

PROCESSES AND SYSTEMS FOR STEAM CRACKING HYDROCARBON FEEDS**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 63/176,423 having a filing date of April 19, 2021, the disclosure of which is incorporated herein by reference in its entirety.

FIELD

[0002] Embodiments disclosed herein generally relate to processes and systems for steam cracking hydrocarbon feeds. More particularly, such embodiments relate to processes and systems for steam cracking a plurality of hydrocarbon feeds, where each feed is cracked within one or more radiant coils disposed within different segments of a firebox of a steam cracking furnace.

BACKGROUND

[0003] Steam cracking is the primary means to generate ethylene and other products from a variety of feedstocks. Modern plants employ optimization models and controls to optimize profit. At times, these models and controls call for multiple feeds or multiple operating conditions, sometimes in smaller increments than a full furnace can provide. Steam cracking two or more different feeds within different segments within the radiant section of the steam cracker has proved challenging.

[0004] Prior attempts to steam crack multiple hydrocarbon feeds within a firebox of a single steam cracking furnace have implemented a dividing wall to provide more independent zones within that exhausted flue gases from the independent zones to a single convection section. While this arrangement provides multiple feed capability, it comes at the expense of a dividing wall inside the extremely high temperature firebox, which must have structural support and refractory lining. In practice, this results in a similar plot space requirement to a separate furnace, reducing much of the economy of scale benefit for combining feeds in a single furnace. In addition, the complexity, cost, and physical space requirements for a dividing wall naturally limit segments in a furnace to at most two.

[0005] There is a need, therefore, for improved processes and systems for steam cracking a plurality of hydrocarbon feeds, where each feed is cracked within one or more radiant coils disposed within different segments of a firebox of a steam cracking furnace. This disclosure satisfies this and other needs.

SUMMARY

[0006] Processes and systems for steam cracking a plurality of hydrocarbon feeds, where each feed is cracked within one or more radiant coils disposed within different segments of a firebox of a steam cracking furnace. In some embodiments, the process for steam cracking

5 hydrocarbons can include introducing a first hydrocarbon feed into one or more radiant coils disposed within a first segment of a firebox of a steam cracker to produce a first steam cracker effluent having a first coil outlet temperature. The first segment can include one or more burners providing heat thereto. A second hydrocarbon feed can be introduced into one or more radiant coils disposed within a second segment of the firebox of the steam cracker to produce

10 a second steam cracker effluent having a second coil outlet temperature. The second segment can include one or more burners providing heat thereto. The one or more burners in the first and second segments can be operated at substantially the same firing rate such that an amount of heat produced by each of the one or more burners in the first and second segments is substantially the same. A feed rate of the first hydrocarbon feed introduced into the one or

15 more radiant coils disposed within the first segment can be controlled based, at least in part, on a composition of the first hydrocarbon feed and the first coil outlet temperature.

[0007] In some embodiments, the system for steam cracking one or more hydrocarbon feeds can include a steam cracker that can include a firebox having one or more radiant coils and one or more burners disposed within a first segment of the firebox and one or more radiant coils

20 and one or more burners disposed within a second segment of the firebox. The one or more radiant coils in the first segment can be configured to receive a first hydrocarbon feed via a first feed control valve and produce a first steam cracker effluent having a first coil outlet temperature. The one or more radiant coils in the second segment can be configured to receive a second hydrocarbon feed via a second feed control valve and produce a second steam cracker

25 effluent having a second coil outlet temperature. The one or more burners in the first and second segments can be configured to operate at substantially the same firing rate such that an amount of heat produced by each of the one or more burners in the first and second segments is substantially the same. The first and second feed control valves can be configured to independently adjust a feed rate of the first and second hydrocarbon feeds introduced into the

30 one or more radiant coils in the first and second segments, respectively, to independently adjust the first and second coil outlet temperatures of the first and second steam cracker effluents, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended
5 drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] FIG. 1 depicts a schematic of an illustrative steam cracking furnace in operation to convert first and second hydrocarbon feeds within first and second segments, respectively, of
10 a firebox in the steam cracking furnace, according to one or more embodiments described.

[0010] FIG. 2 depicts a plan view of an illustrative firebox of a steam cracking furnace having a footprint area divided into four segments, according to one or more embodiments described.

[0011] FIG. 3 depicts a plan view of the firebox shown in FIG. 2 where each of the four segments include a plurality of burners and a plurality of tubes disposed therein, according to
15 one or more embodiments.

DETAILED DESCRIPTION

[0012] It is to be understood that the following disclosure describes several exemplary embodiments for implementing different features, structures, and/or functions of the invention. Exemplary embodiments of components, arrangements, and configurations are described
20 below to simplify the present disclosure; however, these exemplary embodiments are provided merely as examples and are not intended to limit the scope of the invention. Additionally, the present disclosure may repeat reference numerals and/or letters in the various exemplary embodiments and across the Figures provided herein. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various exemplary
25 embodiments and/or configurations discussed in the Figures. Moreover, the exemplary embodiments presented below can be combined in any combination of ways, *i.e.*, any element from one exemplary embodiment can be used in any other exemplary embodiment, without departing from the scope of the disclosure.

[0013] The indefinite article “a” or “an”, as used herein, means “at least one” unless specified
30 to the contrary or the context clearly indicates otherwise. Thus, embodiments using “a separator” include embodiments where one or two or more separators are used, unless specified to the contrary or the context clearly indicates that only one separator is used. Likewise,

embodiments using “a separation stage” include embodiments where one or two or more separation stages are used, unless specified to the contrary.

[0014] Certain embodiments and features are described using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges including the combination of any two values, *e.g.*, the combination of any lower value with any upper value, the combination of any two lower values, and/or the combination of any two upper values are contemplated unless otherwise indicated. Certain lower limits, upper limits and ranges appear in one or more claims below. All numerical values are “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0015] As used herein, the term “hydrocarbon” means a class of compounds containing hydrogen bound to carbon. The term “C_n” hydrocarbon means hydrocarbon having n carbon atom(s) per molecule, where n is a positive integer. The term “C_{n+}” hydrocarbon means hydrocarbon having at least n carbon atom(s) per molecule, where n is a positive integer. The term “C_{n-}” hydrocarbon means hydrocarbon having no more than n number of carbon atom(s) per molecule, where n is a positive integer. “Hydrocarbon” encompasses (i) saturated hydrocarbon, (ii) unsaturated hydrocarbon, and (iii) mixtures of hydrocarbons, including mixtures of hydrocarbon compounds (saturated and/or unsaturated), including mixtures of hydrocarbon compounds having different values of n.

[0016] It has been surprisingly and unexpectedly discovered that two or more hydrocarbon feeds can each be steam cracked within one or more radiant coils disposed within separate segments of a firebox in a steam cracking furnace to produce two or more steam cracker effluents by operating one or more burners disposed within each segment at substantially the same firing rate by independently adjusting a feed rate of each hydrocarbon feed. It has also been surprisingly and unexpectedly discovered that two or more hydrocarbon feeds can each be steam cracked within one or more radiant coils disposed within separate segments of the firebox in the steam cracking furnace to produce the two or more steam cracker effluents by having one or more burners within one or more of the segments off while operating the other burners within the one or more segments at a substantially constant firing rate by independently adjusting the feed rate of each hydrocarbon feed. As used herein, the phrase “substantially the same firing rate” means that an amount of heat produced by each burner disposed within each segment is within 20%, within 15%, within 10%, within 7%, within 5%, within 3%, or within 1% of one another. Such control scheme of the steam cracking furnace, which can also be

referred to as a “coil outlet temperature to feed rate scheme”, provides a much more precise and localized control as compared to independently adjusting the firing rate of the burners to adjust the coil outlet temperatures of the two or more hydrocarbon feeds, which can also be referred to as a “coil outlet temperature to firing scheme”. The control scheme of the steam cracking furnace disclosed herein can also be accomplished without the use of one or more dividing walls being disposed between two or more segments. It should be understood, however, that in some embodiments, one or more dividing walls can optionally be disposed between two or more segments.

[0017] The feed rate of each hydrocarbon feed introduced into the radiant coil(s) disposed within each segment can be controlled based, at least in part, on the coil outlet temperature of each steam cracker effluent recovered from each segment. The coil outlet temperature of each steam cracker effluent can be monitored and the feed rate of a given hydrocarbon feed can be increased or decreased to reduce or increase the coil outlet temperature, respectively, for the given steam cracker effluent. One or more flow control devices, e.g., valves, can be used to control the amount of each of the hydrocarbon feeds introduced into the radiant coil(s) disposed within each segment.

[0018] In some embodiments, each of the two or more hydrocarbon feeds can be mixed, blended, combined, or otherwise contacted with steam to produce mixtures that can be heated by indirect heat exchange within a convection section of the steam cracking furnace. In some embodiments, the mixtures that include the hydrocarbon feeds can be heated to a temperature of 200°C, 300°C, 400°, or 450°C to 500°C, 600°C, 700°C, or 750°C within the convection section. The heated mixtures can then be steam cracked within the radiant coil(s) disposed within each segment to produce the steam cracker effluents. In such embodiment, the steam contacted with the hydrocarbon feeds can also be adjusted independently from one another such that at least one of the one or more hydrocarbon feeds can be mixed with a different amount of steam as compared to at least one other of the one or more hydrocarbon feeds. One or more flow control devices, e.g., valves, can be used to control the amount of steam contacted with each hydrocarbon feed.

[0019] In some embodiments, the steam cracking conditions can include, but are not limited to, one or more of: exposing the heated mixtures of the hydrocarbon feed and steam in line (or a vapor phase product separated therefrom) to a temperature (as measured at a radiant outlet of the steam cracking furnace) of $\geq 400^{\circ}\text{C}$, e.g., a temperature of about 700°C, about 800°C, or about 900°C to about 950°C, about 1,000°C, or about 1050°C, a pressure of about 10 kPa-

absolute to about 500 kPa-absolute or more, and/or a steam cracking residence time of about 0.01 seconds to about 5 seconds. In some embodiments, the hydrocarbon and steam mixtures can include steam in an amount in of about 10 wt% to about 95 wt%, based on the weight of the hydrocarbon and steam mixture. In some embodiments, the heated mixtures or a vapor
5 phase product separated therefrom can be steam cracked according to the processes disclosed in U.S. Patent Nos. 6,419,885; 7,993,435; 9,637,694; and 9,777,227; and International Patent Application Publication No. WO 2018/111574.

[0020] In some embodiments, the steam cracker effluents can be cooled by indirect heat exchange in one or more heat exchange stages, *e.g.*, via one or more transfer line exchangers,
10 with water or steam to produce steam, *e.g.*, medium pressure steam or superheated steam, and cooled steam cracker effluents. In some embodiments, the steam cracker effluents can be cooled by direct contact with a quench medium to produce the cooled steam cracker effluents. In other embodiments, the steam cracker effluents can be cooled by indirect heat exchange and by direct contact with a quench medium to produce the cooled steam cracker effluent. In some
15 embodiments, the steam cracker effluents can be mixed and cooled together. In other embodiments, the steam cracker effluents can be cooled separately and the mixed with one another. In still other embodiments, the steam crack effluents can be cooled separately and can be further processed separately.

[0021] In some embodiments, the quench medium that can be contacted with the steam
20 cracker effluents can be or can include a utility fluid. In some embodiments, the utility fluid can be the same or similar to the utility fluids described in U.S. Patent Nos. 9,090,836; 9,637,694; and 9,777,227; and International Patent Application Publication No. WO 2018/111574.

[0022] Suitable steam crackers, process gas recovery configurations, other equipment, and
25 process conditions can include those disclosed in U.S. Patent Nos.: 6,419,885; 7,560,019; 7,993,435; 8,105,479; 8,197,668; 8,882,991; 9,637,694; 9,777,227; U.S. Patent Application Publication Nos.: 2014/0061096; 2014/0357923; 2016/0376511; 2018/0170832; 2019/0016975; and WO Publication No.: WO 2018/111574; WO/2020/096972; WO/2020/096974; WO/2020/096977; and WO/2020/096979. Suitable dividing walls that can
30 optionally be disposed between two or more segments can include those disclosed in U.S. Patent No. 7,718,052.

[0023] In some embodiments, an olefin plant recovery section can require at least some minimum amount of a given feed to function appropriately. For example, recovery sections

may need a minimum amount of a heavy feed for a suitable flow of the heaviest furnace yields. Such minimum heavy feed requirement can come at a significant economic debit if the heavy feed is a higher cost feed than lighter feeds but remains necessary to provide any production through the plant without significant costly modifications. By running a small portion of a furnace, e.g., only a single segment or a small number of segments of the furnace, on this minimized amount of heavy feed, the minimum feed requirement can be minimized further than if forced to process on an entire furnace or furnace segment with a divided wall. Additionally, by running this small portion of the heavy feed in a furnace with manipulated operating conditions (reduced feed or increased steam) the actual rate can be turned down further than if the segment of the furnace were running full of the minimized heavy feed.

[0024] In some plants, some recovery sections operating at very cold conditions can require a minimum amount of heavy feeds for a suitable flow of fuel molecules to achieve a desired hydrogen to methane ratio for stable and desired refrigeration capacity. Gas crackers, or especially liquid crackers that have transitioned to gas crackers, typically require a minimum amount of methane for the right hydrogen-to-methane ratio to operate the recovery section “cold box” at optimum conditions. LPG or heavier feeds are typically used to satisfy the methane requirement. By running a small portion of a furnace, e.g., only a single segment or small number of segments of the furnace, on the minimized amount of heavy feed, the minimum feed requirement can be minimized further than if forced to process on an entire furnace or furnace segment with a divided wall. Additionally, by running this small portion of the heavy feed in a furnace with manipulated operating conditions (reduced feed or increased steam) or optimized firebox heat distribution (online burner pattern) the actual rate can be turned down further than if the segment of the furnace were running full of the minimized heavy feed.

[0025] In some plants, a feed slate can potentially leave one section of the plant relatively unloaded. While this may not present a feasibility constraint as discussed above, an optimized solution can select operating conditions on some feeds that would fill this unloaded portion of the plant to make products. An example could arise from a propylene/propane fractionator in a plant designed for higher propylene production now running mostly ethane feed (with little propylene production). By running much of a furnace on recycle or fresh ethane, at maximum conversion to maximize production against an ethylene fractionator constraint (by minimizing uncracked ethane that consumes capacity of the ethylene fractionator), and running a portion of a furnace on fresh or recycle propane streams at reduced conversion to maximize propylene

production and/or maximize methane production and/or minimize acetylene production, both the ethylene fractionator and propylene fractionator can be filled for increased profitability.

[0026] In plants, a refinery gas integration stream taken into the olefins plant or pyrolysis furnaces, where the refinery gas stream(s) require different operating conditions to manage
5 unique content, even a small refinery gas integration stream can present a significant impact to plant operations through impacting operating conditions on larger feed streams. In such embodiment, a refinery gas that requires different operating conditions due to contaminants or different composition can be cracked separately from the other fresh or recycle feed(s) to best tailor operating conditions to each stream almost regardless of size.

10 [0027] In new furnace construction, the control scheme disclosed herein can allow for a single furnace with a single stack and single set of post-combustion emissions reduction facilities to accommodate multiple feeds or operating conditions while also maximizing economy of scale.

[0028] It has also been observed that the control scheme disclosed herein can provide several
15 process advantages even when not utilized for multiple different hydrocarbon feeds. For example, the control scheme can mitigate process safety risks like furnace flooding, e.g., a fuel-rich firebox atmosphere, and/or furnace tube overheat.

[0029] Furnace flooding refers to a condition where insufficient air is present in the firebox to provide an excess of oxygen after combustion. Instead, an excess of fuel exists after
20 combustion in the firebox and presents a potential deflagration or explosion hazard if air were suddenly introduced. Where this occurs, the heat released from a fuel input that is not completely combusted declines, causing the coil outlet temperatures to decline for a given fuel flow input. Coil outlet temperature to firing schemes do not explicitly control firing heat input, but rather only a fuel rate selected to deliver desired firing when the fuel is fully combusted.
25 Therefore, declining coil outlet temperatures due to uncombusted fuel could cause a coil outlet temperature to firing control scheme to increase the fuel rate that could result in even more excess fuel remaining uncombusted (since air is the limiting reactant in a flooding scenario). On the other hand, a coil outlet temperature to feed rate scheme would not add fuel and aggravate the mismatch between fuel input and air input. Rather the coil outlet temperature to
30 feed rate scheme can respond to a declining coil outlet temperature from uncombusted fuel by reducing the feed rate of the hydrocarbon feed(s) to maintain the same coil outlet temperature setpoint without the amount of fuel input to each of the burners increasing. Therefore, the coil

outlet temperature to feed rate scheme does not worsen the flooding situation like the coil outlet temperature to firing scheme.

[0030] Similarly, the coil outlet temperature to feed scheme has been found to be significantly more useful in preventing or mitigating furnace tube overheat in a loss of feed or firing excursion scenario. While industry standard furnaces use coil outlet temperature to firing to control coil outlet temperature because of the widespread impacts of firing among multiple temperature outlets and the overall firebox (including air input), these firing controls tend to be tuned very slowly to prevent upsets with too much fuel (and not enough air) or too little fuel (and a large temperature swing on the furnace). An effect of the slow tuning is that a potential overheat scenario is addressed too slowly to prevent significant furnace damage due to overheating. Conversely, the coil outlet temperature to feed scheme has a much more localized impact on just the set of tubes with the controlled coil outlet temperature. Therefore, the coil outlet temperature to feed scheme can be tuned much more rapidly to provide a faster response to any overheat scenario.

[0031] FIG. 1 depicts a schematic of an illustrative steam cracking furnace 100 in operation to convert a first hydrocarbon feed in line 1001 and a second hydrocarbon feed in line 1003, within one or more first radiant coils 1025 and within one or more second radiant coils 1027, respectively, disposed within a radiant section 1029 of the steam cracking furnace 100, according to one or more embodiments. A feed rate of the first hydrocarbon feed in line 1001 can be controlled via a first flow control device 1002 and a feed rate of the second hydrocarbon feed in line 1003 can be controlled via a second flow control device 1004.

[0032] In some embodiments, the first hydrocarbon feed in line 1001 and the second hydrocarbon feed in line 1003 can be mixed, blended, combined, or otherwise contacted with steam in lines 1007 and 1009, respectively, to produce first and second hydrocarbon and steam mixtures in lines 1011 and 1013, respectively. As shown, the steam in lines 1007 and 1009 can be provided from a common source, e.g., steam in line 1005. In other embodiments, however, the steam in lines 1007 and 1009 can be provided from different sources. A feed rate of the steam contacted with the first hydrocarbon feed in line 1001 can be controlled by a third flow control device 1008 and a feed rate of the steam contacted with the second hydrocarbon feed in line 1003 can be controlled by a fourth flow control device 1010. The amount of steam contacted with the first and second hydrocarbon feeds in lines 1001 and 1003 can be the same or different with respect to one another.

[0033] The first and second mixtures in lines 1011 and 1013 can each be heated within one or more convection coils 1015 and 1017, respectively, disposed within the convection section 1019 of the steam cracking furnace 100 to produce first and second heated mixtures via lines 1021 and 1023, respectively. In some embodiments, the first and second mixtures in lines 1011 and 1013 can be heated to a temperature of 200°C, 300°C, 400°, or 450°C to 500°C, 600°C, 700°C, or 750°C within the convection section 1019. The first and second heated mixtures in lines 1021 and 1023 can be further heated and subjected to steam cracking conditions within the one or more first radiant coils 1025 and within the one or more second radiant coils 1027, respectively, disposed within the radiant section 1029 of the steam cracking furnace 100 to produce first and second steam cracker effluents via lines 1031 and 1033, respectively.

[0034] The first radiant coil(s) 1025 and the second radiant coil(s) 1027 can be heated by a plurality of burners (four are shown – 1035, 1037, 1039, and 1041). The burners 1035 and 1037 can be considered as being disposed within a first segment of the radiant section 1029 and the burners 1039 and 1041 can be considered as being disposed within a second segment of the radiant section 1029. As such, the first segment of the radiant section occupies the left half of the radiant section 1029 and the second segment of the radiant section 1029 occupies the right half of the radiant section 1029, as shown in FIG. 1. During operation, the burners 1035, 1037, 1039, and 1041 can be operated at substantially the same firing rate such that the amount of heat produced by each burner in the first and second segments is substantially the same.

[0035] The first steam cracker effluent in line 1031 can have a first coil outlet temperature upon exiting the first radiant coil(s) 1025 and the second steam cracker effluent in line 1033 can have a second coil outlet temperature upon exiting the second radiant coil(s) 1027. The first coil outlet temperature of the first steam cracker effluent in line 1031 can be measured with a first temperature measuring device, e.g., thermocouple, 1043 and the second coil outlet temperature of the second steam cracker effluent in line 1033 can be measured with a second temperature measuring device, e.g., thermocouple, 1045.

[0036] The feed rate of the first hydrocarbon feed in line 1001 and the feed rate of the second hydrocarbon feed in line 1003 can be controlled based, at least in part, on the composition(s) of the first and second hydrocarbon feeds and/or the first and second coil outlet temperatures, respectively. In some embodiments, the feed rate of the first hydrocarbon feed in line 1001 can be reduced to increase the first coil outlet temperature of the first steam cracker effluent in line 1031. In other embodiments, the feed rate of the first hydrocarbon feed in line 1001 can

be increased to reduce the first coil outlet temperature of the first steam cracker effluent in line 1031. The feed rate of the second hydrocarbon feed in line 1003 can be controlled in a similar manner as the feed rate of the first hydrocarbon feed in line 1001.

[0037] Similar to the feed rates of the first and second hydrocarbon feeds, the feed rate of the steam in line 1007 and the steam in line 1009 that can be contacted with the first hydrocarbon feed in line 1001 and the second hydrocarbon feed in line 1003, respectively, can be controlled based, at least in part, on the composition(s) of the first and second hydrocarbon feeds and the first and second coil outlet temperatures, respectively. By controlling the feed rate of the first and second hydrocarbon feeds and the steam contacted therewith, the feed rate of the heated first and second hydrocarbon feeds introduced via lines 1021 and 1023, respectively, can be increased or decreased as desired to control or otherwise adjust the first coil outlet temperature and the second coil outlet temperature as desired.

[0038] In some embodiments, the steam cracking conditions can include, but are not limited to, one or more of: exposing the heated mixtures of the hydrocarbon feed and steam in line (or a vapor phase product separated therefrom) to a temperature (as measured at a radiant outlet of the steam cracking furnace) of $\geq 400^{\circ}\text{C}$, *e.g.*, a temperature of about 700°C , about 800°C , or about 900°C to about 950°C , about $1,000^{\circ}\text{C}$, or about 1050°C , a pressure of about 10 kPa-absolute to about 500 kPa-absolute or more, and/or a steam cracking residence time of about 0.01 seconds to about 5 seconds. In some embodiments, the hydrocarbon and steam mixtures can include steam in an amount in of about 10 wt% to about 95 wt%, based on the weight of the hydrocarbon and steam mixture.

[0039] FIG. 2 depicts a plan view of an illustrative firebox 200 of a steam cracking furnace having a footprint area divided into four segments, namely segments 2001, 2003, 2005, and 2007, according to one or more embodiments. FIG. 3 depicts a plan view of the firebox 200 shown in FIG. 2 where each of the segments 2001, 2003, 2005, and 2007 include a plurality of burners A, B, C, and D and a plurality of tubes T_A , T_B , T_C , and T_D , respectively, disposed therein, according to one or more embodiments. The firebox 200 can include any desired number of segments. In some embodiments, the firebox 200 can include 2, 3, 4, 5, 6, 7, 8, 9, 10, or more segments. During operation the burners A, B, C, and D in segments 2001, 2003, 2005, and 2007, respectively, can be operated at substantially the same firing rate such that the amount of heat produced by each of the burners A, B, C, and D, in the segments 2001, 2003, 2005, and 2007 is substantially the same.

[0040] In some embodiments, one or more burners can be shut off during operation. In some embodiments, radiant heat in a hotter pass, i.e., the coil outlet temperature of the steam cracker effluent is greater than a colder pass, could be re-radiating the colder pass, which could have the effect of un-optimized cracking temperatures in the colder pass. In such embodiment, one or more burners primarily radiating heat to the hotter pass can be shut off to reduce or eliminate the amount heat being re-radiated to the colder pass. For example, if segment 2001 includes the hotter pass and segment 2003 includes the colder pass, one or more burners A and/or one or more burners B disposed along the boundary between segment 2001 and segment 2003 can be shut off. Similarly, if segment 2001 includes the hotter pass and segment 2005 includes the colder pass, one or more burners A and/or one or more burners C can be shut off.

Hydrocarbon Feeds

[0041] In some embodiments, the first and/or second hydrocarbon feeds in line 1001 and 1003, respectively, can be or can include, but are not limited to, relatively high molecular weight hydrocarbons ("heavy feedstocks"), such as those that produce a relatively large amount of steam cracker tar ("SCT") during steam cracking. Examples of heavy feedstocks can include one or more of steam cracked gas oil and residues, gas oils, heating oil, jet fuel, diesel, kerosene, coker naphtha, steam cracked naphtha, catalytically cracked naphtha, hydrocrackate, reformat, raffinate reformat, Fischer-Tropsch liquids, Fischer-Tropsch gases, distillate, crude oil, atmospheric pipestill bottoms, vacuum pipestill streams including bottoms, gas oil condensates, heavy non-virgin hydrocarbon streams from refineries, vacuum gas oils, heavy gas oil, naphtha contaminated with crude, atmospheric residue, heavy residue, C₄/residue admixture, naphtha/residue admixture, gas oil/residue admixture, crude oil, or any mixture thereof. In some embodiments, the first and/or second hydrocarbon feeds in lines 1001 and 1003, respectively, can be or can include, but are not limited to, lighter hydrocarbons such as C₁-C₅ alkanes, naphtha distillate, aromatic hydrocarbons, or any mixture thereof. In some embodiments, as noted above, two or more hydrocarbon feeds can be introduced into the steam cracker and the two hydrocarbon feeds can be the same or different with respect to one another. In some embodiments, the first hydrocarbon feed in line 1001 can include one or more lighter hydrocarbons and the second hydrocarbon feed in line 1003 can include one or more heavy feedstocks. In some embodiments, the second hydrocarbon feed in line 1003 can have a nominal final boiling point $\geq 315^{\circ}\text{C}$, $\geq 399^{\circ}\text{C}$, $\geq 454^{\circ}\text{C}$, or $\geq 510^{\circ}\text{C}$. Nominal final boiling

point means the temperature at which 99.5 wt. % of a particular sample has reached its boiling point.

[0042] In other embodiments, the first and second hydrocarbon feeds in line 1001 and 1003, respectively, can include one or more relatively low molecular weight hydrocarbon (light feedstocks), particularly those aspects where relatively high yields of C₂ unsaturates (ethylene and acetylene) can be desired. Light feedstocks can include substantially saturated hydrocarbon molecules having fewer than five carbon atoms, *e.g.*, ethane, propane, and mixtures thereof (*e.g.*, ethane-propane mixtures or “E/P” mix). For ethane cracking, a concentration of at least 75 wt. % of ethane is typical. For E/P mix, a concentration of at least 75 wt. % of ethane plus propane is typical, the amount of ethane in the E/P mix can be ≥ 20 wt. % based on the weight of the E/P mix, *e.g.*, of about 25 wt. % to about 75 wt. %. The amount of propane in the E/P mix can be, *e.g.*, ≥ 20 wt. %, based on the weight of the E/P mix, such as of about 25 wt. % to about 75 wt. %. In some embodiments, the first hydrocarbon and/or the second hydrocarbon feed can be or can include, but is not limited to, a refinery gas stream that can include one or more C₂ to C₅, saturated or unsaturated hydrocarbons. In some embodiments, the first hydrocarbon feed can include primarily ethane, propane, or a mixture thereof, and the second hydrocarbon feed can include a refinery gas stream. Suitable hydrocarbon feeds can be or can include those described in U.S. Patent Nos.: 7,138,047; 7,993,435; 8,696,888; 9,327,260; 9,637,694; 9,657,239; and 9,777,227; and International Patent Application Publication No. WO 2018/111574.

[0043] Optionally, *e.g.*, when the first and/or second hydrocarbon feeds in lines 1001 and 1003, respectively, include certain heavy feedstocks, the system 100 can include one or more vapor/liquid separators (sometimes referred to as flash pot or flash drum) integrated therewith. When used, the vapor-liquid separator can be configured to upgrade the hydrocarbon feed, *e.g.*, by upgrading the hydrocarbon and steam mixture, upstream of the radiant section 1029. In some embodiments, it can be desirable to integrate a vapor-liquid separator with the furnace when the hydrocarbon feed includes ≥ 1 wt% of non-volatiles, *e.g.*, ≥ 5 wt%, such as about 5 wt% to about 50 wt% of non-volatiles having a nominal boiling point of $\geq 760^{\circ}\text{C}$. In some embodiments, it can be desirable to integrate a vapor/liquid separator with the furnace when the non-volatiles include asphaltenes, such as $\geq$ about 0.1 wt% asphaltenes based on the weight of the hydrocarbon feed, *e.g.*, $\geq$ about 5 wt%. Conventional vapor/liquid separation devices can be utilized to do this, though the invention is not limited thereto. Examples of such conventional vapor/liquid separation devices can include those disclosed in U.S. Patent Nos.

7,138,047; 7,090,765; 7,097,758; 7,820,035; 7,311,746; 7,220,887; 7,244,871; 7,247,765; 7,351,872; 7,297,833; 7,488,459; 7,312,371; 6,632,351; 7,578,929; and 7,235,705. A vapor phase can be separated from the hydrocarbon feed in the vapor/liquid separation device. The separated vapor phase can be conducted away from the vapor/liquid separator to the radiant
5 coil(s) for steam cracking. The liquid-phase separated from the hydrocarbon feed can be conducted away from the vapor/liquid separation device, *e.g.*, for storage and/or further processing.

[0044] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the pertinent art have given
10 that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[0045] While the foregoing is directed to embodiments of the present invention, other and
15 further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS:

What is claimed is:

1. A process for steam cracking hydrocarbons, comprising:
 - introducing a first hydrocarbon feed into one or more radiant coils disposed within a first segment of a firebox of a steam cracker to produce a first steam cracker effluent having a first coil outlet temperature, wherein the first segment comprises one or more burners providing heat thereto;
 - introducing a second hydrocarbon feed into one or more radiant coils disposed within a second segment of the firebox of the steam cracker to produce a second steam cracker effluent having a second coil outlet temperature, wherein the second segment comprises one or more burners providing heat thereto;
 - operating the one or more burners in the first and second segments at substantially the same firing rate such that an amount of heat produced by each of the one or more burners in the first and second segments is substantially the same; and
 - controlling a feed rate of the first hydrocarbon feed introduced into the one or more radiant coils disposed within the first segment based, at least in part, on a composition of the first hydrocarbon feed and the first coil outlet temperature.
2. The process of claim 1, further comprising controlling a feed rate of the second hydrocarbon feed introduced into the one or more radiant coils disposed within the second segment based, at least in part, on a composition of the second hydrocarbon feed and the second coil outlet temperature.
3. The process of claim 2, wherein the feed rate of the first hydrocarbon feed and the feed rate of the second hydrocarbon feed are different with respect to one another.
4. The process of any of claims 1 to 3, wherein the first hydrocarbon feed and the second hydrocarbon feed each include steam, and wherein an amount of steam in the first hydrocarbon feed is the same as an amount of steam in the second hydrocarbon feed.

5. The process of any of claims 1 to 3, wherein the first hydrocarbon feed and the second hydrocarbon feed each include steam, and wherein an amount of steam in the first hydrocarbon feed is different than an amount of steam in the second hydrocarbon feed.
6. The process of any of claims 1 to 5, wherein the first segment comprises a plurality of burners, wherein at least one burner in the plurality of burners is shut down while maintaining operation of the additional one or more burners in the plurality of burners at substantially the same firing rate as the one or more burners in the second segment.
7. The process of any of claims 1 to 6, wherein a composition of the first hydrocarbon feed and a composition of the second hydrocarbon feed are different.
8. The process of any of claims 1 to 7, wherein the first coil outlet temperature and the second coil outlet temperature are different.
9. The process of any of claims 1 to 8, wherein the first hydrocarbon feed and the second hydrocarbon feed independently comprise ethane, propane, one or more C₄ hydrocarbons, one or more C₅ hydrocarbons, steam cracked gas oil, steam cracked residues, gas oils, heating oil, jet fuel, diesel, kerosene, gasoline, coker naphtha, steam cracked naphtha, catalytically cracked naphtha, hydrocrackate, reformat, raffinate reformat, Fischer-Tropsch liquids, Fischer-Tropsch gases, natural gasoline, distillate, virgin naphtha, crude oil, atmospheric pipestill bottoms, vacuum pipestill streams including bottoms, wide boiling range naphtha to gas oil condensate, heavy non-virgin hydrocarbon streams from refineries, vacuum gas oils, heavy gas oil, naphtha contaminated with crude, atmospheric resid, heavy residium, C₄'s/residue admixture, naphtha residue admixture, or any mixture thereof.
10. The process of any of claims 1 to 8, wherein at least one of the first and second hydrocarbon feeds comprises greater than 50 wt% of ethane, based on a total weight of the hydrocarbon feed.
11. The process of any of claims 1 to 8, wherein the first hydrocarbon feed comprises primarily ethane and the second hydrocarbon feed comprises primarily propane.

12. The process of any of claims 1 to 6, wherein the first hydrocarbon feed comprises a first refinery gas stream comprising one or more C₂ to C₅, saturated or unsaturated hydrocarbons, and wherein the second hydrocarbon feed comprises a second refinery gas stream comprising one or more C₂ to C₅, saturated or unsaturated, hydrocarbons, and wherein a composition of the first hydrocarbon feed and a composition of the second hydrocarbon feed are the same or different with respect to one another.

13. The process of any of claims 1 to 8, wherein the first hydrocarbon feed comprises primarily ethane, propane, or a mixture thereof, and wherein the second hydrocarbon feed comprises a refinery gas stream comprising one or more C₂ to C₅, saturated or unsaturated, hydrocarbons.

14. The process of any of claims 1 to 6, wherein a composition of the first hydrocarbon feed and a composition of the second hydrocarbon feed are the same.

15. The process of any of claims 1 to 14, wherein the firebox is free of any dividing wall disposed between the first segment and the second segment.

16. The process of any of claims 1 to 14, wherein the firebox comprises at least one dividing wall disposed between the first segment and the second segment.

17. The process of any of claims 1 to 16, further comprising:
stopping introduction of the first hydrocarbon feed into the one or more radiant coils disposed within the first segment of the firebox while maintaining introduction of the second hydrocarbon feed into the one or more radiant coils disposed within the second segment of the firebox; and

introducing a decoking feed comprising steam into the one or more radiant coils disposed within the first segment of the firebox to remove at least a portion of any coke deposited on an inner surface of the one or more radiant coils.

18. The process of any of claims 1 to 17, wherein, when any uncombusted fuel causes a reduced coil outlet temperature for the first steam cracker effluent, the feed rate of the first hydrocarbon feed introduced into the one or more radiant coils disposed within the first

segment is reduced, at least in part, due to an effluent temperature control target without the amount of fuel input to each of the one or more burners in the first and second segments increasing.

19. A system for steam cracking one or more hydrocarbon feeds, comprising:
a steam cracker comprising a firebox having one or more radiant coils and one or more burners disposed within a first segment of the firebox and one or more radiant coils and one or more burners disposed within a second segment of the firebox, wherein:

the one or more radiant coils in the first segment are configured to receive a first hydrocarbon feed via a first feed control valve and produce a first steam cracker effluent having a first coil outlet temperature,

the one or more radiant coils in the second segment are configured to receive a second hydrocarbon feed via a second feed control valve and produce a second steam cracker effluent having a second coil outlet temperature,

the one or more burners in the first and second segments are configured to operate at substantially the same firing rate such that an amount of heat produced by each of the one or more burners in the first and second segments is substantially the same, and

the first and second feed control valves are configured to independently adjust a feed rate of the first and second hydrocarbon feeds introduced into the one or more radiant coils in the first and second segments, respectively, to independently adjust the first and second coil outlet temperatures of the first and second steam cracker effluents, respectively.

20. The system of claim 19, wherein the first segment comprises a plurality of burners, wherein at least one burner in the plurality of burners is configured to be shut down during operation while maintaining operation of at least one burner in the plurality of burners at substantially the same firing rate as the one or more burners in the second segment.

21. The system of claim 19 or claim 20, wherein the firebox is free of any dividing wall disposed between the first segment and the second segment.

22. The system of claim 19 or claim 20, wherein the firebox comprises at least one dividing wall disposed between the first segment and the second segment.

23. The system of any of claims 19 to 22, wherein:
the first and second feed control valves are configured to periodically close at different times with respect to one another to stop introduction of the first and second hydrocarbon feeds, respectively,

the one or more radiant coils in the first segment are configured to receive a first decoking feed comprising steam via a first decoking control valve when the first feed control valve is closed, and

the one or more radiant coils in the second segment are configured to receive a second decoking feed comprising steam via a second decoking control valve when the second feed control valve is closed.

24. The system of any of claims 19 to 23, wherein the fire box further comprises one or more radiant coils and one or more burners disposed within a third segment of the firebox, wherein:

the one or more radiant coils in the third segment are configured to receive a third hydrocarbon feed via a third feed control valve and produce a third steam cracker effluent having a third coil outlet temperature,

the one or more burners in the third segment are configured to operate at substantially the same firing rate as the one or more burners in the first and second segments such that an amount of heat produced by each of the one or more burners in the first, second, and third segments is substantially the same.

25. The system of claim 24, wherein the firebox further comprises one or more radiant coils and one or more burners within a fourth segment of the firebox, wherein:

the one or more radiant coils in the fourth segment are configured to receive a fourth hydrocarbon feed via a fourth feed control valve and produce a fourth steam cracker effluent having a fourth coil outlet temperature,

the one or more burners in the fourth segment are configured to operate at substantially the same firing rate as the one or more burners in the first, second, and third segments such that an amount of heat produced by each of the one or more burners in the first, second, third, and fourth segments is substantially the same.