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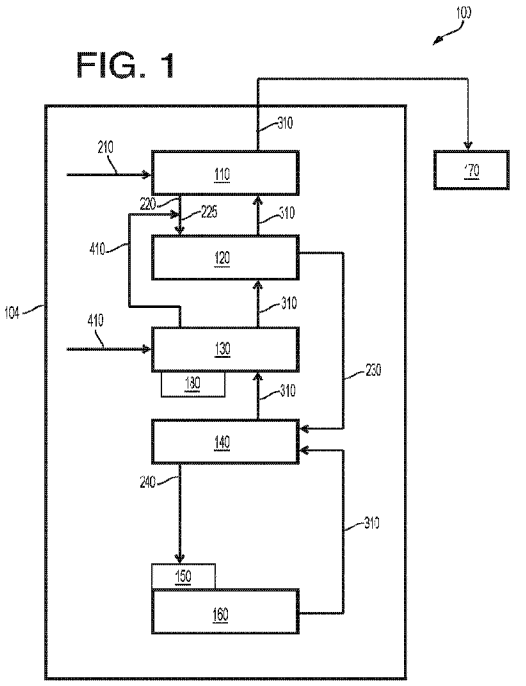
(54) **Titre : SYSTEMES ET PROCEDES PERMETTANT D'AMELIORER LA VALORISATION DES HYDROCARBURES**
(54) **Title: SYSTEMS AND PROCESSES FOR IMPROVING HYDROCARBON UPGRADING**

FIG. 1



(57) **Abrégé/Abstract:**
A system and process for upgrading a hydrocarbon-based composition, that includes introducing the hydrocarbon-based composition into a reaction zone heated with electricity, concentrated solar radiation heat, nuclear reactor heat, geothermal heat, molten salt, molten metal, or combinations thereof; heating the hydrocarbon-based composition in the reaction zone to create a product stream; cooling the product stream create a cooled product stream, wherein: the reaction zone does not produce flue gas.

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Abstract:

A system and process for upgrading a hydrocarbon-based composition, that includes introducing the hydrocarbon-based composition into a reaction zone heated with electricity, concentrated solar radiation heat, nuclear reactor heat, geothermal heat, molten salt, molten metal, or combinations thereof; heating the hydrocarbon-based composition in the reaction zone to create a product stream; cooling the product stream create a cooled product stream, wherein: the reaction zone does not produce flue gas.

SYSTEMS AND PROCESSES FOR IMPROVING HYDROCARBON UPGRADING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of and priority to U.S. Application Serial No. 63/290,692 filed on December 17, 2021, and entitled "SYSTEMS AND PROCESSES FOR IMPROVING HYDROCARBON UPGRADING," the entire contents of which are incorporated by reference in the present disclosure.

BACKGROUND

Field

[0002] The present specification generally relates to systems and processes for converting a hydrocarbon-based composition to desired products while minimizing carbon dioxide (CO_2) emissions through the use of electrical heating. In particular, the present specification relates to systems and processes that use reaction zones heated via electricity.

Technical Background

[0003] Feedstock ethane, propane, butane, naphtha, and other hydrocarbons must be upgraded before they can be used as a commercially valuable product, such as hydrogen, olefins, and aromatic hydrocarbons. This upgrading process conventionally utilizes a reactor system in which combustion—such as, for example, combustion of methane—is used to heat a hydrocarbon-based composition converting the hydrocarbon-based composition to a product stream comprising desired products. Furthermore, the combustion furnace of conventional reactor systems produces additional CO_2 emissions.

[0004] Accordingly, a need exists for systems and processes for converting hydrocarbon-based compositions to desired products while reducing CO_2 emissions.

SUMMARY

[0005] According to one embodiment of the present disclosure, a system for upgrading a hydrocarbon-based composition comprises: a reaction vessel comprising a heating column, a heat recovery exchanger comprising molten salt, molten metal, organic fluid, as heat transfer medium, or without intermediate fluid heat transfer, or combinations thereof, and an electric heater,

wherein: the heating column is thermally connected to the electric heater; and the heating column is thermally connected to the heat recovery exchanger.

[0006] According to another embodiment of the present disclosure, a process for upgrading a hydrocarbon-based composition comprises: introducing the hydrocarbon-based composition into a reaction zone heated with electricity, concentrated solar radiation heat, nuclear reactor heat, geothermal heat, molten salt, molten metal, or combinations thereof; heating the hydrocarbon-based composition in the reaction zone to create a product stream; cooling the product stream to create a cooled product stream, wherein: the reaction zone does not product flue gas.

[0007] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0008] It is to be understood that both the foregoing general description and the following detailed description describe various embodiments and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various embodiments, and are incorporated into and constitute a part of this specification. The drawings illustrate the various embodiments described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 schematically depicts a system and process for upgrading a hydrocarbon-based composition to desired products according to embodiments disclosed and described herein.

[0010] FIG. 2 schematically depicts a system and process for upgrading a hydrocarbon-based composition to desired products according to embodiments disclosed and described herein.

DETAILED DESCRIPTION

[0011] Reference will now be made in detail to embodiments of systems and processes for upgrading hydrocarbon-based compositions to desired products, such as, for example, at least one of hydrogen, olefins, or aromatic hydrocarbons, embodiments of which are illustrated in the

accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts.

[0012] In one embodiment, a system for upgrading a hydrocarbon-based composition comprises: a reaction vessel comprising a heating column, a heat recovery exchanger comprising molten salt, molten metal, organic fluid, as heat transfer medium, or without intermediate fluid heat transfer, or combinations thereof, and an electric heater, wherein: the heating column is thermally connected to the electric heater; and the heating column is fluidly connected to the heat recovery exchanger. One or more of these systems may be replaced by another type of heat exchanger.

[0013] In another embodiment, a process for upgrading a hydrocarbon-based composition comprises: introducing the hydrocarbon-based composition into a reaction zone; heating the hydrocarbon-based composition in the reaction zone to create a product stream; cooling the product stream to create a cooled product stream, wherein: the reaction zone is heated via electricity.

[0014] With reference now to FIG. 1, an embodiment of a system for converting hydrocarbon-based compositions to desired products is provided. It should be understood that the embodiment depicted in FIG. 1 is exemplary and does not limit the scope of this disclosure. As shown in the embodiment depicted in FIG. 1, a system **100** for converting a hydrocarbon-based composition **240** to a product stream **310** that comprises desired products includes, in series and/or in parallel, a feed pre-heat unit **110**, a first hydrocarbon heat unit **120**, a dilution steam heat unit **130**, a second hydrocarbon heat unit **140**, an electric heater **150**, and a reaction zone **160**. It should be understood that according to various embodiments, the system **100** may include various combinations of the above-listed components of the system **100**. Furthermore, the system **100** may comprise one or more heat exchangers, which may be thermally coupled to one another, in series and/or in parallel.

[0015] As shown in FIG. 1, in embodiments, a reaction zone **160** may be a portion of the heating column **104** that is capable of creating reaction conditions as defined herein. However, in embodiments, the reaction zone **160** may be outside the heating column **104** and may be fluidly connected to the heating column **104**, as shown in FIG. 2. The reaction zone **160** may operate at a temperature ranging from 600°C to **120**0°C, such as from 800°C to 1000°C, from 850°C to 950°C, or from 825°C to 900°C; and a pressure that is greater than 0 bar gauge (0 kPa gauge),

such as at least 0.5 bar (50 kPa), or at least 1 bar (100 kPa). The lower the operating pressure the better for selectivity. Operating pressure is limited by downstream pressure drop and the desire typically to run the downstream process at above atmospheric pressure. In embodiments, the operating pressure in the reaction zone may be at any value greater than 0 bar gauge (0 kPa gauge). In some embodiments, the reaction zone **160** may operate at a gauge pressure of from 0.5 to 3 bar (from 50 to 300 kPa), from 1 to 3 bar (from 100 to 300 kPa), from 2 to 3 bar (from 200 to 300 kPa), from 0.5 to 2 bar (from 50 to 200 kPa), from 1 to 2 bar (from 100 to 200 kPa), or from 0.5 to 1 bar (from 50 to 100 kPa).

[0016] In some embodiments, the duty (or power) required for the reaction within the reaction zone **160** may range from 20 Gigacalories per hour (Gcal/hr) to 50 Gcal/hr, from 20 Gcal/hr to 40 Gcal/hr, from 20 Gcal/hr to 35 Gcal/hr, from 20 Gcal/hr to 32 Gcal/hr, from 25 Gcal/hr to 50 Gcal/hr, from 25 Gcal/hr to 40 Gcal/hr, from 25 Gcal/hr to 35 Gcal/hr, from 25 Gcal/hr to 32 Gcal/hr, from 30 Gcal/hr to 50 Gcal/hr, from 30 Gcal/hr to 40 Gcal/hr, from 30 Gcal/hr to 35 Gcal/hr, or from 30 Gcal/hr to 32 Gcal/hr. It is understood that the duty required for the reaction may be proportional with throughput, according to embodiments.

[0017] The systems and processes for converting hydrocarbon-based compositions to desired products as disclosed herein address the need for reducing CO_2 emissions heating the at least one reaction zone **160** through electrical heating; or direct or indirect heat input via convection, conduction, or thermal radiation. Some examples include concentrated solar radiation heat, nuclear reactor heat, geothermal heat, or stored heat in molten salt or molten metal. In embodiments, an electric heater **150** heats hydrocarbon-based composition **240** to the desired reaction zone **160** inlet temperature of approximately 600°C. Conventional combustion reactors produce flue gas (having a temperature that is generally greater than 600 °C) as a by-product from the combustion. In conventional upgrading systems and processes, the flue gas comprises approximately 60% of the heat and energy input of the combustion reaction, thereby producing significant inefficiencies. As the flue gas is a natural consequence of the combustion reaction and has approximately 60% of the energy of the reaction, heat from the flue gas is conventionally utilized upstream of the conversion reaction zone to heat the hydrocarbon-based composition prior to reaction and to heat dilution steam streams. Because the reaction zones as disclosed herein do not create flue gas, the systems and the processes of the present disclosure incorporate new process

designs to heat the hydrocarbon-based composition prior to reaction and to heat dilution steam streams.

[0018] In some embodiments, the reactor system **100** is connected to a source of electrical current that provides electrical current to the reactor system **100** through electrical lead lines. In embodiments, the heating column **104** may include at least one trim temperature controller **180**. In embodiments, the trim temperature controller **180** may be a trim heater or a trim cooler configured to heat or cool. In embodiments, the trim heater **180** may be a single unit to either heat or cool, in other embodiments heating and cooling may be provided by separate units. In embodiments, the trim heater may be electrically driven. The electrical current may be supplied to the electric heater **150**, the trim heater, or combinations thereof. The electrical lead lines transfer the electrical current from the source of electrical current to the electric heater **150,** the at least one trim temperature controller **180**, or both via an electrical connection between the source of electrical current and the electric heater **150,** the at least one trim temperature controller **180**, or both. In various embodiments, the source of electrical current may be a renewable energy source, leading to no CO_2 emissions. The source of electrical current may, in embodiments, be nuclear power, steam energy, natural gas, coal, or the like. The source of electrical current may, in embodiments, be a renewable source, such as a battery, solar power, wind energy, hydroelectric power, or the like. The electrical current may be decreased or increased outside of the system **100**. In some embodiments, the electrical current may be actively controlled, turned on and off, and decreased or increased to control the heat generated in the electric heater **150,** the at least one trim temperature controller **180**, or both.

[0019] In some embodiments, the heating column **104** of the reactor system **100** comprises one reaction zone **160** (as shown). In some embodiments, the heating column **104** comprises at least two reaction zones **160** (additional reaction zones not shown). The at least two reaction zones **160** may be configured in parallel or in series. Each of these at least two reaction zones **160** may independently receive electrical current. The voltage of the electrical current that may be converted to heat along with the specific amperes of the electrical current are indicative of the heat of the reaction zone **160**. Specifically, the temperature of the reaction zone **160** during the process of converting the hydrocarbon-based composition **240** may be determined from the values of the resistivity of an electric heater heating the reaction zone **160** and the amperes of the electrical current that is converted to heat in the electric heater **150**. Joule's first law states that the power

(P) of heating generated by an electrical conductor is proportional to the product of its resistance (R) and the square of the current (I), as shown by Equation 1:

$$P \propto I^2 R \quad (1)$$

[0020]

[0021] According to embodiments, one or more additional components may be included in the reactor system **100**. In embodiments, such as shown in FIG. 1, the heating column **104** may further include a feed pre-heat unit **110**, a first hydrocarbon heat unit **120**, a dilution steam heat unit **130**, and a second hydrocarbon heat unit **140**. The first hydrocarbon heat unit **120** may be fluidly connected to the feed pre-heat unit **110**, the dilution steam heat unit **130**, and the second hydrocarbon heat unit **140**. The second hydrocarbon heat unit **140** may be fluidly connected to the dilution steam heat unit **130**, the first hydrocarbon heat unit **120**, and a reaction zone **160**. The feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, and the second hydrocarbon heat unit **140** may function as heat exchangers. There may be one or more heat exchangers within the system **100**, which may be parallel and/or in series. The heat exchangers may minimize the electrical energy consumption of the system. As previously described, the heating column **104** may further include at least one trim temperature controller **180**. The trim temperature controller **180** may be thermally connected to at least one of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, or the second hydrocarbon heat unit **140**. FIG. 1 shows the trim temperature controller **180** thermally connected to only the dilution steam heat unit **130**, however, this should be understood as solely an example embodiment. As shown in FIG. 2, there may be trim temperature controllers **180** connected to each of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, or the second hydrocarbon heat unit **140**. Therefore, it should be understood that the trim temperature controller **180** may be connected or not connected to any of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, or the second hydrocarbon heat unit **140** as necessary. In embodiments, the trim temperature controller **180** may be a trim heater or a trim cooler configured to heat or cool at least one of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, or the second hydrocarbon heat unit **140** as needed. In embodiments, trim temperature controller **180** may be electrically heated and cooled by other means. The trim temperature controller **180** operates to heat or cool any of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution

steam heat unit **130**, or the second hydrocarbon heat unit **140** to optimize heating and cooling efficiency within the system.

[0022] According to one or more embodiments, a process for converting a hydrocarbon-based composition **240** to desired products such as, for example, a product stream **310** comprising at least one of hydrogen, olefins, or aromatic hydrocarbons that uses the system **100** depicted in the embodiment of FIG. 1 will now be described. A hydrocarbon-based composition **240** is introduced into the reaction zone **160**. It should be understood that the hydrocarbon-based composition **240** may comprise at least one of naphtha or heavier hydrocarbons mixtures, methane, ethane, propane, butane, pentane, water, and low levels of CO_2, CO, N_2, and H_2, according to various embodiments. In embodiments, naphtha may include atmospheric gasoil, vacuum gasoil, or both, as nonlimiting examples. In embodiments, butane may include n-butane, i-butane, or both, as nonlimiting examples. In some embodiments, the hydrocarbon-based composition **240** comprises C_1 to C_5 hydrocarbons. In other embodiments, the hydrocarbon-based composition **240** comprises C_1 to C_{20} hydrocarbons. In yet another embodiment, the hydrocarbon-based composition **240** comprises C_1 to C_{50} hydrocarbons.

[0023] Although the temperature at which the reaction zone **160** is operated is not particularly limited so long as it can drive the reactions for converting the hydrocarbon-based composition **240** to the desired products such as, for example, hydrogen, olefins, aromatic hydrocarbons, or combinations thereof. In embodiments, the reaction zone **160** may convert the hydrocarbon-based composition **240** comprising at least C_2 hydrocarbons to a product stream **310** comprising at least C_2 olefins. In one or more embodiments, the reaction zone **160** is operated at a temperature from 600 degrees Celsius (°C) to 850°C, such as from 825°C to 845°C, or about 840°C. Likewise, the pressure at which the reaction zone **160** is operated is not particularly limited so long as it can drive the above reactions, in one or more embodiments, the reaction zone **160** is operated at a pressure of from 0.3 to 3 bar(g) (from 30 to 300 kPa), from 1 to 3 bar(g) (from 100 to 300 kPa), from 2 to 3 bar(g) (from 200 to 300 kPa), from 0.5 to 2 bar(g) (from 50 to 200 kPa), from 1 to 2 bar(g) (from 100 to 200 kPa), or from 0.5 to 1 bar(g) (from 50 to 100 kPa).

[0024] Lastly, the process comprises converting the hydrocarbon-based composition **240** to a product stream **310** within the reaction zone **160**, and removing the product stream **310** from the reaction zone **160**. Converting the hydrocarbon-based composition **240** to the product stream **310** may comprise increasing the temperature of the hydrocarbon-based composition **240**, thereby

causing a chemical reaction that produces the product stream **310**. The hydrocarbon-based composition **240** may be heated by the electric heater **150** under reaction conditions sufficient to form a product stream **310**. The reaction conditions may comprise: a temperature from 600 degrees Celsius (°C) to 850°C, such as from 825°C to 845°C, or about 840°C; and at a pressure of from 0.3 to 3 bar (from 30 to 300 kPa), from 1 to 3 bar (from 100 to 300 kPa), from 2 to 3 bar (from 200 to 300 kPa), from 0.5 to 2 bar (from 50 to 200 kPa), from 1 to 2 bar (from 100 to 200 kPa), or from 0.5 to 1 bar (from 50 to 100 kPa) In some embodiments, the electric heater **150** is heated to a temperature of greater than 500°C, greater than 600°C, greater than 700°C, greater than 750°C, greater than 800°C, greater than 850°C, greater than 900°C, greater than 950°C, or greater than 1000°C. The reactions that occur in the reaction zone **160** produce a product stream **310**. In some embodiments, the reactions that occur further produce byproducts comprising one or more of CO, CO_2, H_2, H_2O, CH_4, C_2H_6, C_2H_2, C_3H_6, C_3H_8, and C_3H_4. The temperature of the product stream **310** leaving the reaction zone **160** may be from 750°C to 900°C, from 780°C to 900°C, from 800°C to 900°C, from 850°C to 900°C, from 860°C to 900°C, from 870°C to 900°C, from 880°C to 900°C, from 890°C to 900°C, from 750°C to 890°C, from 780°C to 890°C, from 800°C to 890°C, from 850°C to 890°C, from 860°C to 890°C, from 870°C to 890°C, from 880°C to 890°C, from 750°C to 880°C, from 780°C to 880°C, from 800°C to 880°C, from 850°C to 880°C, from 860°C to 880°C, from 870°C to 880°C, from 750°C to 870°C, from 780°C to 870°C, from 800°C to 870°C, from 850°C to 870°C, from 860°C to 870°C, or approximately 860°C.

[0025] The product stream **310** comprises at least one of hydrogen, olefins, and aromatic hydrocarbons. In one or more embodiments, the product stream **310** consists essentially of or consists of at least one of hydrogen, olefins, and aromatic hydrocarbons. In embodiments, the olefins comprise C_2 to C_5 olefins such as, for example, ethylene (C_2H_4), propylene (C_3H_6), butylene (C_4H_8), butadiene (C_4H_6), or combinations thereof. In embodiments, butylene may include 1-butylene, 2-butylene, i-butylene, or combinations thereof, as nonlimiting examples. In other embodiments, the olefins comprise C_2 to C_{10} olefins. The olefins may comprise C_2 to C_{20} olefins. In yet another embodiment, the olefins may comprise C_2 to C_{50} olefins. The aromatic hydrocarbons may comprise benzene and derivatives thereof, such as toluene, ethylbenzene, *o*-xylene, *p*-xylene, *m*-xylene, mesitylene, durene, 2-phenylhexane, and biphenyl. The product stream **310** is collected and separated or purified in various other processes to make desired intermediate and end products.

[0026] The process may further comprise pre-heating the hydrocarbon-based composition **240** before introducing the hydrocarbon-based composition **240** to the reaction zone **160**. As discussed previously, flue gas produced from conventional combustion reactions is conventionally used to heat the hydrocarbon-based composition prior to reaction. However, as the systems and processes of the present disclosure do not use conventional combustion reactions to heat the reaction zone **160**, there is no flue gas present in the systems and processes disclosed herein. Therefore, the absence of flue gas opens the path for new process designs to heat the hydrocarbon-based composition prior to reaction. One or more heat exchangers may be present, such as the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, and the second hydrocarbon heat unit **140**, where the product stream **310** (which has a temperature greater than the hydrocarbon-based composition **240** before the hydrocarbon-based composition **240** enters the reaction zone **160**) may be passed through one or more of the feed pre-heat unit **110**, the first hydrocarbon heat unit **120**, the dilution steam heat unit **130**, and the second hydrocarbon heat unit **140**, which is described in more detail below, to heat the hydrocarbon-based composition **240**, any stream precursor to the hydrocarbon-based composition, the dilution steam stream **410**, or combinations thereof. By using the heat of the product stream **310** to heat other streams within the heating column **104**, the overall efficiency of the process is increased by reusing the energy of the reaction. In embodiments, the systems and processes of the present disclosure may require less than 99%, less than 95%, less than 90%, less than 85%, less than 80%, less than 75%, less than 70%, less than 65%, or less than 62% of the power of conventional hydrocarbon upgrading systems and processes that use conventional gas fired combustion reactions. By using heat this way, stack losses from a conventional gas fired furnace may be eliminated and result in an energy saving of approximately 10%. Eliminating high pressure steam production results in an energy input saving of the furnace of up 40%. As high pressure steam production is needed, downstream process compressors may switch from steam turbine drives to electromotor drives. In embodiments, the systems and processes of the present disclosure may require from 50% to 99%, from 50% to 95%, from 50% to 90%, from 50% to 85%, from 50% to 80%, from 50% to 75%, from 50% to 70%, from 50% to 65%, from 50% to 62%, from 55% to 99%, from 55% to 95%, from 55% to 90%, from 55% to 85%, from 55% to 80%, from 55% to 75%, from 55% to 70%, from 55% to 65%, from 55% to 62%, from 60% to 99%, from 60% to 95%, from 60% to 90%, from 60% to 85%, from 60% to 80%, from 60% to 75%, from 60% to 70%, from 60% to 65%, or

from 60% to 62% of the power of conventional hydrocarbon upgrading systems and processes that use conventional gas fired combustion reactions.

[0027] In embodiments, the process includes passing a feed stream **210** through a feed pre-heat unit **110** to create a pre-heated hydrocarbon-based composition **220**. The temperature of the feed stream **210** before introduced to the feed pre-heat unit **110** may be from 50°C to 110°C, from 60°C to 110°C, from 70°C to 110°C, from 80°C to 110°C, from 90°C to 110°C, from 100°C to 110°C, from 50°C to 100°C, from 60°C to 100°C, from 70°C to 100°C, from 80°C to 100°C, from 90°C to 100°C, from 50°C to 90°C, from 60°C to 90°C, from 70°C to 90°C, from 80°C to 90°C, from 50°C to 80°C, from 60°C to 80°C, from 70°C to 80°C, from 50°C to 70°C, from 60°C to 70°C, or from 50°C to 60°C. The exit temperature of the pre-heated hydrocarbon-based composition **220** from the feed pre-heat unit **110** may be below the operating temperature of the reaction zone **160**. The exit temperature of the pre-heated hydrocarbon-based composition **220** from the feed pre-heat unit **110** may be from 150°C to 300°C, from 150°C to 275°C, from 150°C to 250°C, from 150°C to 225°C, from 150°C to 220°C, from 150°C to 200°C, from 150°C to 175°C, from 175°C to 300°C, from 175°C to 275°C, from 175°C to 250°C, from 175°C to 225°C, from 175°C to 220°C, from 175°C to 200°C, from 200°C to 300°C, from 200°C to 275°C, from 200°C to 250°C, from 200°C to 225°C, from 200°C to 220°C, from 220°C to 300°C, from 220°C to 275°C, from 220°C to 250°C, from 220°C to 225°C, from 225°C to 300°C, from 225°C to 275°C, from 225°C to 250°C, from 250°C to 300°C, from 250°C to 275°C, or from 275°C to 300°C. The feed pre-heat unit **110** can be used to remove heat from the product stream **310**, wherein the heat removed from the product stream **310** can be used to pre-heat the hydrocarbon-based composition **240**. The feed pre-heat unit **110** may cool the product stream **310** to below the reaction temperature. Cooling the product stream **310** below the reaction temperature prevents further reactions, or conversion, of the product stream **310**. The feed pre-heat unit **110** may cool the product stream **310** to from 300°C to 500°C, from 300°C to 450°C, from 300°C to 425°C, from 300°C to 405°C, from 300°C to 400°C, from 300°C to 375°C, from 300°C to 350°C, from 350°C to 500°C, from 350°C to 450°C, from 350°C to 425°C, from 350°C to 405°C, from 350°C to 400°C, from 350°C to 375°C, from 375°C to 500°C, from 375°C to 450°C, from 375°C to 425°C, from 375°C to 405°C, from 375°C to 400°C, from 400°C to 500°C, from 400°C to 450°C, from 400°C to 425°C, from 400°C to 405°C, from 425°C to 500°C, from 425°C to 450°C, or from 450°C to 500°C. This may be an optional component to the systems and processes disclosed herein, as the hydrocarbon-based composition **240** need not be pre-heated prior to introducing the hydrocarbon-based composition

240 to the electric heater **150** or the reaction zone **160**, when the hydrocarbon-based composition **240** is a vapor stream.

[0028] In embodiments, the process may further comprise of mixing heated dilution steam **410** from dilution steam heat unit **130** with pre-heated composition **220** from feed pre-heater **110**, resulting in mixed hydrocarbons based composition **225**, followed by heating the mixed hydrocarbons based composition **225** by introducing the mixed hydrocarbons based composition **225** into the first hydrocarbon heat unit **120** to create a heated hydrocarbon-based composition **230**. In embodiments where heated dilution steam **410** is not mixed with pre-heated composition **220**, the process may include heating the pre-heated composition **220** by introducing the pre-heated composition **220** into the first hydrocarbon heat unit **120** to create a heated hydrocarbon-based composition **230**. The exit temperature of the heated hydrocarbon-based composition **230** from the first hydrocarbon heat unit **120** may be below the operating temperature of the reaction zone **160**. The exit temperature of the heated hydrocarbon-based composition **230** from the first hydrocarbon heat unit **120** may be from 300°C to 500°C, from 300°C to 450°C, from 300°C to 425°C, from 300°C to 400°C, from 300°C to 375°C, from 300°C to 350°C, from 300°C to 325°C, from 325°C to 500°C, from 325°C to 450°C, from 325°C to 425°C, from 325°C to 400°C, from 325°C to 375°C, from 325°C to 350°C, from 350°C to 500°C, from 350°C to 450°C, from 350°C to 425°C, from 350°C to 400°C, from 350°C to 375°C, from 375°C to 500°C, from 375°C to 450°C, from 375°C to 425°C, from 375°C to 400°C, from 400°C to 500°C, from 400°C to 450°C, from 400°C to 425°C, from 425°C to 500°C, from 425°C to 450°C, or from 450°C to 500°C. The first hydrocarbon heat unit **120** can be used to remove heat from the product stream **310**, wherein the heat removed from the product stream **310** can be used to heat the pre-heated hydrocarbon-based composition **240**. The first hydrocarbon heat unit **120** may cool the product stream **310** to below the reaction temperature. Cooling the product stream **310** below the reaction temperature prevents further reactions, or conversion, of the product stream **310**. The first hydrocarbon heat unit **120** may cool the product stream **310** to from 450°C to 600°C, from 450°C to 575°C, from 450°C to 550°C, from 450°C to 525°C, from 450°C to 500°C, from 450°C to 475°C, from 475°C to 600°C, from 475°C to 575°C, from 475°C to 550°C, from 475°C to 525°C, from 475°C to 500°C, from 500°C to 600°C, from 500°C to 575°C, from 500°C to 550°C, from 500°C to 525°C, from 525°C to 600°C, from 525°C to 575°C, from 525°C to 550°C, from 550°C to 600°C, from 550°C to 575°C, or from 575°C to 600°C. This may similarly be an optional component to the systems and processes disclosed herein.

[0029] The process may further comprise heating the heated hydrocarbon-based composition **230** by introducing the pre-heated hydrocarbon-based composition **220** into the second hydrocarbon heat unit **140** to create the hydrocarbon-based composition **240**. The exit temperature of the hydrocarbon-based composition **240** from the second hydrocarbon heat unit **140** may be below the operating temperature of the reaction zone **160**. The exit temperature of the hydrocarbon-based composition **240** from the second hydrocarbon heat unit **140** may be from 450°C to 600°C, from 450°C to 575°C, from 450°C to 550°C, from 450°C to 525°C, from 450°C to 500°C, from 450°C to 475°C, from 475°C to 600°C, from 475°C to 575°C, from 475°C to 550°C, from 475°C to 525°C, from 475°C to 500°C, from 500°C to 600°C, from 500°C to 575°C, from 500°C to 550°C, from 500°C to 525°C, from 525°C to 600°C, from 525°C to 575°C, from 525°C to 550°C, from 550°C to 600°C, from 550°C to 575°C, or from 575°C to 600°C. The second hydrocarbon heat unit **140** can be used to remove heat from the product stream **310**, wherein the heat removed from the product stream **310** can be used to heat the heated hydrocarbon-based composition **240**. The second hydrocarbon heat unit **140** may quickly cool the product stream **310** to below the reaction temperature. Cooling the product stream **310** below the reaction temperature prevents further reactions, or conversion, of the product stream **310**. The second hydrocarbon heat unit **140** may cool the product stream **310** to from 600°C to 800°C, from 600°C to 750°C, from 600°C to 725°C, from 600°C to 700°C, from 600°C to 675°C, from 600°C to 650°C, from 600°C to 625°C, from 625°C to 800°C, from 625°C to 750°C, from 625°C to 725°C, from 625°C to 700°C, from 625°C to 675°C, from 625°C to 650°C, from 650°C to 800°C, from 650°C to 750°C, from 650°C to 725°C, from 650°C to 700°C, from 650°C to 675°C, from 675°C to 800°C, from 675°C to 750°C, from 675°C to 725°C, from 675°C to 700°C, from 700°C to 800°C, from 700°C to 750°C, from 700°C to 725°C, from 725°C to 800°C, from 725°C to 750°C, or from 750°C to 800°C. In some embodiments, the second hydrocarbon heat unit **140** cools the product stream **310** to below 800°C, below 700°C, below 600°C, or below 500°C within 1000 milliseconds, 500 milliseconds, 200 milliseconds, 100 milliseconds, or 50 milliseconds. This may similarly be an optional component to the systems and processes disclosed herein.

[0030] In some embodiments, the process further comprises removing heat from the product stream **310** after removing the product stream **310** from the reaction zone **160** by passing the product stream **310** through a dilution steam heat unit **130**. The dilution steam heat unit **130** may cool the product stream **310** to below the reaction temperature. Cooling the product stream **310** quickly below the reaction temperature prevents further reactions, or conversion, of the product

stream **310**. In some embodiments, the dilution steam heat unit **130** cools the product stream **310** to below 600°C, or below 500°C. The process may further comprise passing a dilution steam stream **410** through the dilution steam heat unit **130**. The temperature of the dilution steam stream **410** before being introduced to the dilution steam heat unit **130** may be from 150°C to 200°C, from 160°C to 200°C, from 170°C to 200°C, from 180°C to 200°C, from 190°C to 200°C, from 150°C to 190°C, from 160°C to 190°C, from 170°C to 190°C, from 180°C to 190°C, from 150°C to 180°C, from 160°C to 180°C, from 170°C to 180°C, from 150°C to 170°C, from 160°C to 170°C, from 150°C to 160°C, or approximately 175°C. The process may comprise cooling the product stream **310** in the dilution steam heat unit **130** with the dilution steam stream **410**. In embodiments, the process may further comprise passing the dilution steam stream **410** from the dilution steam heat unit **130** to mix with the pre-heated hydrocarbon-based composition **220**, thereby transferring heat from the dilution steam stream **410** to the pre-heated hydrocarbon-based composition **220**. Passing the dilution steam stream **410** may increase the energy efficiency of the system **100**. Additionally, it is contemplated that mixing the dilution steam stream **410** with the pre-heated hydrocarbon-based composition **220** before introducing the pre-heated hydrocarbon-based composition **220** to the first hydrocarbon heat unit **120** may prevent condensation. These are optional components to the systems and processes disclosed herein, as the product stream **310** may be cooled according to other methods known in the art.

[0031] In embodiments, the process may further include cooling the product stream **310** in a heat recovery exchanger **170**. The heat recovery exchanger **170** may include a heat exchanger with molten salt, molten metal, organic fluid, or water as heat transfer medium, a spray nozzle, a quench column, direct heat transfer, or combinations thereof. In embodiments, the product stream **310** may have been cooled to below reaction temperature before being introduced to the heat recovery exchanger **170**. In embodiments, the product stream **310** may not have been cooled to below reaction temperature before being introduced to the heat recovery exchanger **170**, and this may serve as a quenching step. Quenching the product stream **310** below the reaction temperature prevents further reactions, or conversion, of the product stream **310** to quickly stop such reactions and conversions in the product stream. It should be understood that the term "cool" is used throughout this disclosure to describe various steps wherein the streams described herein are cooled and may encompass steps in which a stream is quenched. The term "cool" is not meant to be limiting, and instead, is meant to encompass embodiments in which a stream is quenched to stop reactions or conversions within the stream. When the cooling step includes direct heat

transfer, the process may further comprise passing a cold coolant stream (not shown) through a coolant drum (not shown) and then to the heat recovery exchanger **170**. The process may comprise cooling the product stream **310** in the heat recovery exchanger **170** with the cold coolant stream.

[0032] Additionally, in some embodiments, the systems and processes claimed herein produce no CO_2 emissions from the heating process. Specifically, the systems and processes herein utilize electrical heating systems and processes, which result in no direct CO_2 production from the heating systems and processes, as compared to conventional systems that utilize combustion reactions to generate heat. These combustion reaction systems and processes conventionally burn methane or other gases, which produce CO_2 emissions. Although the product stream **310** may include CO_2, the systems and processes claimed herein produce no CO_2 emissions from the heating process.

EXAMPLES

[0033] The following examples illustrate one or more embodiments of the present disclosure previously discussed. Additionally, a comparative example was conducted.

[0034] Comparative Example A

[0035] A conventional upgrading process was determined where a feedstock was introduced into a preheater at 90°C and heated to 149°C. A dilution steam stream was introduced to the dilution steam heat unit where the dilution steam stream was heated from an initial 175°C to 465°C. The dilution steam stream was then mixed with the feedstock before the feedstock was sent to a first hydrocarbon heat unit, and heated the feedstock to 205°C. The feedstock was then introduced to the first hydrocarbon heat unit and was heated to 385°C..The feedstock was then sent to the second hydrocarbon heat unit and heated to 597°C and sent to a reaction zone where it was heated and converted to form a product stream with a propylene/ethylene ratio of 0.51, resulting in an outlet temperature of 861°C. The product stream was then sent to 2 transfer line exchangers in series, and was cooled from 855°C to 469°C in the first transfer line exchanger and then cooled from 469°C to 353°C in the second transfer line exchanger. High pressure steam with a temperature of 310°C was generated in the transfer line exchangers. The product stream was then sent to a heat recovery exchanger. The flue gas from the conventional combustion reaction zone was used to superheat the steam in steam superheater units 1 and 2, from 311°C to 433°C and from 391°C to 490°C respectively. Boiler Feed water going to the steam drum is pre-heated

in the Economizer, from 120°C to 202°C. The flue gas in this simulation is cooled down from 1187°C to 136°C. The results of this simulation are summarized in Tables 1 and 2 below:

Table 1: Product stream temperature, flow rate, and duty in a conventional upgrading process.

	T in	T out	Flow	Duty
	C	C	MT/h	Gcal/hr
Preheater	90	149	46.0	2.51
Economizer	120	202	57.7	4.91
First hydrocarbon heat unit	205	385	73.6	7.67
Dilution Steam Unit	175	465	27.6	4.05
Steam Superheater Unit 1	310	433	56.6	6.36
Steam Superheater Unit 2	391	490	59.3	3.91
Second Hydrocarbon heat unit	385	597	73.6	10.87
				Absorbed heat
Reaction Zone	588	861	73.6	31.49
Transfer Line Exchanger 1	855	469	73.6	20.08
Transfer Line Exchanger 2	469	353	73.6	5.21
High pressure steam			59.298	

Table 2: Flue gas/steam temperature, flow rate, and duty in a conventional upgrading process.

	T in	T out	dT	Duty
	C	C	C	Gcal/hr
Preheater	208	136	72	2.51
Economizer	346	208	138	4.91
First hydrocarbon heat unit	554	346	208	7.67
Dilution Steam Unit	659	554	105	4.05
Steam Superheater Unit 1	820	659	161	6.36
Steam Superheater Unit 2	917	820	97	3.91
Second Hydrocarbon heat unit	1178	917	261	10.87
				Fired duty:
Reaction Zone				77.42
Transfer Line Exchanger 1	310	310		20.08
Transfer Line Exchanger 2	310	310		5.21

[0036] Example 1

[0037] An upgrading process in accordance with the present disclosure was determined. A procedure similar to Comparative Example A was done, but there was no flue gas present in Example 1 because an electrically heated reaction zone was used (as opposed to the conventional

combustion reaction zone of Comparative Example A) and the steam was instead heated using electric heaters since no flue gas was produced in Example 1. A feedstock was introduced into a preheater at 90°C and heated to 149°C. A dilution steam stream was introduced to the dilution steam heat unit where the dilution steam stream was heated from an initial 175°C to 465°C. The dilution steam stream was then mixed with the feedstock before the feedstock was sent to a first hydrocarbon heat unit, and heated the feedstock to 205°C. The feedstock was then introduced to the first hydrocarbon heat unit and was heated to 385°C. The feedstock was then sent to the second hydrocarbon heat unit and heated to 597°C and sent to a reaction zone where it was heated to 861°C to form a product stream. The product stream was then sent to 2 transfer line exchangers in series, and was cooled from 855°C to 469°C in the first transfer line exchanger and then cooled from 469°C to 353°C in the second transfer line exchanger. High pressure steam with a temperature of 310°C was used in the transfer line exchangers. The product stream was then sent to a heat recovery exchanger. The results of this simulation are summarized in Table 3 below:

Table 3: Feedstock temperature, flow rate, and duty for Example 1.

	Product feed			
	T in	T out	Flow	E-heat input
	C	C	MT/h	Gcal/hr
Preheater	90	149	46	2.51
Economizer	**120**	202	57.7	4.91
First Hydrocarbon heat unit	205	385	73.6	7.67
Dilution steam heat unit	175	465	27.6	4.05
Steam Superheater Unit 1	310	433	56.6	6.36
Steam Superheater Unit 2	391	490	59.3	3.91
Second Hydrocarbon heat unit	385	597	73.6	10.87
				Absorbed heat
Reaction Zone	588	861	73.6	31.49
Transfer Line Exchanger 1	855	469	73.6	20.08
Transfer Line Exchanger 2	469	353	73.6	5.21
High Pressure Steam			**59.298**	

[0038] Example 2

[0039] An upgrading process in accordance with the present disclosure was determined. The reaction zone was heated electrically similar to Example 1, but Example 2 further utilized the product stream to heat the feed stream to maximize process efficiency. As a result of this change the intermediate temperatures of the feed stream and the product stream were further optimized.

In Example 2, no high pressure steam was produced, as opposed to Comparative Example A and Example 1. For comparison reasons only, the equivalent shaft power per ton of produced high pressure steam was calculated for a 90 bar to condensing steam turbine. Using the calculated steam production from Example 1, an equivalent electrical power requirement for an electromotor was calculated and included as "High Pressure Steam Credit for Turbine" in the form of electrical power, as shown in Table 4. A feedstock stream **210** was introduced into a preheater **110** at 90°C and heated to 224°C to form a pre-heated hydrocarbon-based composition **220**. A dilution steam stream **410** was introduced to the dilution steam heat unit **130** where the dilution steam stream **410** was heated from an initial 175°C to 465°C. The dilution steam stream **410** was then mixed with the pre-heated hydrocarbon-based composition **220** before the mixed hydrocarbons based composition **225** was sent to a first hydrocarbon unit **120**. The mixed hydrocarbon-based composition **225** was was then introduced to the first hydrocarbon heat unit **120** and was heated to 385°C to create a heated hydrocarbon-based composition **230**. The heated hydrocarbon-based composition **230** was then sent to a second hydrocarbon heat unit **140** and heated to 550°C to form a hydrocarbon-based composition **240** and sent to an electric heater **150** and heated to 597°C. The hydrocarbon-based composition **240** was then sent to a reaction zone **160** where it was heated to 861°C to form a product stream **310**. The product stream **310** was then passed to the second hydrocarbon heat unit **140** where it heated the heated hydrocarbon-based composition **230** as described previously, and was thereby cooled from 855°C to 692°C. The product stream **310** was then passed to the dilution steam heat unit **130** where the product stream **310** heated the dilution steam stream **410** as described previously, and was thereby cooled to 615°C. The product stream **310** was then sent to the first hydrocarbon heat unit **120** where the product stream **310** heated the pre-heated hydrocarbon-based composition **220** as described previously, and was thereby cooled to 528°C. The product stream **310** was then passed to the preheater **110** where the product stream **310** heated the feedstream **210** as described previously, and was thereby cooled to 401°C. The results of this simulation are summarized in Tables 4 and 5 below:

Table 4: Feedstock temperature, flow rate, and duty for Example 2.

	T in	T out	Flow	Duty
	C	C	MT/h	Gcal/hr
Preheater	90	224	46.0	5.70
First Hydrocarbon heat unit	280	385	57.7	4.48
Dilution steam heat unit	175	465	73.6	4.05

Second Hydrocarbon heat unit	385	550	73.6	8.46
Electric Heater	550	597	73.6	2.41
Reaction Zone	588	861	73.6	31.49
Direct Electric Power				**33.90**
High Pressure Steam Credit For Turbine				9.80
Total electric power required				**43.70**

Table 5: Product stream temperature, flow rate, and duty for Example 2.

	T in	T out	Flow	Duty	T pinch	T salt
	C	C	MT/h	Gcal/hr	C	C
Preheater	528	401	73.6	5.70	177	264
First Hydrocarbon heat unit	615	528	73.6	4.48	143	425
Dilution steam heat unit	692	615	73.6	4.05	150	505
Second Hydrocarbon heat unit	855	692	73.6	8.46	142	590

[0040] Pinch analysis is a methodology for minimizing energy consumption of chemical processes by calculating thermodynamically feasible energy targets (or minimum energy consumption) and achieving them by optimizing heat recovery systems, energy supply methods and process operating conditions. The pinch temperature is the minimum temperature difference (ΔT) between the feedstock and the product stream. The salt temperature is the temperature of the salt bath (which is equal to the feedstock temperature out plus the offset). The offset is the difference between the temperature of the salt bath and the inlet feedstock temperature. This energy balance is based on the worst case assumption of an isothermal temperature for the heat transfer fluid (salt bath), in other embodiments an temperature profile of the heat transfer fluid may be achieved, resulting in a higher minimum temperature difference (ΔT) between the feedstock and the product stream.

[0041] The energy consumption of each of Comparative Example A, Example 1, and Example 2 is shown in Table 6 below.

Table 6: A comparison of the energy consumption of Comparative Example A, Example 1, and Example 2.

Comparison	Fired Duty	High Pressure Steam Generated	Electric Heating Power	Electric Motor Power		Total Electric Power
	Gcal/hr	Metric Ton/hr	Gcal/hr	Gcal/hr		Gcal/hr
Comparative Example A	77.42	59.298	0	0		0.00
Example 1	0	59.298	71.77	0		71.77
Example 2	0	0	33.90	9.80		43.70
Comparing Example 2 to Example 1			**47%**			**61%**

[0042] Comparative Example A utilized a conventional combustion reaction zone and required 77.42 Gcal/hr of fired duty (power) to operate the reaction. The high pressure steam was generated in Comparative Example A by recovering the residual heat from the conventional fired furnace. Example 1, in which all heating was done electrically, as described previously, require 71.77 Gcal/hr of power, which was slightly less than Comparative Example A due to the elimination of stack losses. The high pressure steam was generated in Example 1 by recovering the residual heat from the electric heating. Example 2 did not include a high pressure steam stream because by using the product stream to heat the feed stream there was no residual heat. Example 2 exhibited a 61% reduction in electric power usage as compared to Example 1, which shows that utilizing the product stream to heat the feed stream to reduced the necessary power to operate the system from 71.77 Gcal/hr to 43.8 Gcal/hr (in other words, Example 2 requires 61% of the power required by Comparative Example A and Example 1, decreasing power consumption as compared to Comparative Example A and Example 1 by 39%).

[0043] It will be apparent to those skilled in the art that various modifications and variations can be made to the embodiments described herein without departing from the spirit and scope of the claimed subject matter. Thus it is intended that the specification cover the modifications and variations of the various embodiments described herein provided such modification and variations come within the scope of the appended claims and their equivalents.

CLAIMS

1. A process for upgrading a hydrocarbon-based composition comprising:

introducing the hydrocarbon-based composition into a reaction zone heated with electricity, concentrated solar radiation heat, nuclear reactor heat, geothermal heat, molten salt, molten metal, or combinations thereof;

heating the hydrocarbon-based composition in the reaction zone to create a product stream; and

cooling the product stream to create a cooled product stream, wherein:

the reaction zone does not produce flue gas.

2. The method of claim 1, further comprising pre-heating the hydrocarbon-based composition before heating the hydrocarbon-based composition in the reaction zone, wherein pre-heating the hydrocarbon-based composition comprises transferring heat from the product stream to the hydrocarbon-based composition, thereby cooling the product stream.

3. The method of any previous claim, wherein cooling the product stream comprises:

transferring heat from the product stream to a dilution steam stream;

transferring heat from the product stream to the hydrocarbon-based composition; or

both.

4. The method of any previous claim, further comprising:

introducing a feed stream into a feed pre-heat unit;

introducing the product stream into the feed pre-heat unit; and

pre-heating the feed stream in the feed pre-heat unit to create a pre-heated hydrocarbon-based composition and cooling the product stream in the feed pre-heat unit by transferring heat from the product stream to the feed stream.

5. The method of claim 4, further comprising:

introducing the pre-heated hydrocarbon-based composition into a first hydrocarbon heat unit;

introducing the product stream into the first hydrocarbon heat unit; and

heating the pre-heated hydrocarbon-based composition in the first hydrocarbon heat unit to create a heated hydrocarbon-based composition and cooling the product stream in the first hydrocarbon heat unit comprise transferring heat from the product stream to the pre-heated hydrocarbon-based composition.

6. The method of claim 5, further comprising:

introducing the heated hydrocarbon-based composition into a second hydrocarbon heat unit;

introducing the product stream into the second hydrocarbon heat unit; and

heating the heated hydrocarbon-based composition in the second hydrocarbon heat unit to create the hydrocarbon-based composition and cooling the product stream in the second hydrocarbon heat unit comprise transferring heat from the product stream to the heated hydrocarbon-based composition.

7. The method of claim 5 or claim 6, further comprising:

introducing a dilution steam stream into a steam unit;

introducing the product stream into the steam unit; and

cooling the product stream in the dilution steam heat unit by transferring heat from the product stream to the dilution steam stream.

8. The method of any previous claim, wherein heating the hydrocarbon-based composition in the reaction zone to create a product stream comprises heating the hydrocarbon-based composition to a reaction temperature that ranges from 700°C to 950°C, thereby cracking the hydrocarbon-based composition to create the product stream.

9. The method of any previous claim, further comprising additionally cooling the cooled product stream with comprising molten salt, molten metal, organic fluid, inorganic fluid, or combinations thereof.

10. The method of any previous claim, wherein the hydrocarbon-based composition comprises naphtha, ethane, propane, butanes, pentanes, atmospheric gas oil (AGO), vacuum gas oil (VGO), or combinations thereof; and the product stream comprises hydrogen, olefins, and aromatic

hydrocarbons. In embodiments, the olefins comprise C_2 to C_5 olefins such as, for example, ethylene (C_2H_4), propylene (C_3H_6), butylene (C_4H_8), or combinations thereof.

11. A system for upgrading a hydrocarbon-based composition comprising:

a reaction vessel comprising a heating column,

a heat recovery exchanger comprising molten salt, molten metal, organic fluid, inorganic fluid, or combinations thereof, and

an electric heater, wherein:

the heating column is thermally connected to the electric heater; and

the heating column is thermally connected to the heat recovery exchanger.

12. The system of claim 11, further comprising a reaction zone, wherein the heating column comprises a pre-heat unit, a first hydrocarbon unit, a dilution unit, a second hydrocarbon unit, and a trim heater, a trim cooler, or both, wherein:

the first hydrocarbon unit is fluidly connected to the pre-heat unit, the dilution unit, and the second hydrocarbon unit; and

the second hydrocarbon unit is fluidly connected to the dilution unit, the first hydrocarbon unit, and the reaction zone.

13. The system of claim 11 or 12, wherein the heating column is solely heated via the electric heater.

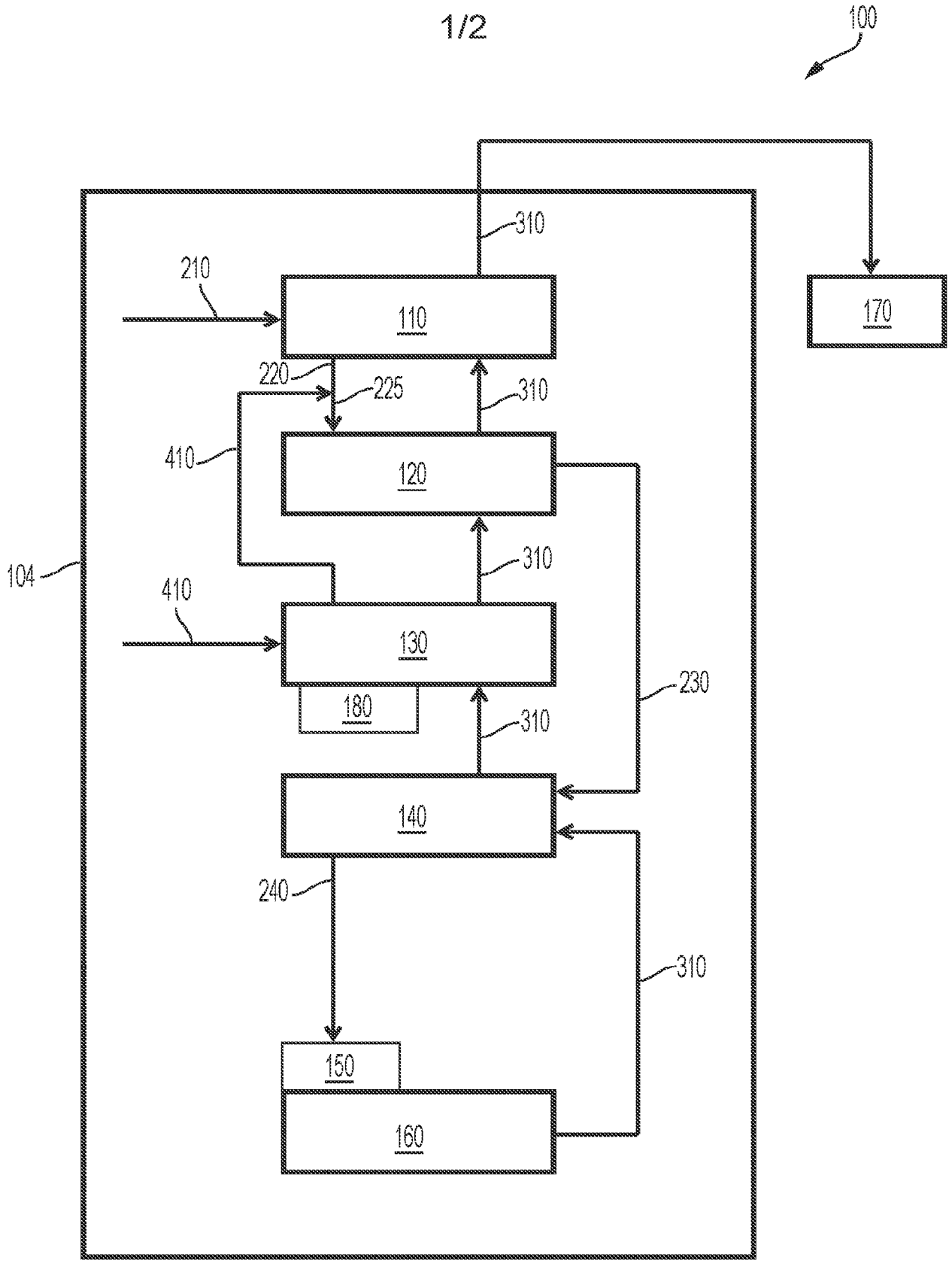
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FIG. 1

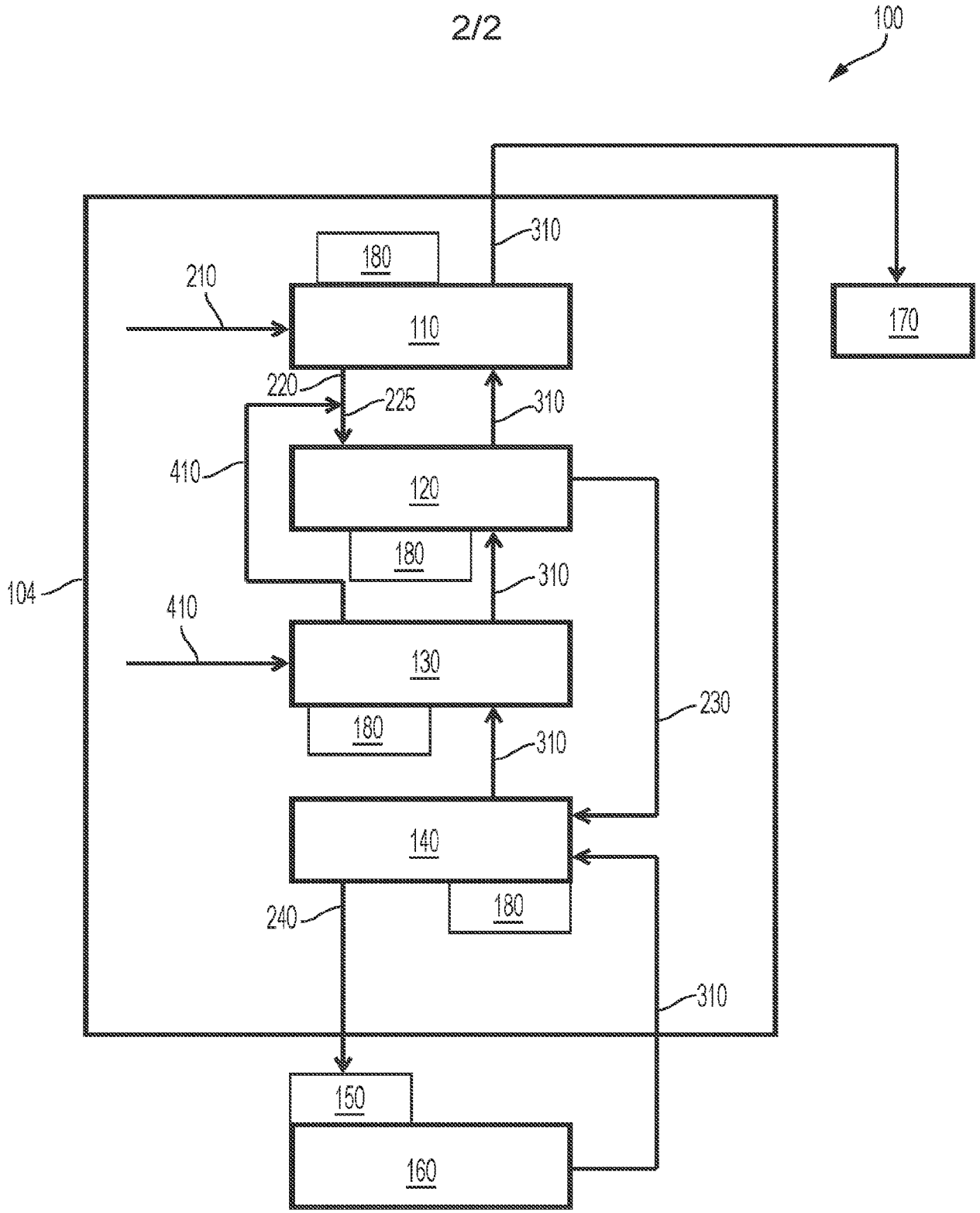
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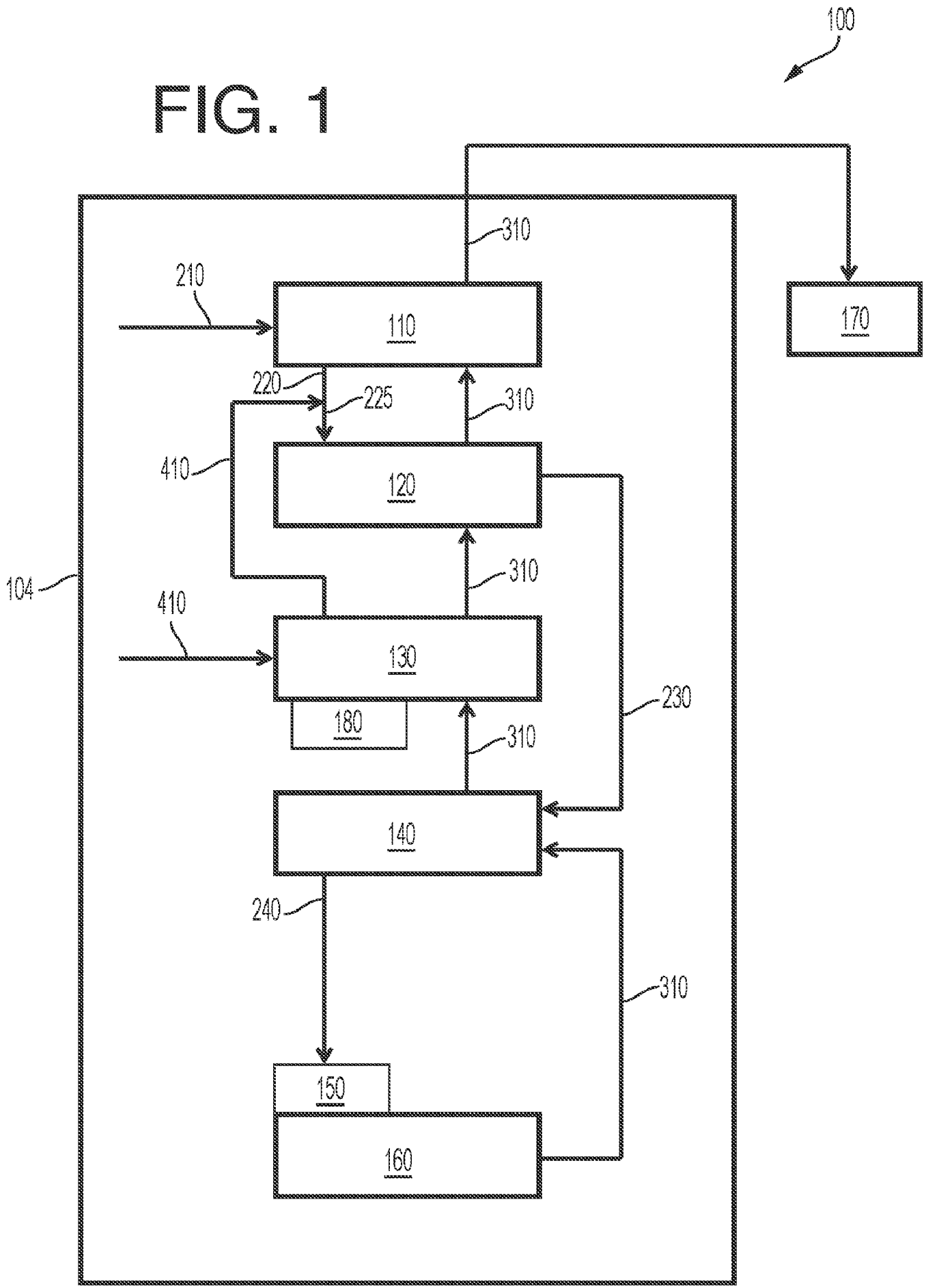
FIG. 2

FIG. 1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