combined before introducing the two heated portions of the feed stream from the charge heater into the reaction zone.

17. The method of claim 12 wherein:
   - there are at least two shell and tube heat exchangers;
   - the feed stream is divided into at least four portions;
   - two portions of the feed stream are sent to the first shell and tube heat exchanger and two portions of the feed stream are sent to the second shell and tube heat exchanger;
   - the four preheated portions of the feed stream are heated in the charge heater;
   - the four heated portions of the feed stream from the charge heater are introduced into the reaction zone.

18. The method of claim 12 wherein there are at least two baffles in each compartment and wherein the at least two baffles in the first compartment or the at least two baffles in the second compartment or both are arranged with an opening at a first end of the first baffle followed by an opening at an opposite end of the second baffle.

19. The method of claim 12 wherein the feed inlets of each compartment are at a first end of the shell and the feed outlets of each compartment are at a second end of the shell.

20. The method of claim 12 wherein the effluent inlet and the effluent outlet are at the same end of the shell and wherein the feed outlets of each compartment are at the same end of the shell as the effluent inlet and the effluent outlet, and wherein the plurality of tubes are U-shaped tubes.

* * * * *