EO/EG Device and Method for Preparing EO/EG Thereof

Technical Field of the Invention

[0001] The present invention relates to the technical field of ethylene oxide (EO)/ethylene glycol (EG) production, and in particular to an EO/EG device and a method for preparing EO/EG by using the EO/EG device.

Background of the Invention

[0002] The production method related to the production of ethylene oxide (EO)/ethylene glycol (EG) primarily employs an ethylene oxidation method, in which ethylene and oxygen are used as raw materials and subjected to oxidation reaction to produce ethylene oxide (EO), and the EO is then converted into ethylene glycol (EG) via conventional hydration or catalytic hydrolysis processes.

[0003] Existing devices for preparing EO/EG typically include a reactor, an EO absorption tower and a shell-and-tube heat exchanger. The shell-and-tube heat exchanger is used to exchange heat between the reaction products discharged from the reactor and the reaction feeds (i.e., raw materials), so that the temperature of the reaction feeds is raised and the temperature of the reaction products is lowered. However, the shell-and-tube heat exchanger in an existing EO/EG device has many problems such as large equipment diameter (the diameters of both the tube sheet and the funnel are the same as that of the cylinder) and excessive equipment height. Specifically:

[0004] 1. Due to the relatively large diameters of the tube sheet and funnel, the reaction products entering the funnel are distributed unevenly, making it prone to the formation of vortices. Severe vortices can generate static electricity and trigger explosions (as the reaction products contain flammable and explosive media such as O_2, EO, and ethylene). Furthermore, uneven fluid distribution leads to thermal stress in the large-diameter tube sheet and uneven flow velocity distribution within the tubes, ultimately, this exacerbates the accumulation and clogging caused by oligomers at the low-temperature ends of the tubes during production (since the reaction products contain by-products such as carbonates, oligomers, and catalyst fines, which easily form ammonium salts and oligomer deposits at low temperature, causing clogging in the tubes), thereby compromising the unit's long-cycle operation.

[0005] 2. The design of the baffles within the cylinder results in significant leakage flow, severe flow maldistribution, non-uniform flow velocity distribution across the given

cross-section, and a tendency for high-velocity gas to induce acoustic vibration. These issues not only adversely affect heat exchange efficiency but also pose safety risks to the equipment.

[0006] 3. The excessive equipment height (an overall height of over 50 meters and a cylinder length of approximately 29 meters) leads to inconsistent thermal expansion between the tube passage and the shell passage. In addition, the inability to install expansion joints due to the large diameter makes the equipment susceptible to damage. The large equipment height also increases the difficulty of device design and piping layout.

Summary of the Invention

[0007] It is a first object of the present invention to provide an EO/EG device capable of safely and efficiently producing EO/EG.

[0008] It is a second object of the present invention to provide an EO/EG device which has an enhanced safety.

[0009] It is a third object of the present invention to provide an EO/EG device capable of preventing blockage of heat exchange tubes.

[0010] It is a fourth object of the present invention to provide a method for preparing EO/EG using the above said EO/EG device.

[0011] For achieving the first object, the EO/EG device comprises a spiral-wound heat exchanger; a reactor having an inlet and an outlet; and an EO absorption tower having an inlet and a bottom outlet; wherein, the heat exchanger has a tube passage, a shell passage, a tube-passage inlet, a tube-passage outlet, a shell-passage inlet and a shell-passage outlet; the tube-passage inlet of the heat exchanger is in communication with the outlet of the reactor, the tube-passage outlet of the heat exchanger is in communication with the inlet of the EO absorption tower, the shell-passage inlet of the heat exchanger is in communication with a feed pipeline for delivering a reaction feed containing oxygen and ethylene, and the shell-passage outlet of the heat exchanger is in communication with the inlet of the reactor.

[0012] In the EO/EG device, the reaction product discharged from the outlet of the reactor flows in the tube passage of the spiral-wound heat exchanger, while the reaction feed containing oxygen and ethylene discharged from the feed pipeline flows in the shell passage of the spiral-wound heat exchanger. The reaction feed within the shell passage contacts the wall of each heat exchange tube of the heat exchanger, thereby reducing the risks of flow leakage and flow maldistribution of the reaction feed; in addition, the reaction feed is distributed uniformly across any given cross-section, thereby ensuring the heat exchange efficiency while enhancing the safety.

[0013] Preferably, a water cooler is disposed on a pipeline connected between the tube-passage outlet of the spiral-wound heat exchanger and the inlet of the EO absorption tower.

[0014] Preferably, the EO absorption tower has a gas outlet at a top of the EO absorption tower, the gas outlet of the EO absorption tower is in communication with the feed pipeline through a circulation pipeline, a compressor and a heater are respectively disposed on the circulation line.

[0015] Preferably, the device further comprises a steam generator capable of generating steam by heating water via reaction heat from the reactor; the steam generator has a hot-water inlet for receiving external hot water, a steam outlet for outputting steam, a heat inlet and a cold outlet respectively in communication with the reactor.

[0016] In the above-described technical schemes, preferably, the spiral-wound heat exchanger comprises:

[0017] a vertical shell-passage cylinder having a top and a bottom;

[0018] an upper tube sheet and a lower tube sheet respectively disposed at the top and the bottom of the shell-passage cylinder;

[0019] an upper funnel disposed above the upper tube sheet and a lower funnel disposed below the lower tube sheet, the upper funnel having the tube-passage inlet, and the lower funnel having the tube-passage outlet; and

[0020] a plurality of heat exchange tubes disposed inside the shell-passage cylinder along an axis of the shell-passage cylinder, each heat exchange tube has a top end which is supported by the upper tube sheet and in communication with the upper funnel, and a bottom end which is supported by the lower tube sheet and in communication with the lower funnel; the shell-passage inlet is located on a lower portion of a side wall of the shell-passage cylinder and the shell-passage outlet is located on an upper portion of the side wall the shell-passage cylinder.

[0021] Preferably, the upper tube sheet comprises a central portion and a peripheral portion surrounding the central portion, the heat exchanger has the tube-passage inlet at a top of the upper funnel corresponding to the central portion of the upper tube sheet.

[0022] For achieving the second object, preferably, the spiral-wound heat exchanger further comprises:

[0023] a hollow first guide cylinder disposed within the upper funnel; the first guide cylinder has a peripheral wall flaring outwardly from top to bottom, the peripheral wall is separated from a side wall of and faces the upper funnel; the first guide cylinder has a closed cone head joined by a top edge of the peripheral wall and disposed opposite the

tube-passage inlet; a bottom of the first guide cylinder opens downward, a bottom edge of the peripheral wall corresponds to the peripheral portion of the upper tube sheet; the first guide cylinder has a plurality of first through holes circumferentially distributed at intervals on the peripheral wall for allowing a tube-passage medium to pass through.

[0024] Under such a design, after the tube-passage medium enters the upper funnel via the tube-passage inlet, the tube-passage medium flows downward along the peripheral wall of the first guide cylinder. During this flow, a portion of the tube-passage medium passes through the first through holes into the first guide cylinder, then flows to the central portion of the upper tube sheet and enters the heat exchange tubes supported in the central portion of the upper tube sheet. Another portion of the tube-passage medium flows downward along the peripheral wall of the first guide cylinder to the peripheral portion of the upper tube sheet and enters the heat exchange tubes supported in the peripheral portion of the upper tube sheet. This ensures that the tube-passage medium entering the upper funnel flows uniformly into the various heat exchange tubes. Furthermore, the conical first guide cylinder of the present invention can prevent the tube-passage medium from forming vortices or turbulent flow, so that the safety of the device can be increased.

[0025] Preferably, an inclination angle of the peripheral wall relative to a vertical axis is defined as α, and α is less than 45°. The lowest value of the inclination angle α is greater than 0°, and a bottom edge of the peripheral wall of the first guide cylinder faces the peripheral portion of the upper tube sheet.

[0026] Preferably, the plurality of first through holes is arranged in groups, and the first guide cylinder has at least two groups of the first through holes vertically arranged at intervals.

[0027] Preferably, the cone head of the first guide cylinder has a spherical-cap shape, and the first guide cylinder has a plurality of second through holes distributed at intervals on the cone head for allowing the tube-passage medium to pass through. The spherical cap-shaped cone head avoids safety issues caused by sharp points interacting with the fluid.

[0028] Preferably, a radius of the cone head of the first guide cylinder is not less than 200 mm.

[0029] Preferably, the first guide cylinder has a straight cylindrical portion extending downward from the bottom of the peripheral wall, and an annular side wall; the straight cylindrical portion has a bottom edge which is supported on the peripheral portion of the upper tube sheet; the straight cylindrical portion has a plurality of third through holes circumferentially disposed at intervals on an annular wall of the cylindrical portion for allowing the tube-passage medium to pass through. The design of the straight cylinder is

determined based on the actual flow field. Alternatively, the straight cylinder may be omitted, and the bottom edge of the peripheral wall of the first guide cylinder rests directly on the peripheral portion of the upper tube sheet.

[0030] Preferably, the spiral-wound heat exchanger further comprises a central cylinder vertically disposed inside the shell-passage cylinder;

[0031] wherein the central portion of the upper tube sheet comprises a first portion connected to a top end of the central cylinder and a second portion surrounding the first portion;

[0032] the plurality of heat exchange tubes is wound around an outer periphery of the central cylinder along a lengthwise direction, the top end of each heat exchange tube is supported on the second portion and the peripheral portion of the upper tube sheet;

[0033] the spiral-wound heat exchanger further comprises a second guide cylinder vertically disposed within the first guide cylinder and located above the first portion of the upper tube sheet, the second guide cylinder has a conical shape corresponding to the shape of the first guide cylinder, so that the tube-passage medium falling onto the second guide cylinder is guided onto the second portion of the upper tube sheet.

[0034] The design of the second guide cylinder prevents the tube-passage medium from flowing toward the first portion of the upper tube sheet, thereby preventing the tube-passage medium from forming vortices or turbulent flow in a non-perforated region (i.e., the first portion of the upper tube sheet), so that the fluid can uniformly flow into the respective heat exchange tubes.

[0035] Preferably, the upper funnel has a side wall in a form of a conical shape that flares outwardly from top to bottom.

[0036] Preferably, the first through holes on the first guide cylinder are circular or oblong. Alternatively, the first through holes may be oval or of other shapes. The shape and distribution pattern of the first through holes are designed based on the actual flow field.

[0037] For achieving the third object, preferably, the lower funnel comprises a cleaning-liquid inlet nozzle;

[0038] the spiral-wound heat exchanger further comprises a plurality of capillary tubes each having a first end and a second end, each capillary tube has a liquid inlet hole in communication with the cleaning-liquid inlet nozzle at the first end thereof, and a liquid outlet hole at the second end thereof; the second end of each capillary tube is inserted into a corresponding heat exchange tube along a lengthwise direction;

[0039] an outer peripheral wall of each capillary tube located within the heat exchange tube faces and is separated from an inner peripheral wall of the corresponding heat

exchange tube, and an annular chamber is defined between each capillary tube and the corresponding heat exchange tube.

[0040] Under such a design, the cleaning liquid is delivered into the capillary tubes through the cleaning-liquid inlet nozzle and then sprayed out from the liquid outlet hole at the second ends of the capillary tubes. The sprayed cleaning liquid cleans the inner wall of the heat exchange tube to prevent blockage thereof. Furthermore, an annular chamber is defined between the outer peripheral wall of each capillary tube and the inner peripheral wall of the corresponding heat exchange tube, the tube-passage medium can pass through the annular chamber. Accordingly, the capillary tubes in the present invention do not interfere with the normal operation of the heat exchange tubes.

[0041] Preferably, each capillary tube has a plurality of positioning bumps protruding from the outer peripheral wall of a portion of each capillary tube located within the corresponding heat exchange tube to the inner peripheral wall of the corresponding heat exchange tube, the plurality of positioning bumps is circumferentially disposed at intervals on the outer peripheral wall of the portion of each capillary tube located within the corresponding heat exchange tube, and an end of each positioning bump faces towards and is adjacent to the inner peripheral wall of the corresponding heat exchange tube or an end of each positioning bump faces towards and contacts with the inner peripheral wall of the corresponding heat exchange tube. The plurality of positioning bumps ensures that the outer peripheral wall of each capillary tube faces the inner peripheral wall of the corresponding heat exchange tube, thereby preventing the capillary tube from contacting the heat exchange tube.

[0042] Preferably, the plurality of circumferentially arranged positioning bumps is defined as one positioning-member group, at least two positioning-member groups are disposed at intervals along a lengthwise direction of the capillary tube.

[0043] Preferably, the second end of each capillary tube is disposed adjacent to a lower end of the corresponding heat exchange tube and relatively away from the upper end thereof. During the production of ethylene oxide/ethylene glycol (EO/EG), oligomer accumulation tends to occur near the lower end of the heat exchange tube. In the present invention, the capillary tubes, disposed near the lower end of the heat exchange tube, can prevent such oligomer accumulation.

[0044] Preferably, the second end of each capillary tube is inserted into the corresponding heat exchange tube from the lower end, while the first end of the capillary tube is located outside the corresponding heat exchange tube.

[0045] To facilitate the delivery of cleaning fluid into each capillary tube, preferably, the

device further comprises an annular liquid collecting pipe disposed within the lower funnel; the annular liquid collecting pipe has a liquid inlet in communication with the cleaning-liquid inlet nozzle and a plurality of liquid outlets circumferentially disposed at intervals on a surface of the annular liquid collecting pipe, each liquid outlet faces and is in communication with the liquid inlet hole of a corresponding capillary tube.

[0046] Preferably, the liquid collecting pipe comprises at least two annular pipe units concentrically sleeved one inside another, adjacent annular pipe units are in communication with each another through one or more radially extending intermediate pipes, each annular pipe unit has the plurality of liquid outlets circumferentially disposed thereon, and the outermost annular pipe unit has the liquid inlet.

[0047] Preferably, at least two intermediate pipes are circumferentially disposed at intervals between the adjacent annular pipe units.

[0048] For achieving the fourth object, the method for preparing EO/EG by using the above said EO/EG device comprises:

[0049] inputting a reaction feed containing oxygen and ethylene and having a temperature of 40-65°C in the feed pipeline into the shell passage of the spiral-wound heat exchanger through the shell-passage inlet, the reaction feed serving as a shell-passage medium; discharging the reaction feed from the shell-passage outlet at a temperature of 170-210°C, and inputting the reaction feed into the reactor for reaction; discharging an EO reaction product from the reactor at a temperature of 200-230°C, the EO reaction product serving as a tube-passage medium, and inputting the EO reaction product into the tube passage of the spiral-wound heat exchanger through the tube-passage inlet to exchange heat with the shell-passage medium; discharging the EO reaction product from the tube-passage outlet at a temperature of 70-90°C, and delivering the EO reaction product into the EO absorption tower; and delivering a material discharged from the bottom outlet of the EO absorption tower to a downstream equipment to produce EG.

[0050] In the method for preparing the EO/EG of the present invention, the ratio of oxygen to ethylene refers to the prior art to ensure the production of EO via the reaction of oxygen and ethylene within the reactor.

[0051] Compared to the prior art, the EO/EG device of the present invention has the following advantages. A spiral-wound heat exchanger is disposed additionally to the reactor and the EO absorption tower, and the reaction product discharged from the outlet of the reactor flows in the tube passage of the spiral-wound heat exchanger, while the reaction feed containing oxygen and ethylene discharged from the feed pipeline flows in the shell passage of the spiral-wound heat exchanger. The reaction feed in the shell passage contacts

the wall of each heat exchange tube of the heat exchanger, so that the risks of flow leakage and flow maldistribution of the reaction feed is reduced. In addition, the reaction feed is distributed uniformly across any given cross-section, it can ensure the heat exchange efficiency and enhance the safety.

[0052] Furthermore, the reaction product flows through the tube passage, which is equipped with guide cylinders at the tube-passage inlet to prevent the formation of vortices and capillary tubes at the tube-passage outlet for cleaning purposes. This design addresses the scaling issue in the low-temperature section and enables online cleaning and descaling, so that the operational lifespan of the device can be extended and the safety can be enhanced.

Brief Description of the Drawings

[0053] Fig. 1 is a view of an EO/EG device according to Embodiment 1 of the present invention;

[0054] Fig. 2 is a front view of a part of a spiral-wound heat exchanger according to Embodiment 1 of the present invention;

[0055] Fig. 3 is an enlarged sectional view of part-I in Fig. 2 when viewed from the left side;

[0056] Fig. 4 is an enlarged view of part-A in Fig. 3;

[0057] Fig. 5 is a top view with an enlarged view of a first guide cylinder according to Embodiment 1 of the present invention;

[0058] Fig. 6 is an enlarged sectional view of a lower portion of the heat exchanger in Fig. 2;

[0059] Fig. 7 is an enlarged view of part-B in Fig. 6;

[0060] Fig. 8 is a view of a capillary tube and a heat exchange tube when viewed from direction-C in Fig. 7;

[0061] Fig. 9 is a view with an enlarged view of a liquid collecting pipe according to Embodiment 1 of the present invention;

[0062] Fig. 10 is a view of a tube clamp according to Embodiment 1 of the present invention;

[0063] Fig. 11 is a view of the tube clamp and the heat exchanger tube according to Embodiment 1 of the present invention;

[0064] Fig. 12 is another view of the tube clamp and the heat exchanger tubes according to Embodiment 1 of the present invention;

[0065] Fig. 13 is a sectional view of a part of the tube clamp and a spacer strip according

to Embodiment 1 of the present invention;

[0066] Fig. 14 is a top view with an enlarged view of a first guide cylinder according to Embodiment 2 of the present invention;

[0067] Fig. 15 is a view with an enlarged view of a liquid collecting pipe according to Embodiment 2 of the present invention;

[0068] Fig. 16 is a view of a liquid collecting pipe according to Embodiment 3 of the present invention.

Detailed Description of the Invention

[0069] The present invention will be further described in detail with reference to the accompanying drawings by embodiments.

[0070] Embodiment 1

[0071] Figs. 1-13 show a first preferred embodiment of an EO/EG device and a method for preparing EO/EG of the present invention. The EO/EG device comprises a reactor 8, an EO absorption tower 9, a spiral-wound heat exchanger 1 having a tube passage and a shell passage, and a steam generator 6. The steam generator 6 can generate steam by heating water via reaction heat from the reactor 8. The steam generator 6 has a hot-water inlet 61 for receiving external hot water, a steam outlet 62 for outputting steam, a heat inlet 63 and a cold outlet 64 respectively in communication with the reactor 8.

[0072] The heat exchanger 1 has a tube-passage inlet 110, a tube-passage outlet 120, a shell-passage inlet 170 and a shell-passage outlet 180. The tube-passage inlet 110 of the heat exchanger 1 is in communication with the outlet of the reactor 8, the tube-passage outlet 120 of the heat exchanger 1 is in communication with the inlet of the EO absorption tower 9 via a pipeline. A water cooler 7 is disposed on the pipeline. The shell-passage inlet 170 of the heat exchanger 1 is in communication with a feed pipeline 171 for delivering a reaction feed containing oxygen and ethylene, and the shell-passage outlet 180 of the heat exchanger 1 is in communication with the inlet of the reactor 8. The EO absorption tower 9 has an inlet, a bottom outlet, and a gas outlet at a top of the EO absorption tower 9, the gas outlet of the EO absorption tower 9 is in communication with the feed pipeline 171 through a circulation pipeline 172, a compressor 173 and a heater 174 are respectively disposed on the circulation line 172.

[0073] The specific configuration of components of the spiral-wound heat exchanger 1 in this embodiment will be described below.

[0074] As shown in Fig. 2, the spiral-wound heat exchanger 1 comprises a shell-passage cylinder 150, an upper tube sheet 160, an upper funnel 161, a lower tube sheet 140, a lower

funnel 141, a central cylinder 730, a plurality of heat exchange tubes 200, guide cylinders, a plurality of capillary tubes 210, a liquid collecting pipe 300, and a support mechanism.

[0075] The shell-passage cylinder 150 is arranged vertically, and has the shell-passage inlet 170 on a lower portion of a side wall and the shell-passage outlet 180 on an upper portion of a side wall.

[0076] The upper tube sheet 160 is disposed at a top of the shell-passage cylinder 150 and comprises a centrally located first portion 161a, a second portion 162a surrounding the first portion 161a and a peripheral portion 16b surrounding the second portion 162a. The first portion 161a and the second portion 162a are collectively referred to as a central portion 16a. Specifically, the first portion 161a is a non-perforated portion having no through holes, while the second portion 162a and the peripheral portion 16b are perforated portions each having a plurality of through holes. Please refer to Figs. 3 and 4 for details.

[0077] The upper funnel 161 is disposed above the upper tube sheet 160, and has the tube-passage inlet 110 at a top of the upper funnel 161 at a position corresponding to the central portion 16a of the upper tube sheet 160 for receiving the tube-passage medium. The upper funnel 161 has a side wall in a form of a conical shape that flares outwardly from top to bottom.

[0078] The lower tube sheet 140 is disposed at a bottom of the shell-passage cylinder 150. The lower funnel 141 is disposed beneath the lower tube sheet 140, and has a cleaning-liquid inlet nozzle 130 on a side wall of the lower funnel 141 and the tube-passage outlet 120 at a bottom of the lower funnel 141.

[0079] The central cylinder 730 having a top end and a bottom end is disposed axially within the shell-passage cylinder 150. The top end of the central cylinder 730 faces and is connected to the first portion 161a of the upper tube sheet 160 and the bottom end of the central cylinder 730 is supported on the lower tube sheet 140.

[0080] The plurality of heat exchange tubes 200 is disposed inside the shell-passage cylinder 150 and wound around an outer periphery of the central cylinder 730 along a lengthwise direction. The top end of each heat exchange tube 200 is supported on the second portion 162a and the peripheral portion 16b of the upper tube sheet 160. Each heat exchange tube 200 communicates with the upper funnel 161 through corresponding through holes in the second portion 162a and the peripheral portion 16b. The bottom end of each heat exchange tube 200 is supported on the lower tube sheet 140 and communicates with the lower funnel 141.

[0081] As shown in Figs. 3 -5, the spiral-wound heat exchanger has two guide cylinders, that are a first guide cylinder 710 and a second guide cylinder 720. The first guide cylinder

710 is hollow and disposed within the upper funnel 161. The first guide cylinder 710 has a peripheral wall 711 in a cone extending upwardly from top to bottom, and the peripheral wall 711 is separated from a side wall of and faces the upper funnel 161. An inclination angle of the peripheral wall 711 relative to a vertical axis is defined as α, and α is less than 45°. Meanwhile, the first guide cylinder 710 has a plurality of circular first through holes 713 circumferentially distributed at intervals on the peripheral wall 711 for allowing a tube-passage medium to pass through. The plurality of first through holes 713 is arranged in groups, and the first guide cylinder 710 has at least two groups of the first through holes 713 vertically arranged at intervals. The first guide cylinder 710 has a closed cone head 712 joined by a top edge of the peripheral wall 711 and disposed opposite the tube-passage inlet 110. The cone head 712 of the first guide cylinder 710 has a spherical-cap shape and a radius of the cone head 712 is not less than 200 mm. The first guide cylinder 710 has a plurality of circular second through holes 714 distributed at intervals on the cone head 712 for allowing the tube-passage medium to pass through. A lower edge of the cone head 712 is tangent to an upper edge of the peripheral wall 711. The bottom of the peripheral wall 711 is open and the first guide cylinder 710 has a straight cylindrical portion 715 extending downward from the bottom of the peripheral wall 711. The straight cylindrical portion 715 has a bottom edge which is supported on the peripheral portion 16b of the upper tube sheet 160. The straight cylindrical portion 715 has a plurality of third through holes 716 circumferentially disposed at intervals on an annular wall of the cylindrical portion 715 for allowing the tube-passage medium to pass through.

[0082] The second guide cylinder 720 is vertically disposed within the first guide cylinder 710 and located above the first portion 161a of the upper tube sheet 160. The second guide cylinder 720 has a conical shape corresponding to the shape of the first guide cylinder 710, so that the tube-passage medium falling onto the second guide cylinder 720 is guided onto the second portion 162a of the upper tube sheet 160.

[0083] In operation, after the tube-passage medium enters the upper funnel 161 through the tube-passage inlet 110, the tube-passage medium passes over the cone head 712 at the top of the first guide cylinder 710 and then flows downward along the peripheral wall 711 of the first guide cylinder 710. During this flow, a portion of the tube-passage medium enters the first guide cylinder 710 through the plurality of second through holes 714 on the cone head 712 and the plurality of first through holes 713 on the peripheral wall 711, while another portion of the tube-passage medium flows downward along the peripheral wall 711 of the first guide cylinder 710 to the peripheral portion 16b of the upper tube sheet 160 and enters the heat exchange tubes 200 supported on the peripheral portion 16b. Furthermore,

the tube-passage medium entering the first guide cylinder 710 either flows directly toward the second portion 162a of the upper tube sheet 160 or along a side wall of the second guide cylinder 720 toward the second portion 162a of the upper tube sheet 160, and then enters the heat exchange tubes supported by the second portion 162a. Under such a design, the tube-passage medium entering the upper funnel 161 flows uniformly into the heat exchange tubes 200. Furthermore, in this embodiment, the conical-shaped guide cylinders prevent the tube-passage medium from forming vortices or turbulent flows.

[0084] As shown in Figs. 6 - 9, the number of the capillary tubes 210 corresponds to the number of heat exchange tubes 200. Each capillary tube 210 having a first end and a second end has a liquid inlet hole 211 at the first end thereof and a liquid outlet hole 212 at the second end thereof. The second end of each capillary tube 210 is inserted upward into the corresponding heat exchange tube 200 from its lower end (the second end of the capillary tube 210 is located adjacent to the bottom end of the heat exchange tube 200 and relatively away from the top end thereof, specifically at a location where the heat exchange temperature is ≤85°C), while the first end of each capillary tube 210 faces downward and is located outside the heat exchange tube 200 and within the lower funnel 141. Meanwhile, each capillary tube 210 has a plurality of positioning bumps 213 protruding from the outer peripheral wall of a portion of each capillary tube 210 located within the corresponding heat exchange tube 200 to the inner peripheral wall of the corresponding heat exchange tube 200. The plurality of positioning bumps 213 is circumferentially disposed at intervals on the outer peripheral wall of the portion of each capillary tube 210 located within the corresponding heat exchange tube 200. An end of each positioning bump 213 faces towards and is adjacent to the inner peripheral wall of the corresponding heat exchange tube 200, or an end of each positioning bump faces towards and contacts with the inner peripheral wall of the corresponding heat exchange tube. The plurality of circumferentially arranged positioning bumps 213 is defined as one positioning-member group, at least two positioning-member groups are disposed at intervals along a lengthwise direction of the capillary tube 210. With the arrangement of positioning bumps 213, an outer peripheral wall of each capillary tube 210 located within the heat exchange tube 200 faces and is separated from an inner peripheral wall of the corresponding heat exchange tube 200, and an annular chamber 20 is defined between each capillary tube 210 and the corresponding heat exchange tube 200. The tube-passage medium can pass through the annular chamber 20, so that the arrangement of the capillary tubes 210 does not interfere with normal operation of the heat exchange tube 200.

[0085] The liquid collecting pipe 300 is annular and disposed transversely within the

lower funnel 141, beneath the capillary tubes 210. The liquid collecting pipe 300 has a liquid inlet 310 in communication with the cleaning-liquid inlet nozzle 130 and a plurality of liquid outlets 320 circumferentially disposed at intervals on a surface of the annular liquid collecting pipe 300, each liquid outlet 320 faces and is in communication with the liquid inlet hole 211 of a corresponding capillary tube 210.

[0086] Under such a design, when it is necessary to clean the heat exchange tubes 200, the cleaning liquid is delivered into the capillary tubes 210 through the cleaning-liquid inlet nozzle 130 and is then sprayed out from the liquid outlet holes 212 at the second ends of the capillary tubes 210. The sprayed cleaning liquid cleans inner walls of the heat exchange tubes 200, preventing blockage of the heat exchange tubes 200. Furthermore, the sprayed cleaning liquid passes through the annular chamber 20 and is discharged from the bottom ends of the heat exchange tubes 200.

[0087] As shown in Figs. 10-13, the heat exchange tubes 200 in this embodiment are spirally wound in multiple layers from the inside outward, two adjacent layers of the heat exchange tubes 200 are positioned relative to one another by a support mechanism which comprises a spacer strip 500 and a tube clamp 400.

[0088] Two adjacent layers of heat exchange tubes 200 are herein defined as the first heat exchange tube 201 and the second heat exchange tube 202.

[0089] The tube clamp 400 is in an inverted U-shape and has an upward-extending first support section 41, a second support section 43 arranged alongside the first support section 41, and a transition section 42 connecting the first support section 41 and the second support section 43. The first support section 41, the second support section 43, and the transition section 42 jointly define a recess 420 having a downward-facing opening 410, so that the first heat exchange tube 201 can be inserted into the recess 420 through the opening 410. Furthermore, a lower end of the first support section 41 and a lower end of second support section 43 of each tube clamp 400 respectively has a retaining tab 44, and the two retaining tabs 44 extend outwardly in opposite directions. Meanwhile, the tube clamp 400 is an elastic member capable of elastic deformation, so that the lower end portions of the first support section 41 and second support section 43 of the tube clamp 400 constantly tend to move away from each other.

[0090] The spacer strip 500 has an upward-facing first surface, and has a first slot 510 and a second slot 520 on the first surface at positions corresponding to the first support section 41 and the second support section 43, respectively. And, each of the first slot 510 and the second slot 520 comprises an insertion section 5a extending downwards and a locking section 5b extending outwards from a lower end of the insertion section 5a. The

retaining tabs 44 on the first and second support sections 41, 43 are inserted into the respective insertion sections 5a and, under the elastic force of the tube clamp 400 itself, extend into the respective locking sections 5b. In this state, an outer side surface of the lower end portion of the first support section 41 and the outer side surface of the lower end portion of the second support section 43 respectively contact the side wall of the corresponding insertion section 5a, and the attached portions are connected by welding. The welding locations are indicated at A in Fig. 13.

[0091] An inner peripheral surface of the transition section 42 of the tube clamp 400 comprises a first inner arc surface 421, a second inner arc surface 422, and a third inner arc surface 423 arranged sequentially in a circumferential direction. The second inner arc surface 422 faces the opening 410 and is configured to mate with the outer peripheral wall of the first heat exchange tube 201. The first inner arc surface 421 and the third inner arc surface 423 are both recessed outwards. Furthermore, the tube clamp 400 has a first bump 424 protruding inwards and faces the outer peripheral wall of the first heat exchange tube 201 at the junction of the first inner arc surface 421 and the second inner arc surface 422. Furthermore, the tube clamp 400 has a second bump 425 protruding inwards and faces the outer peripheral wall of the first heat exchange tube 201 at the junction of the third inner arc surface 423 and the second inner arc surface 422. An axis extending in an up-down direction and passing through a center of the second inner arc surface 422 is defined as the first axis 430. The first inner arc surface 421 and the third inner arc surface 423 are arranged symmetrically about the first axis 430. Meanwhile, the outer peripheral surface of the transition section 42 of the tube clamp 400 has a first outer arc surface 441, a second outer arc surface 442, and a third outer arc surface 443 arranged sequentially in a circumferential direction. The second outer arc surface 442 is located corresponding to the second inner arc surface 422 and is recessed inward to support the outer peripheral wall of the second heat exchange tube 202. The first outer arc surface 441 is located corresponding to the first inner arc surface 421 and is projected outward, and the first outer arc surface 441 and the first inner arc surface 421 are concentric. The third outer arc surface 443 is located corresponding to the third inner arc surface 423 and is projected outward, and the third outer arc surface 443 and the third inner arc surface 423 are concentric. Meanwhile, in this embodiment, adjacent outer arc surfaces and adjacent inner arc surfaces are interconnected by respective smooth transition surfaces 440 to prevent damage to the heat exchange tubes 200.

[0092] After the first heat exchange tube 201 has been wound around the spacer strip 500, the two retaining tabs 44 on the tube clamp 400 are inserted into the corresponding first

slot 510 and second slot 520 on the spacer strip 500, respectively. Subsequently, the tube clamp 400 is welded to the spacer strip 500 at location A (shown in Fig. 13), thereby securely fastening the tube clamp 400 to the spacer strip 500.

[0093] When the first heat exchange tube 201 expands due to fluctuations in operating conditions (such as changes in temperature, operating pressure, or operating load), the first inner arc surface 421 and the third inner arc surface 423 can elastically deform under the influence of the first heat exchange tube. This provides space for the expansion of the first heat exchange tube, preventing it from being tightly clamped by the tube clamp 400 upon expansion. The second inner arc surface 422 of the tube clamp 400 mates with the outer peripheral wall of the first heat exchange tube, effectively constraining the first heat exchange tube 201. Meanwhile, the second outer arc surface 442 of the tube clamp 400 supports the outer peripheral wall of the second heat exchange tube 202. In other words, the tube clamp 400 in this embodiment can constrain two adjacent heat exchange tubes simultaneously. Please refer to Fig. 12 for details.

[0094] The method for preparing EO/EG using the EO/EG device of this embodiment comprises:

[0095] inputting a reaction feed containing oxygen and ethylene and having a temperature of 40-65°C in the feed pipeline 171 into the shell passage of the spiral-wound heat exchanger 1 through the shell-passage inlet 170, the reaction feed serving as a shell-passage medium; discharging the reaction feed from the shell-passage outlet 180 at a temperature of 170-210°C, and inputting the reaction feed into the reactor 8 for reaction; discharging an EO reaction product from the reactor 8 at a temperature of 200-230°C, the EO reaction product serving as a tube-passage medium, and inputting the EO reaction product into the tube passage of the spiral-wound heat exchanger 1 through the tube-passage inlet 110 to exchange heat with the shell-passage medium; discharging the EO reaction product from the tube-passage outlet 120 at a temperature of 70-90°C, and delivering the EO reaction product into the EO absorption tower 9; and delivering a material discharged from a bottom outlet of the EO absorption tower 9 to a downstream equipment to produce EG.

[0096] Embodiment 2

[0097] Figs. 14-15 show a second preferred embodiment of an EO/EG device and a method for preparing EO/EG of the present invention. This embodiment is substantially the same as Embodiment 1, and the difference of this embodiment is that, the first through holes 713 on the peripheral wall 711 of the first guide cylinder 710, the second through

holes 714 on the cone head 712, and the third through holes 716 on the straight cylinder 715 are all elongated holes. Meanwhile, in this embodiment, the liquid collecting pipe 300 comprises two annular pipe units 30 concentrically sleeved one inside another. The two adjacent annular pipe units 30 are communicated with each other through radially extending intermediate pipes 31. Four intermediate pipes 31 are disposed at regular intervals in a circumferential direction. Meanwhile, each annular pipe unit 30 has the plurality of liquid outlets 320 circumferentially disposed thereon, and the outermost annular pipe unit 30 has the liquid inlet 310.

[0098] Embodiment 3

[0099] Figs. 16 shows a third preferred embodiment of an EO/EG device and a method for preparing EO/EG of the present invention. This embodiment is substantially the same as Embodiment 2, and the difference of this embodiment is that, the EO/EG device has three annular pipe units 30.

Claims

1. An ethylene oxide (EO) /ethylene glycol (EG) device, comprising:

a spiral-wound heat exchanger (1);

a reactor (8) having an inlet and an outlet; and

an EO absorption tower (9) having an inlet and a bottom outlet;

wherein, the heat exchanger (1) has a tube passage, a shell passage, a tube-passage inlet (110), a tube-passage outlet (120), a shell-passage inlet (170) and a shell-passage outlet (180);

the tube-passage inlet (110) of the heat exchanger (1) is in communication with the outlet of the reactor (8), the tube-passage outlet (120) of the heat exchanger (1) is in communication with the inlet of the EO absorption tower (9), the shell-passage inlet (170) of the heat exchanger (1) is in communication with a feed pipeline (171) for delivering a reaction feed containing oxygen and ethylene, and the shell-passage outlet (180) of the heat exchanger (1) is in communication with the inlet of the reactor (8).

2. The EO/EG device of claim 1, wherein a water cooler (7) is disposed on a pipeline connected between the tube-passage outlet (120) of the spiral-wound heat exchanger (1) and the inlet of the EO absorption tower (9).

3. The EO/EG device of claim 1, wherein the EO absorption tower (9) has a gas outlet at a top of the EO absorption tower (9), the gas outlet of the EO absorption tower (9) is in communication with the feed pipeline (171) through a circulation pipeline (172), a compressor (173) and a heater (174) are respectively disposed on the circulation line (172).

4. The EO/EG device of claim 1, wherein the device further comprises a steam generator (6) capable of generating steam by heating water via reaction heat from the reactor (8);

the steam generator (6) has a hot-water inlet (61) for receiving external hot water, a steam outlet (62) for outputting steam, a heat inlet (63) and a cold outlet (64) respectively in communication with the reactor (8).

5. The EO/EG device of any one of claims 1-4, wherein the spiral-wound heat exchanger (1) comprises:

a vertical shell-passage cylinder (150) having a top and a bottom;

an upper tube sheet (160) and a lower tube sheet (140) respectively disposed at the top and the bottom of the shell-passage cylinder (150);

an upper funnel (161) disposed above the upper tube sheet (160) and a lower funnel (141) disposed below the lower tube sheet (140), the upper funnel (161) having the

tube-passage inlet (110), and the lower funnel (141) having the tube-passage outlet (120); and

a plurality of heat exchange tubes (200) disposed inside the shell-passage cylinder (150) along an axis of the shell-passage cylinder (150), each heat exchange tube (200) has a top end which is supported by the upper tube sheet (160) and in communication with the upper funnel (161), and a bottom end which is supported by the lower tube sheet (140) and in communication with the lower funnel (141);

the shell-passage inlet (170) is located on a lower portion of a side wall of the shell-passage cylinder (150) and the shell-passage outlet (180) is located on an upper portion of the side wall the shell-passage cylinder (150).

6. The EO/EG device of claim 5, wherein the upper tube sheet (160) comprises a central portion (16a) and a peripheral portion (16b) surrounding the central portion (16a), the heat exchanger (1) has the tube-passage inlet (110) at a top of the upper funnel (161) corresponding to the central portion (16a) of the upper tube sheet (160).

7. The EO/EG device of claim 6, wherein the spiral-wound heat exchanger (1) further comprises a hollow first guide cylinder (710) disposed within the upper funnel (161);

the first guide cylinder (710) has a peripheral wall (711) flaring outwardly from top to bottom, the peripheral wall (711) is separated from a side wall of and faces the upper funnel (161);

the first guide cylinder (710) has a closed cone head (712) joined by a top edge of the peripheral wall (711) and disposed opposite the tube-passage inlet (110);

a bottom of the first guide cylinder (710) opens downward, a bottom edge of the peripheral wall (711) corresponds to the peripheral portion (16b) of the upper tube sheet (160);

the first guide cylinder (710) has a plurality of first through holes (713) circumferentially distributed at intervals on the peripheral wall (711) for allowing a tube-passage medium to pass through.

8. The EO/EG device of claim 7, wherein an inclination angle of the peripheral wall (711) relative to a vertical axis is defined as α, and α is less than 45°.

9. The EO/EG device of claim 7, wherein the plurality of first through holes (713) is arranged in groups, and the first guide cylinder (710) has at least two groups of the first through holes (713) vertically arranged at intervals.

10. The EO/EG device of claim 7, wherein the cone head (712) of the first guide

cylinder (710) has a spherical-cap shape, and the first guide cylinder (710) has a plurality of second through holes (714) distributed at intervals on the cone head (712) for allowing the tube-passage medium to pass through.

11. The EO/EG device of claim 10, wherein a radius of the cone head (712) of the first guide cylinder (710) is not less than 200 mm.

12. The EO/EG device of claim 7, wherein the first guide cylinder (710) has a straight cylindrical portion (715) extending downward from the bottom of the peripheral wall (711), and an annular side wall;

the straight cylindrical portion (715) has a bottom edge which is supported on the peripheral portion (16b) of the upper tube sheet (160);

the straight cylindrical portion (715) has a plurality of third through holes (716) circumferentially disposed at intervals on an annular wall of the cylindrical portion (715) for allowing the tube-passage medium to pass through.

13. The EO/EG device of claim 7, wherein the spiral-wound heat exchanger (1) further comprises a central cylinder (730) vertically disposed inside the shell-passage cylinder (150);

wherein the central portion (16a) of the upper tube sheet (160) comprises a first portion (161a) connected to a top end of the central cylinder (730) and a second portion (162a) surrounding the first portion (161a);

the plurality of heat exchange tubes (200) is wound around an outer periphery of the central cylinder (730) along a lengthwise direction, the top end of each heat exchange tube (200) is supported on the second portion (162a) and the peripheral portion (16b) of the upper tube sheet (160);

the spiral-wound heat exchanger (1) further comprises a second guide cylinder (720) vertically disposed within the first guide cylinder (710) and located above the first portion (161a) of the upper tube sheet (160), the second guide cylinder (720) has a conical shape corresponding to the shape of the first guide cylinder (710), so that the tube-passage medium falling onto the second guide cylinder (720) is guided onto the second portion (162a) of the upper tube sheet (160).

14. The EO/EG device of claim 7, wherein the upper funnel (161) has a side wall in a form of a conical shape that flares outwardly from top to bottom.

15. The EO/EG device of claim 5, wherein the lower funnel (141) comprises a cleaning-liquid inlet nozzle (130);

the spiral-wound heat exchanger (1) further comprises a plurality of capillary tubes (210) each having a first end and a second end, each capillary tube (210) has a liquid inlet hole (211) in communication with the cleaning-liquid inlet nozzle (130) at the first end thereof, and a liquid outlet hole (212) at the second end thereof; the second end of each capillary tube (210) is inserted into a corresponding heat exchange tube (200) along a lengthwise direction;

an outer peripheral wall of each capillary tube (210) located within the heat exchange tube (200) faces and is separated from an inner peripheral wall of the corresponding heat exchange tube (200), and an annular chamber (20) is defined between each capillary tube (210) and the corresponding heat exchange tube (200).

16. The EO/EG device of claim 15, wherein each capillary tube (210) has a plurality of positioning bumps (213) protruding from the outer peripheral wall of a portion of each capillary tube (210) located within the corresponding heat exchange tube (200) to the inner peripheral wall of the corresponding heat exchange tube (200), the plurality of positioning bumps (213) is circumferentially disposed at intervals on the outer peripheral wall of the portion of each capillary tube (210) located within the corresponding heat exchange tube (200), and an end of each positioning bump (213) faces towards and is adjacent to the inner peripheral wall of the corresponding heat exchange tube (200).

17. The EO/EG device of claim 16, wherein the plurality of circumferentially arranged positioning bumps (213) is defined as one positioning-member group, at least two positioning-member groups are disposed at intervals along a lengthwise direction of the capillary tube (210).

18. The EO/EG device of claim 15, wherein the second end of each capillary tube (210) is disposed adjacent to a lower end of the corresponding heat exchange tube (200).

19. The EO/EG device of claim 18, wherein the device further comprises an annular liquid collecting pipe (300) disposed within the lower funnel (141);

the annular liquid collecting pipe (300) has a liquid inlet (310) in communication with the cleaning-liquid inlet nozzle (130) and a plurality of liquid outlets (320) circumferentially disposed at intervals on a surface of the annular liquid collecting pipe (300), each liquid outlet (320) faces and is in communication with the liquid inlet hole (211) of a corresponding capillary tube (210).

20. The EO/EG device of claim 19, wherein the liquid collecting pipe (300) comprises at least two annular pipe units (30) concentrically sleeved one inside another, adjacent

annular pipe units (30) are in communication with each another through one or more radially extending intermediate pipes (31), each annular pipe unit (30) has the plurality of liquid outlets (320) circumferentially disposed thereon, and the outermost annular pipe unit (30) has the liquid inlet (310).

21. A method for preparing EO/EG by using the EO/EG device of any one of claims 1-20, comprising:

inputting a reaction feed containing oxygen and ethylene and having a temperature of 40-65°C in the feed pipeline (171) into the shell passage of the spiral-wound heat exchanger (1) through the shell-passage inlet (170), the reaction feed serving as a shell-passage medium;

discharging the reaction feed from the shell-passage outlet (180) at a temperature of 170-210°C, and inputting the reaction feed into the reactor (8) for reaction;

discharging an EO reaction product from the reactor (8) at a temperature of 200-230°C, the EO reaction product serving as a tube-passage medium, and inputting the EO reaction product into the tube passage of the spiral-wound heat exchanger (1) through the tube-passage inlet (110) to exchange heat with the shell-passage medium;

discharging the EO reaction product from the tube-passage outlet (120) at a temperature of 70-90°C, and delivering the EO reaction product into the EO absorption tower (9); and

delivering a material discharged from the bottom outlet of the EO absorption tower (9) to a downstream equipment to produce EG.