

SYSTEMS AND METHODS FOR STEAM CRACKING HYDROCARBONS**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of priority to U.S. Provisional Patent Application No. 63/128,263, filed December 21, 2020, the entire contents of which are
5 hereby incorporated by reference in their entirety.

FIELD OF INVENTION

[0002] The present invention generally relates to systems and methods for steam cracking hydrocarbons. More specifically, the present invention relates to systems and methods for steam cracking hydrocarbons using a steam cracking unit that uses polymer
10 composite tubes in the convection section.

BACKGROUND OF THE INVENTION

[0003] Steam cracking is one of the most commonly used processes for producing light olefins and other high valued chemicals in the chemical industry. In a steam cracking process, feedstock to be cracked and high pressure steam are preheated in a convection section, which
15 comprises a series of tube bundles, via indirect convective heat transfer from flue gas to feedstock and the high pressure steam. The hydrocarbons in the preheated feedstock and steam mixture are then cracked in the radiation section of the steam cracker.

[0004] The convection sections of the cracking furnaces frequently suffer from fouling during processing of liquid feedstocks. Although the exact mechanism of the fouling in the
20 convection section is not yet well-understood, the fouling could be caused by various parameters, including fines, heteroatoms, and un-saturated compounds (e.g., olefins and diolefins). To keep the furnace on-stream, the fouling in the convection section needs to be removed on a regular basis, which takes some effort and reduces production time. Hence, fouling prevention and mitigation in the convection section can significantly improve the
25 production efficiency of the steam cracker.

[0005] Overall, while the systems and methods of removing fouling of steam crackers exist, the need for improvements in this field persists in light of the aforementioned drawbacks with conventional systems and methods.

BRIEF SUMMARY OF THE INVENTION

[0006] A solution to the above-mentioned problem associated with the systems and methods of steam cracking hydrocarbons, especially liquid hydrocarbons, has been discovered. The solution resides in a steam cracking unit that comprises polymer composite tubes in the convection section. This can be beneficial as the polymer composite material(s) used for making the tubes are configured to reduce the fouling rate in the tubes, thereby mitigating the fouling issue in the convection sections of steam crackers and reducing the frequency of cleaning of fouling from the steam crackers. Consequently, the disclosed systems and methods are capable of improving the production efficiency of the steam crackers. Therefore, the disclosed systems and methods of the present invention provide a technical solution to the problem associated with the conventional systems and methods for steam cracking.

[0007] Embodiments of the invention include a method of processing a hydrocarbon stream. The method comprises steam-cracking the hydrocarbon stream in a steam cracker comprising a convection section that comprises one or more polymer composite tubes.

[0008] Embodiments of the invention include a method of processing a pyrolysis oil stream. The method comprises removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil. The method comprises steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics. The steam cracker comprises a convection section that includes one or more polymer composite tubes.

[0009] Embodiments of the invention include a method of processing a pyrolysis oil stream. The method comprises removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil. The method comprises steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics. The steam cracker comprises a feed preheater bank that comprises one or more polymer composite tubes.

[0010] The following includes definitions of various terms and phrases used throughout this specification.

[0011] The terms “about” or “approximately” are defined as being close to as understood by one of ordinary skill in the art. In one non-limiting embodiment the terms are

defined to be within 10%, preferably, within 5%, more preferably, within 1%, and most preferably, within 0.5%.

5 [0012] The terms “wt.%”, “vol.%” or “mol.%” refer to a weight, volume, or molar percentage of a component, respectively, based on the total weight, the total volume, or the total moles of material that includes the component. In a non-limiting example, 10 moles of component in 100 moles of the material is 10 mol.% of component.

[0013] The term “substantially” and its variations are defined to include ranges within 10%, within 5%, within 1%, or within 0.5%.

10 [0014] The terms “inhibiting” or “reducing” or “preventing” or “avoiding” or any variation of these terms, when used in the claims and/or the specification, include any measurable decrease or complete inhibition to achieve a desired result.

[0015] The term “effective,” as that term is used in the specification and/or claims, means adequate to accomplish a desired, expected, or intended result.

15 [0016] The use of the words “a” or “an” when used in conjunction with the term “comprising,” “including,” “containing,” or “having” in the claims or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.”

20 [0017] The words “comprising” (and any form of comprising, such as “comprise” and “comprises”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”) or “containing” (and any form of containing, such as “contains” and “contain”) are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

25 [0018] The process of the present invention can “comprise,” “consist essentially of,” or “consist of” particular ingredients, components, compositions, etc., disclosed throughout the specification.

[0019] The term “primarily,” as that term is used in the specification and/or claims, means greater than any of 50 wt.%, 50 mol.%, and 50 vol.%. For example, “primarily” may include 50.1 wt.% to 100 wt.% and all values and ranges there between, 50.1 mol.% to 100

mol.% and all values and ranges there between, or 50.1 vol.% to 100 vol.% and all values and ranges there between.

[0020] Other objects, features and advantages of the present invention will become apparent from the following figures, detailed description, and examples. It should be understood, however, that the figures, detailed description, and examples, while indicating specific embodiments of the invention, are given by way of illustration only and are not meant to be limiting. Additionally, it is contemplated that changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description. In further embodiments, features from specific embodiments may be combined with features from other embodiments. For example, features from one embodiment may be combined with features from any of the other embodiments. In further embodiments, additional features may be added to the specific embodiments described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] For a more complete understanding, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

[0022] FIG. 1 shows a schematic diagram of a system for processing a hydrocarbon stream, according to embodiments of the invention;

[0023] FIG. 2 shows a schematic diagram of a convection section of a steam cracking furnace, according to embodiments of the invention; and

[0024] FIG. 3 shows a schematic flowchart of a method of processing a hydrocarbon stream, according to embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Currently, convection sections of steam crackers suffer from fouling. Thus, the steam cracker has to be cleaned to remove fouling on a regular basis, resulting in loss of on-stream time and reduced production efficiency for the steam cracker. The present invention provides a solution to this problem. The solution is premised on a steam cracking system comprising polymer composite tubes in the convection section thereof and a method of processing a hydrocarbon stream using the steam cracking system. Notably, the polymer composite tubes are configured to mitigate fouling of the convection section of the steam

cracker, thereby reducing the time needed to remove fouling and improving overall efficiency of the steam cracker. These and other non-limiting aspects of the present invention are discussed in further detail in the following sections.

A. System for processing hydrocarbons

5 [0026] In embodiments of the invention, the system for processing a hydrocarbon stream, including a pyrolysis oil stream, is capable of reducing fouling in a convection section of a steam cracker, thereby improving the production efficiency of the steam cracker. With reference to FIG. 1, a schematic diagram is shown for system 100, which is used for processing a hydrocarbon stream.

10 [0027] According to embodiments of the invention, system 100 includes purification unit 101 configured to purify hydrocarbon stream 11 to produce purified hydrocarbon stream 12. Hydrocarbon stream 11 can include a pyrolysis oil stream derived from pyrolysis of plastics. In embodiments of the invention, the plastics include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC),
15 polycaprolactone (PCL/nylon-like plastic), or combinations thereof. In embodiments of the invention, the pyrolysis oil stream can include heteroatoms including organic nitrogen, organic chlorine, oxygenates, silicone, fluorine, phosphorous, or combinations thereof. The pyrolysis oil stream can further include 10 to 50 wt.% unsaturated hydrocarbons. Purified hydrocarbon stream 12 can include a purified pyrolysis oil stream. Purified hydrocarbon stream 12 may
20 include less than 0.1 wt.% heteroatoms. Purified hydrocarbon stream 12 may include 1 to 50 wt.% unsaturated hydrocarbons. In embodiments of the invention, purification unit 101 is configured to remove the heteroatoms from the pyrolysis oil stream. Purification unit 101 may be further configured to remove at least some fines, particles from the pyrolysis oil stream. In embodiments of the invention, purification unit 101 can include an adsorption unit, a
25 hydrotreatment unit, or combinations thereof.

[0028] According to embodiments of the invention, system 100 includes steam cracking unit 102 configured to steam crack purified hydrocarbon stream 12 to produce cracked stream 13 comprising olefins and/or aromatics. In embodiments of the invention, steam cracking unit 102 comprises one or more steam cracking furnaces. Each steam cracking
30 furnace can include a convection section and a radiation section. In embodiments of the invention, in steam cracking unit 102, the convection section of a steam cracking furnace

comprises one or more polymer composite tubes. The polymer composite tubes can be in bundles. The polymer composite tubes can comprise a polymer composite material comprising polyphenylene sulphide (PPS), polyvinylidene difluoride (PVDF), polytetrafluoroethylene (PTFE), polyethylene (PE), polycarbonate (PC), polyphenylene oxide (PPO), perfluoroalcoxy (PFA), or combinations thereof. The polymer composite tubes comprises polyphenylene sulphide and the composite tubes may have an operating temperature limit of 20 to 300 °C and all ranges and values there between including ranges of 20 to 40 °C, 40 to 60 °C, 60 to 80 °C, 80 to 100 °C, 100 to 120 °C, 120 to 140 °C, 140 to 160 °C, 160 to 180 °C, 180 to 200 °C, 200 to 220 °C, 220 to 240 °C, 240 to 260 °C, 260 to 280 °C, and 280 to 300 °C.

10 **[0029]** In embodiments of the invention, the convection section is configured to prepare feedstock (e.g., purified hydrocarbon stream 12) for cracking in the radiation section. As shown in FIG. 2, the convection section of the steam cracking furnace can include feed preheater bank 201, upper mixed preheater bank 202, and lower mixed preheater bank 203. In embodiments of the invention, feed preheater bank 201 is configured to heat purified hydrocarbon stream 12 (e.g., the pyrolysis oil stream derived from plastics) to a first temperature. In embodiments of the invention, the first temperature is in a range of 60 to 150 °C and all ranges and values there between including ranges of 60 to 70 °C, 70 to 80 °C, 80 to 90 °C, 90 to 100 °C, 100 to 110 °C, 110 to 120 °C, 120 to 130 °C, 130 to 140 °C, and 140 to 150 °C. Upper mixed preheater bank 202 may be configured to heat a mixture of (1) the preheated purified hydrocarbon stream 12 from feed preheater bank 201 and (2) steam to a second temperature. In embodiments of invention, the second temperature is in a range of 150 to 230 °C and all ranges and values there between including ranges of 150 to 160 °C, 160 to 170 °C, 170 to 180 °C, 180 to 190 °C, 190 to 200 °C, 200 to 210 °C, 210 to 220 °C, and 220 to 230 °C. In embodiments of the invention, lower mixed preheater bank 203 is configured to further heat the mixture from upper mixed preheater bank 202 to a third temperature. The third temperature may be in a range of 300 to 600 °C and all ranges and values there between including ranges of 300 to 330 °C, 330 to 360 °C, 360 to 390 °C, to 390 to 420 °C, 420 to 450 °C, 450 to 480 °C, 480 to 510 °C, 510 to 540 °C, 540 to 570 °C, and 570 to 600 °C.

30 **[0030]** In embodiments of the invention, feed preheater bank 201, uppermixed preheater bank 202, and/or lower mixed preheater bank 203 are heated using flue gas from the radiation section of the steam cracking furnace. In embodiments of the invention, the flue gas in feed preheater bank 201 is at a temperature of 140 to 260 °C and all ranges and values there

between 140 to 150 °C, 150 to 160 °C, 160 to 170 °C, 170 to 180 °C, 180 to 190 °C, 190 to 200 °C, 200 to 210 °C, 210 to 220 °C, 220 to 230 °C, 230 to 240 °C, 240 to 250 °C, and 250 to 260 °C. In embodiments of the invention, the flue gas in upper mixed preheater bank 202 is at a temperature of 420 to 550 °C and all ranges and values there between including ranges of 420 to 430 °C, 430 to 440 °C, 440 to 450 °C, 450 to 460 °C, 460 to 470 °C, 470 to 480 °C, 480 to 490 °C, 490 to 500 °C, 500 to 510 °C, 510 to 520 °C, 520 to 530 °C, 530 to 540 °C, and 540 to 550 °C. In embodiments of the invention, the flue gas in lower mixed preheater bank 203 is at a temperature of 760 to 1140 °C and all ranges and values there between including ranges of 760 to 790 °C, 790 to 820 °C, 820 to 850 °C, 850 to 880 °C, 880 to 910 °C, 910 to 940 °C, 940 to 970 °C, 970 to 1000 °C, 1000 to 1030 °C, 1030 to 1060 °C, 1060 to 1090 °C, 1090 to 1120 °C, and 1120 to 1140 °C. According to embodiments of the invention, feed preheater bank 201 comprises one or more of the polymer composite tubes.

B. Method of steam cracking hydrocarbon stream

[0031] In embodiments of the invention, a method of processing a hydrocarbon stream, including a pyrolysis oil stream derived from plastics is described. As shown in FIG. 3, embodiments of the invention include method 300 for processing a pyrolysis oil derived from plastics. Method 300 may be implemented by system 100, as shown in FIG. 1, and described above.

[0032] According to embodiments of the invention, as shown in block 301, method 300 includes removing, in purification unit 101, heteroatom contaminants from pyrolysis oil of hydrocarbon stream 11 to produce purified pyrolysis oil of purified hydrocarbon stream 12. In embodiments of the invention, the pyrolysis oil is produced from pyrolyzing plastics. The plastics may include plastic waste. Exemplary plastics used for producing the pyrolysis oil can include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polycaprolactone (PCL/nylon-like plastic), or combinations thereof.

[0033] In embodiments of the invention, the pyrolysis oil comprises 1000 to 50000 ppm heteroatoms, collectively. The purified pyrolysis oil can comprise 100 to 1000 ppm heteroatoms. In embodiments of the invention, at block 301, purification unit 101 includes an adsorption unit, and/or a hydrotreatment unit. In embodiments of the invention, the adsorption unit is configured to remove contaminants, and/or remove at least some unsaturated compounds. The hydrotreatment unit can be configured to convert contaminants into inorganic

compounds for removal in subsequent processes, and/or convert unsaturated compounds to saturated compounds using hydrogen. Pyrolysis oil at block 301 can include 10 to 50 wt.% unsaturated hydrocarbons. Purified pyrolysis oil, in embodiments of the invention, can comprise 1 to 50 wt.% unsaturated hydrocarbons. In embodiments of the invention, at block 5 301, purification unit 101 is configured to remove substantially no unsaturated hydrocarbons from the pyrolysis oil. Purification unit 101, at block 301, can be operated at an operating temperature of 350 to 450 °C. Purification unit 101, at block 301, can be operated at an operating pressure of 40 to 130 bar.

[0034] According to embodiments of the invention, as shown in block 302, method 300 10 includes steam-cracking, in steam cracking unit 102, the purified pyrolysis oil to produce olefins and aromatics. In embodiments of the invention, at block 302, one or more steam cracking furnaces of steam cracking unit 102 comprise the polymer composite tubes configured to reduce fouling rate in the convection section of the steam cracking furnace. In embodiments of the invention, the fouling in the convection section can include one or more polymers, coke, 15 polystyrene, indienes, cyclopentadiene, or combinations thereof. In embodiments of the invention, the polymer composite tubes are in the convection section of the one or more steam cracking furnaces. The polymer composite tubes can be in the feed preheater bank 201 of the one or more steam cracking furnaces. In embodiments of the invention, the feed pre-heater is operated at a temperature of 140 to 260 °C and all ranges and values there between including 20 ranges of 140 to 150 °C, 150 to 160 °C, 160 to 170 °C, 170 to 180 °C, 180 to 190 °C, 190 to 200 °C, 200 to 210 °C, 210 to 220 °C, 220 to 230 °C, 230 to 240 °C, 240 to 250 °C, and 250 to 260 °C. In embodiments of the invention, at block 302, the pyrolysis oil is cracked at a temperature of 800 to 850 °C and all ranges and values there between including ranges of 800 to 805 °C, 805 to 810 °C, 810 to 815 °C, 815 to 820 °C, 820 to 825 °C, 825 to 830 °C, 830 to 25 835 °C, 835 to 840 °C, 840 to 845 °C, and 845 to 850 °C.

[0035] In embodiments of the invention, at block 302, the steam cracking unit 102 is operated at a residence time of 10 to 700 ms and all ranges and values there between including ranges of 10 to 50 ms, 50 to 100 ms, 100 to 150 ms, 150 to 200 ms, 200 to 250 ms, 250 to 300 ms, 300 to 350 ms, 350 to 400 ms, 400 to 450 ms, 450 to 500 ms, 500 to 550 ms, 550 to 600 ms, 600 to 650 ms, and 650 to 700 ms. In embodiments of the invention, at block 302, the steam-cracking is performed at a steam-to-hydrocarbon weight ratio of 0.35 to 1.0 and all ranges and values there between including ranges of 0.35 to 0.40, 0.40 to 0.45, 0.45 to 0.50,

0.50 to 0.55, 0.55 to 0.60, 0.60 to 0.65, 0.65 to 0.70, 0.70 to 0.75, 0.75 to 0.80, 0.80 to 0.85, 0.85 to 0.90, 0.90 to 0.95, and 0.95 to 1.0. In embodiments of the invention, at block 302, the pyrolysis oil is cracked at a conversion rate of 50 to 100% and all ranges and values there between including ranges of 50 to 60%, 60 to 70%, 70 to 80%, 80 to 90%, and 90 to 100%. In
5 embodiments of the invention, the conversion rate of the pyrolysis oil is dependent on percentages of aromatics in the pyrolysis oil. In some instances, the pyrolysis oil can include 100 wt.% paraffins and the conversion rate of the pyrolysis oil can be substantially 100%. At block 302, the produced olefins can include ethylene, propylene, 1-butene, 2-butene, isobutene, butadiene, pentadiene, or combinations thereof. The produced aromatics can include benzene,
10 toluene, xylene, styrene, or combinations thereof.

[0036] Although embodiments of the present invention have been described with reference to blocks of FIG. 3 should be appreciated that operation of the present invention is not limited to the particular blocks and/or the particular order of the blocks illustrated in FIG. 3. Accordingly, embodiments of the invention may provide functionality as described herein
15 using various blocks in a sequence different than that of FIG. 3.

[0037] The systems and processes described herein can also include various equipment that is not shown and is known to one of skill in the art of chemical processing. For example, some controllers, piping, computers, valves, pumps, heaters, thermocouples, pressure indicators, mixers, heat exchangers, and the like may not be shown.

20 **[0038]** In the context of the present invention, at least the following 12 embodiments are described. Embodiment 1 is a method of processing a hydrocarbon stream. The method includes steam-cracking the hydrocarbon stream in a steam cracker including a convection section that includes one or more polymer composite tubes.

[0039] Embodiment 2 is a method of processing a pyrolysis oil stream. The method
25 includes removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil. The method further includes steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics, wherein the steam cracker includes a convection section that includes one or more polymer composite tubes. Embodiment 3 is the method of any of embodiments 1 and 2, wherein the convection section
30 includes a feed preheater of the steam cracker. Embodiment 4 is the method of any of embodiments 1 to 3, wherein the feed pre-heater is operated at a temperature of 140 to 260 °C.

Embodiment 5 is the method of any of embodiments 1 to 4, wherein the feed pre-heater is heated by a flue gas generated in a radiant section of the steam cracker. Embodiment 6 is the method of any of embodiments 1 to 5, wherein the polymer composite tubes contain polyphenylene sulphide (PPS), polyvinylidene difluoride (PVDF), polytetrafluoroethylene (PTFE), polyethylene (PE), polycarbonate (PC), polyphenylene oxide (PPO), perfluoroalcoxy (PFA), or combinations thereof. Embodiment 7 is the method of any of embodiments 1 to 6, wherein the polymer composite tubes have an operating temperature limit of 20 to 300 °C. Embodiment 8 is the method of any of embodiments 1 to 7, wherein the purifying unit includes an adsorption unit, a hydrotreatment unit. Embodiment 9 is the method of any of embodiments 1 to 8, wherein the pyrolysis oil contains more than 10 wt.% unsaturated molecules. Embodiment 10 is the method of any of embodiments 1 to 9, wherein the polymer composite tubes are configured to mitigate fouling of unsaturated molecules in the steam cracker. Embodiment 11 is the method of any of embodiments 1 to 10, wherein the convection section of the steam cracker includes a feed pre-heater bank, an upper mixed pre-heater bank, and a lower mixed pre-heater bank.

[0040] Embodiment 12 is a method of processing a pyrolysis oil stream. The method includes removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil. The method further includes steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics, wherein the steam cracker includes a feed preheater that includes one or more polymer composite tubes.

[0041] All embodiments described above and herein can be combined in any manner unless expressly excluded.

[0042] Although embodiments of the present application and their advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the embodiments as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the above disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized. Accordingly, the

appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

CLAIMS

What is claimed is:

1. A method of processing a hydrocarbon stream, the method comprising:
steam-cracking the hydrocarbon stream in a steam cracker comprising a convection section that comprises one or more polymer composite tubes.
2. A method of processing a pyrolysis oil stream, the method comprising:
removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil; and
steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics, wherein the steam cracker comprises a convection section that includes one or more polymer composite tubes.
3. The method of claim 2, wherein the convection section includes a feed preheater of the steam cracker.
4. The method of claim 3, wherein the feed pre-heater is operated at a temperature of 140 to 260 °C.
5. The method of claim 3, wherein the feed pre-heater is heated by a flue gas generated in a radiant section of the steam cracker.
6. The method of claim 2, wherein the polymer composite tubes comprise polyphenylene sulphide (PPS), polyvinylidene difluoride (PVDF), polytetrafluoroethylene (PTFE), polyethylene (PE), polycarbonate (PC), polyphenylene oxide (PPO), perfluoroalcoxy (PFA), or combinations thereof.
7. The method of claim 2, wherein the polymer composite tubes have an operating temperature limit of 20 to 300 °C.
8. The method of claim 2, wherein the purifying unit comprises an adsorption unit, a hydrotreatment unit.
9. The method of claim 2, wherein the pyrolysis oil comprises more than 10 wt.% unsaturated molecules.

10. The method of claim 2, wherein the polymer composite tubes are configured to mitigate fouling of unsaturated molecules in the steam cracker.
11. The method of claim 2, wherein the convection section of the steam cracker comprises a feed pre-heater bank, an upper mixed pre-heater bank, and a lower mixed pre-heater bank.
12. A method of processing a pyrolysis oil stream, the method comprising:
removing heteroatom contaminants from the pyrolysis oil stream in a purification unit to produce a purified pyrolysis oil; and
steam-cracking the purified pyrolysis oil stream in a steam cracker to produce olefins and aromatics, wherein the steam cracker comprises a feed preheater that comprises one or more polymer composite tubes.