

OLEFINS PRODUCTION PROCESS

Field of the invention

5 The present invention relates to a process for producing olefins from a feed stream containing hydrocarbons, by pyrolytic cracking of the hydrocarbons in a cracker furnace.

Background of the invention

Pyrolytic cracking of hydrocarbons in a cracker furnace
10 is a petrochemical process that is widely used to produce olefins (such as ethylene, propylene, butylenes and butadiene) and optionally aromatics (such as benzene, toluene and xylene). Where such pyrolytic cracking is performed in the presence of dilution steam, this is referred to as "steam
15 cracking". The feed stream to such pyrolytic cracking process may include one or more of ethane, propane, butane, liquefied petroleum gas (LPG), naphtha, hydrowax and recycled waste plastics oil. In a pyrolytic cracking process, the hydrocarbons containing stream is converted under the
20 influence of heat, and substantially in the absence of oxygen, into an olefins containing effluent.

A cracker furnace comprises a convection section and a radiant section. When considering the direction of the feed stream through a cracker furnace, the convection section is
25 located in an upstream part of the cracker furnace and the radiant section is located in a downstream part thereof. However, when considering the direction of the below-mentioned flue gas through a cracker furnace, the convection section is located in a downstream part of the cracker
30 furnace and the radiant section is located in an upstream part thereof. The convection section comprises one or more tubes into which the hydrocarbon feed stream is introduced, in which tubes the hydrocarbon stream is pre-heated by hot

flue gas which is present outside these tubes and which arises from the radiant section, wherein heat exchange takes place through the walls of said tubes. Said radiant section comprises one or more burners wherein oxygen, e.g. as present
5 in air, and a fuel gas are contacted and the fuel gas is combusted resulting in heat release, which heat is needed to effect the pyrolytic cracking of the hydrocarbon stream in one or more tubes which are also comprised within the radiant section and into which the pre-heated hydrocarbon stream from
10 the convection section is introduced. Generally, the fuel gas used in said burners comprises hydrogen and methane originating from the olefins containing effluent from the radiant section of the cracker furnace.

Combustion of a fuel gas comprising hydrogen and methane
15 in the burners of a cracker furnace results in the production of a flue gas comprising water and carbon dioxide. Generally, carbon dioxide from such flue gas may have to be emitted into the Earth's atmosphere and/or may have to be captured in another form thereby preventing such emission. A distinction
20 can be made between Carbon Capture and Storage (CCS) and Carbon Capture and Use (CCU) which both involve carbon dioxide capture which is cumbersome, requiring additional equipment, and therefore relatively expensive. In addition, CCS further increases the general costs of chemicals
25 manufacturing because of the required energy expenditure for compression and distribution to carbon dioxide storage.

Therefore, in view of the above, it is an objective of the present invention to reduce the total amount of fuel gas needed to produce the desired olefins as contained in the
30 olefins containing effluent from the cracker furnace. An important advantage of such reduced fuel gas consumption is that the amount of carbon dioxide formed in the burners of the cracker furnace relative to the amount of desired

products (i.e. olefins and optionally aromatics) is decreased. In specific, in a case wherein the fuel gas comprises hydrogen which originates from another source than the cracker furnace effluent (e.g. so-called "green" hydrogen sustainably produced through renewable power electrolysis, or 5 so-called "blue" hydrogen produced from hydrocarbons in a process like steam methane reforming in combination with carbon capture and storage, or otherwise produced hydrogen), the above-mentioned reduced fuel gas consumption advantageously results in that less of such on-purpose 10 hydrogen may be needed as cracker furnace fuel gas so that accordingly less hydrogen production may be needed which production may also involve the formation of carbon dioxide and/or may require the use of renewable, non-fossil energy 15 resources which may be limited available.

Further, generally, it is an object of the present invention to provide such process for the production of olefins from a hydrocarbon feed stream, which process is technically advantageous, efficient and affordable, in 20 particular a process which does not have one or more of the above-mentioned disadvantages. Such technically advantageous process would preferably result in a relatively low energy demand and/or relatively low capital expenditure.

Summary of the invention

25 Surprisingly, it was found that one or more of the above-mentioned objectives may be achieved by both (i) pre-heating the hydrocarbon feed stream, that is fed to the convection section of a cracker furnace, outside that cracker furnace, and (ii) pre-heating the oxygen containing stream that is fed 30 to a burner in the radiant section of the cracker furnace and contacted therein with a fuel gas, whereby said burner advantageously needs to provide a reduced heat duty for performing the pyrolytic cracking process at the same

pyrolytic cracking process product output. In other words, by the present invention, a reduced heat duty relative to the amount of desired products (i.e. olefins and optionally aromatics) in the effluent from the cracker furnace is achieved. Consequentially, and advantageously, less fuel gas needs to be combusted in said burner and accordingly, in case the fuel gas comprises e.g. methane, less carbon dioxide is formed and ends up in the flue gas resulting from that combustion.

10 In addition, it has appeared that when pre-heating the above-mentioned oxygen containing stream before feeding to a burner in the radiant section of the cracker furnace, the so-called stack temperature of the flue gas that is emitted into the Earth's atmosphere, after having heated the hydrocarbon
15 feed in the radiant and convection sections of the cracker furnace, surprisingly, can still be maintained relatively low, despite the higher inlet temperature of the pre-heated hydrocarbon feed introduced into the convection section in accordance with the present invention, thereby requiring less
20 heat input from the flue gas present in that same convection section. In other words, advantageously, the same, relatively low stack temperature of the flue gas may still be achieved in the present invention, even at the relatively high inlet temperature of the hydrocarbon feed. Keeping the stack
25 temperature the same is important for ensuring that the overall thermal efficiency of the cracker furnace is not decreased.

Accordingly, the present invention relates to a process for producing olefins from a feed stream containing
30 hydrocarbons by pyrolytic cracking of the hydrocarbons in a cracker furnace, said process comprising:

pre-heating the feed stream outside the cracker furnace;

feeding the pre-heated feed stream to a tube in the convection section of the cracker furnace;

further pre-heating the feed stream in the convection section;

5 feeding the further pre-heated feed stream to a tube in the radiant section of the cracker furnace;

pre-heating an oxygen containing stream;

contacting the pre-heated oxygen containing stream with a fuel gas in a burner in the radiant section; and

10 pyrolytic cracking the feed stream in the radiant section resulting in an effluent containing olefins.

Brief description of the drawings

Figure 1 shows a set-up for the below Reference Example (not according to the present invention), as applied in a process for producing olefins from a feed stream containing hydrocarbons by pyrolytic cracking of the hydrocarbons in a cracker furnace.

Figure 2 shows an alternative set-up for below Example A (according to the present invention), for such olefins production process.

Detailed description of the invention

The process of the present invention comprises multiple steps. In addition, said process may comprise one or more intermediate steps between consecutive steps. Further, said process may comprise one or more additional steps preceding the first step and/or following the last step. For example, in a case where said process comprises steps a), b) and c), said process may comprise one or more intermediate steps between steps a) and b) and between steps b) and c). Further, said process may comprise one or more additional steps preceding step a) and/or following step c).

While the process of the present invention and the stream(s) or composition(s) used in said process are

described in terms of "comprising", "containing" or "including" one or more various described steps and components, respectively, they can also "consist essentially of" or "consist of" said one or more various described steps and components, respectively.

In the context of the present invention, in a case where a stream or a composition comprises two or more components, these components are to be selected in an overall amount not to exceed 100%.

Further, where upper and lower limits are quoted for a property then a range of values defined by a combination of any of the upper limits with any of the lower limits is also implied.

The present invention concerns a process for producing olefins from a feed stream containing hydrocarbons by pyrolytic cracking of the hydrocarbons in a cracker furnace.

The above-mentioned cracker furnace comprises a convection section and a radiant section. As explained in the introduction, when considering the direction of the above-mentioned feed stream through a cracker furnace, the convection section is located in an upstream part of the cracker furnace and the radiant section is located in a downstream part thereof.

The present process comprises a number of steps. Said process comprises pre-heating the feed stream containing hydrocarbons outside the cracker furnace, feeding the pre-heated feed stream to a tube in the convection section, further pre-heating the feed stream in the convection section, feeding the further pre-heated feed stream to a tube in the radiant section, pyrolytic cracking the feed stream in the radiant section resulting in an effluent containing olefins and optionally aromatics).

Within the present specification, "pre-heating" refers to heating a stream before introducing such stream into the radiant section of the cracker furnace.

In the present invention, the feed stream containing
5 hydrocarbons may be pre-heated in the convection section of the cracker furnace before pre-heating the feed stream outside the cracker furnace. However, in the present invention, it is preferred that pre-heating the feed stream containing hydrocarbons outside the cracker furnace is
10 performed before feeding the feed stream to a tube in the convection section of the cracker furnace for a first time. Thus, in the present invention, it is preferred that the feed stream containing hydrocarbons is not pre-heated in the convection section of the cracker furnace before pre-heating
15 the feed stream outside the cracker furnace.

In the present invention, pre-heating through indirect heat exchange does not involve direct contact between the heating medium and the medium to be heated. Further, in the present invention, pre-heating through indirect heat exchange
20 may involve the use of an intermediate fluid as a heat transfer medium. Preferably, in the latter case, said intermediate fluid does not comprise steam. Alternatively, in the present invention, pre-heating through indirect heat exchange may not involve the use of an intermediate fluid.

25 Within the present specification, a "tube in the convection section" refers to a tube suitable for carrying a flow of fluid, such as a gas or a liquid, in which tube the feed stream containing hydrocarbons is further pre-heated.

Within the present specification, a "tube in the radiant
30 section" refers to a tube suitable for carrying a flow of a gas, in which tube the further pre-heated feed stream containing hydrocarbons is pyrolytically cracked.

This means that in the present invention, pre-heating of the hydrocarbon feed before feeding into the radiant section of the cracker furnace, does not only take place in the convection section of the cracker furnace but also outside that cracker furnace. Said pre-heating inside the cracker furnace takes place through indirect heat exchange with the flue gas coming from the radiant section, i.e. a heat transfer from the hot flue gas present in the convection section outside a tube in that same convection section to the hydrocarbon feed stream as fed into said tube.

In accordance with the present invention, outside the cracker furnace, the feed stream containing hydrocarbons may be pre-heated to any temperature, preferably to a temperature which is higher than ambient temperature. Preferably, said feed stream is pre-heated outside the cracker furnace to a temperature of at most 550 °C, more preferably at most 500 °C, more preferably at most 450 °C, more preferably at most 400 °C, most preferably at most 350 °C. Further, preferably, said feed stream is pre-heated outside the cracker furnace to a temperature of at least 75 °C, more preferably at least 100 °C, more preferably at least 150 °C, more preferably at least 200 °C, more preferably at least 250 °C, most preferably at least 300 °C.

As mentioned above, in the present invention, the feed stream that is pre-heated outside the cracker furnace, is fed to a tube in the convection section and further pre-heated therein, preferably to a temperature of from 300 to 800 °C, more preferably of from 500 to 700 °C, most preferably of from 550 to 650 °C.

Further, as mentioned above, in the present invention, the further pre-heated feed stream from the convection section is fed to a tube in the radiant section, wherein pyrolytic cracking of hydrocarbons in the feed stream is

performed, preferably at a temperature of from 700 to 1000 °C, more preferably 700 to 950 °C, most preferably 700 to 900 °C, resulting in an effluent containing olefins.

The heat duty required for enabling pyrolytic cracking of
5 the hydrocarbons in one or more tubes in the radiant section is delivered by one or more burners in the radiant section, wherein oxygen and a fuel gas are contacted and the fuel gas is combusted resulting in heat release in the form of a hot flue gas, further resulting in an indirect heat exchange,
10 i.e. a heat transfer from the hot flue gas present in the radiation section outside a tube in that same radiation section to the further pre-heated hydrocarbon feed stream as fed into said tube.

The olefins-containing effluent leaving the radiant
15 section is still hot and may be used, in the present invention, to provide steam having a relatively high pressure and a relatively high temperature through indirect heat exchange, using so-called "Transfer Line Exchangers" (TLEs), before the effluent is fed to a work-up section outside the
20 cracker furnace in which work-up section several products are separated from the effluent. Said (TLEs) are used to rapidly cool the effluent from a cracker furnace, which TLEs are further discussed below. Such pressurized steam may be generated from water, which may also be referred to as
25 "boiler feed water" (BFW) or "utility water" as opposed to "process water" which process water may be added in the form of steam as a diluent to the hydrocarbon feed itself. Said utility water (or BFW) may be converted in several stages to said high temperature pressurized steam. As mentioned above,
30 heat for generating said high temperature pressurized steam may be obtained by indirect heat exchange with the olefins containing effluent ("process effluent") from the radiant section, but also by indirect heat exchange with the flue gas

in one or more of so-called "banks" in the convection section.

In turn, by expansion of said high temperature pressurized steam, e.g. in a steam turbine, power may be provided to drive a compressor needed to facilitate the separations of the effluent in the above-mentioned work-up section. Through such expansion, a lower temperature and lower pressure steam is generated, which in turn may again be used to drive a compressor generating a steam with a further reduced temperature and a further reduced pressure.

In this way, several types of pressurized steam may be generated involving part of the heat originally generated in the radiant section through combustion of the fuel gas. A distinction can be made between very high pressure ("VHP") steam having a pressure of from greater than 70 bara to 130 bara; high pressure ("HP") steam having a pressure of from greater than 30 bara to 70 bara; medium pressure ("MP") steam having a pressure of from greater than 10 bara to 30 bara; and low pressure ("LP") steam having a pressure of from greater than atmospheric pressure to 10 bara. Such types of pressurized steam may be superheated, where the surplus superheat temperature above the steam saturation temperature may be at least 10 °C or at least 20 °C or at least 30 °C. Further, said surplus superheat temperature may be at most 250 °C or at most 200 °C or at most 100 °C.

In the present invention, one or more of the above-mentioned pressurized steam types and another heat source having a temperature of from greater than 50 °C to 100 °C or of from greater than 50 °C to 90 °C, which said other heat source may have an atmospheric pressure (e.g. process or utility water, or hydrocarbon streams run down from a cracker unit, or hydrocarbon streams within a cracker unit), may be used in pre-heating the feed stream containing hydrocarbons

outside the cracker furnace through indirect heat exchange between the feed stream and such steam or other heat source. Said other lower temperature heat source (not including pressurized steam) may comprise waste heat that is available
5 in a plant for the production of olefins involving cracking of hydrocarbons. Said pre-heating of the feed stream containing hydrocarbons outside the cracker furnace may be carried out in one step or two or more steps, wherein the temperature of the heat source in a preceding pre-heating
10 step is lower than the temperature of the heat source in a subsequent pre-heating step. Preferably, and advantageously, said steam may be generated by heat recovered from the cracker furnace, for example from the olefins containing effluent from the radiant section and/or from flue gas in the
15 convection section. In the present invention, steam that may be used in such indirect heat exchange may have a pressure of from greater than atmospheric pressure to 130 bara and a temperature of from greater than 100 °C to 570 °C. In specific, it is preferred that one or more of above-mentioned
20 LP steam, MP steam and HP steam is or are used for such pre-heating. In a case where two or more different steam types are used for such pre-heating in different subsequent steps, in the 1st step the lowest pressure steam is used and in the last step the highest pressure steam is used.

25 Further, in the present invention, at least a portion of the olefins containing effluent from the radiant section may be used in a direct sense in pre-heating the feed stream containing hydrocarbons outside the cracker furnace through indirect heat exchange between the feed stream and said
30 effluent. This is different from first generating steam using said effluent as heat source and then using the generated steam as a heat source in the feed pre-heating step, as discussed above.

Further, in the present invention, in addition to pre-heating the feed stream containing hydrocarbons outside the cracker furnace, any dilution steam may also be pre-heated outside the cracker furnace separately from pre-heating said
5 feed stream. As mentioned above, where pyrolytic cracking of hydrocarbons in a cracker furnace is performed in the presence of dilution steam, this is referred to as "steam cracking". Further, said dilution steam is "process water" which, as opposed to "utility water", is added in the form of
10 steam as a diluent to the hydrocarbon feed itself. In a case wherein dilution steam is pre-heated outside the cracker furnace, such pre-heating may be performed in the same way as described above with respect to pre-heating the feed stream. In particular, such pre-heating of dilution steam outside the
15 cracker furnace may be carried out by an indirect heat exchange with one or more of the above-mentioned heat sources for pre-heating the feed stream containing hydrocarbons, such heat sources including "VHP", "HP", "MP" and "LP" steam.

Further, in the present invention, an oxygen containing
20 stream is contacted with a fuel gas in a burner in the radiant section, which stream is first pre-heated before such contacting takes place. The latter pre-heating may be carried out inside or outside the cracker furnace, preferably inside the cracker furnace, in particular in the convection section
25 thereof.

Pre-heating of the oxygen containing stream outside the cracker furnace may be carried out by an indirect heat exchange with one or more of the above-mentioned heat sources for pre-heating the feed stream containing hydrocarbons, such
30 heat sources including "VHP", "HP", "MP" and "LP" steam. A suitable example of pre-heating the oxygen containing stream outside the cracker furnace is a case wherein the above-described LP steam is used as a heat source for such pre-

heating, especially in a case where there is a surplus of LP steam after having pre-heated the feed stream containing hydrocarbons outside the cracker furnace as described above. Pre-heating the oxygen containing stream outside the cracker furnace advantageously results in reduced fuel gas consumption. Examples of suitable heat sources for such pre-heating comprise: LP steam, warm water (e.g. as available after heat exchange in quench water tower for dilution steam condensation) having a temperature of from 60 to 90 °C and low-pressure condensate having a temperature of from 100 to 200 °C.

Said oxygen containing stream which is contacted with the fuel gas may comprise an air stream. Alternatively or additionally, it may comprise a stream containing more or less oxygen than air. In particular, such stream containing more or less oxygen than air may be combined with an air stream, before contacting with the fuel gas. A suitable example of a stream which may contain less oxygen than air, is below-mentioned exhaust gas stream from a gas turbine used for power generation (e.g. electrical or shaft power). Such exhaust gas stream may contain oxygen in an amount of from 12 to 18 vol.%, typically around 15 vol.%.

In the present invention, the oxygen containing stream which is contacted with the fuel gas, may contain oxygen in an amount greater than 10 vol.% or greater than 12 vol.% or greater than 21 vol.%. Further, said stream may contain at most 99.9 vol.% of oxygen.

In the present invention, the above-mentioned oxygen containing stream which is contacted with the fuel gas, may be pre-heated to a temperature of from 70 to 550 °C. Said temperature may be at least 70 °C or at least 100 °C or at least 150 °C. Further, said temperature may be at most 550 °C or at most 450 °C or at most 400 °C or at most 350 °C.

In the present invention, the oxygen containing stream which is contacted with the fuel gas, may be pre-heated through indirect heat exchange between the oxygen containing stream and flue gas in the convection section. Heat exchange
5 device equipment to enable this may for example comprise a LCAP ("Liquid Coupled Air Preheater") in which an intermediate fluid is used as heat transfer medium. Advantageously, through such heat transfer, the flue gas heat is reduced before this would be emitted as a loss to the
10 atmosphere, and is indirectly transferred as useful heat duty to combustion oxygen resulting in a reduction of fuel gas consumption. Alternatively or additionally, the heat exchange device equipment may comprise a single equipment heat exchanger, e.g. a "plates and frame" type heat exchanger, or
15 a tubular heat exchanger, or a combination thereof, and with or without fins applied to either such plates or tubes. An example of such "plates and frame" type heat exchanger is a recuperative static heat exchanger equipment whereby heat is transferred through a surface made of rectangular, finned
20 channels. These channels are stacked vertically alongside each other to form rows, then the various horizontal rows on top of each other form a single module. These modules are stacked on top of each other to create a multi-pass arrangement. In most applications the flue gas passes
25 vertically downward outside over the channels, while the oxygen containing supply flows in a cross-counter flow into and inside the channels. An example of such "plates and frame" type heat exchanger is a cast-iron "DEKA" heat exchanger which is commercially available. Alternatively or
30 additionally, the heat exchange device equipment may be of a regenerative type. An example of the latter heat exchange device equipment is a commercially available Ljungström® heat

exchanger which comprises a shaft connected to a rotor with heat transfer plates.

In the present invention, alternatively or additionally, the oxygen containing stream which is contacted with the fuel gas, may be pre-heated through direct heat exchange between the oxygen containing stream and flue gas from the convection section by mixing these outside the cracker furnace prior to introduction into (a burner in) the radiant section. The above-described indirect and direct heat exchange between convection section flue gas and an oxygen containing stream are both technically feasible and the selection choice may depend on furnace design geometry, available plot space and utility connection locations, which may be optimized during detailed design.

Further, in the present invention, an oxygen containing stream, which may have been pre-heated, may be mixed with another oxygen containing stream having a different temperature, before contacting with the fuel gas. Said other oxygen containing stream may have a higher temperature, such as an exhaust gas stream from a gas turbine used for power generation which stream may still contain around 15 vol.% of oxygen as further described above. In the latter case, there is question of a direct heat exchange to increase the temperature of the oxygen containing stream to be contacted with the fuel gas. Alternatively, said other oxygen containing stream may have a lower temperature, thereby reducing the temperature of the combined oxygen containing stream to be contacted with the fuel gas. Such other oxygen containing stream having a lower temperature is preferably an oxygen-enriched stream containing oxygen in an amount greater than 21 vol.%.

Further, in the present invention, the pre-heated oxygen containing stream is then contacted with the fuel gas in a

burner in the radiant section. Said fuel gas may comprise hydrogen and methane, in specific hydrogen and methane originating from the olefins containing effluent from the radiant section of the cracker furnace. Further, hydrogen may
5 be used as the only fuel gas. For example, said fuel gas may comprise at most 99.9 vol.% of hydrogen. In the latter case, the fuel gas may comprise hydrogen originating from the above-mentioned olefins containing effluent and/or hydrogen that is generated elsewhere.

10 In the case of hydrogen as fuel gas, there is no carbon-based fuel gas component involved in a direct sense, so that reduction of the formation of carbon dioxide from such carbon-based fuel gas component cannot be achieved. However, advantageously, the present invention does result in lowering
15 the demand of such hydrogen fuel which would be sourced from relatively expensive on-purpose generation through renewable power electrolysis (so-called "green" hydrogen), or steam methane reforming in combination with Carbon Capture and Use (CCU) or Carbon Capture and Sequestration (CCS) (so-called
20 "blue" hydrogen), or other forms of hydrogen produced external to the cracker furnace which production may involve the formation of carbon dioxide and which hydrogen may be relatively expensive. Thus, in specific, in a case wherein the fuel gas comprises hydrogen which does not originate from
25 the cracker furnace effluent but from another source, the reduced fuel gas consumption advantageously results in that less of such hydrogen may be needed so that accordingly less external hydrogen production may be needed which production may also involve the formation of carbon dioxide and/or may
30 require the use of renewable, non-fossil energy resources which may be limited available (and hence relatively expensive).

An additional advantage of pre-heating the feed stream containing hydrocarbons outside the cracker furnace, in accordance with the present invention, is that heat exchangers outside the furnace are easier to clean than the convection section banks within the furnace itself. In addition, outside the furnace, heat exchangers can be placed in parallel which allows for some fouling to take place because one of the heat exchangers may be taken out of service for cleaning. Such parallel placement of convection section banks within the furnace itself is usually not possible or complicated. As a consequence, regarding pre-heating in the convection section of the cracker, one needs to be stringent on hydrocarbon feed related fouling risk. In the present invention, said risk is less important.

Yet another advantage of the present invention is that it allows a cracker furnace design which can be applied generically to a wider variation of hydrocarbon feedstocks ranging from ethane to heavy liquid feeds, as compared to conventional cracker furnaces of which its design may be feed-specific to ethane, propane, butane, mixed LPG, naphtha, condensate or a heavier liquid feed. By placing the pre-heating, which may also include vaporization, of the feed stream containing hydrocarbons outside the cracker furnace, as in the present invention, that furnace may be designed in a more generic way accommodating different types of hydrocarbon feedstocks.

The stream that is fed to the present process for producing olefins is a stream containing hydrocarbons. Said feed stream contains saturated hydrocarbons. In addition, it may contain unsaturated hydrocarbons. Further, before said feed stream is subjected to the present process, it may be gaseous or may be in liquid form. In specific, said feed stream may comprise one or more of ethane, propane, butane,

liquefied petroleum gas (LPG), naphtha, hydrowax and recycled waste plastics oil.

The cracking may be performed in any known way. The cracking is performed at an elevated temperature, preferably
5 in the range of from 650 to 1000 °C, more preferably of from 700 to 900 °C, most preferably of from 750 to 850 °C. Steam is usually added to the cracking zone (which is also referred to as "steam cracking"), acting as a diluent to reduce the hydrocarbon partial pressure and thereby enhance the olefin
10 yield. Steam also reduces the formation and deposition of carbonaceous material or coke in the cracking zone. The cracking occurs in the absence of oxygen. The residence time at the cracking conditions is very short, suitably of from 0.05 to 0.8 second, more suitably of from 0.10 to 0.6 second.

15 From the cracker, a cracker effluent is obtained that may comprise aromatics (as produced in the cracking process) which may include one or more of benzene, toluene and xylene, and that comprises olefins which may include one or more of ethylene, propylene, butylenes and butadiene, and hydrogen,
20 water and carbon dioxide. The specific products obtained depend on the composition of the feed, the hydrocarbon-to-steam ratio, the cracking temperature and the furnace residence time. The cracked products from the cracker are then passed through a system comprising one or more indirect
25 heat exchangers, such system often referred to as a TLE ("transfer line exchanger"). If a TLE comprises multiple heat exchangers, they can be arranged in parallel and/or in series. Further, if multiple TLEs are used, they can be arranged in parallel and/or in series, preferably in series.
30 By said TLEs, the temperature of the cracked products is reduced. In this way, the composition of the process gas may be rapidly frozen. The TLEs preferably cool the cracked products by reducing the temperature at the outlet of the TLE

or the final TLE to a temperature in the range of from 150 to 700 °C.

In the present invention, the above-mentioned cooling of the cracker process effluent in a TLE, downstream of the outlet of the cracker furnace, may be carried out in two or more stages, using two or more TLEs arranged in series.

In one preferred embodiment wherein two or more TLEs arranged in series are used, in a first stage, pressurized steam is generated from water, which may also be referred to as "boiler feed water" (BFW) or "utility water" as mentioned above, by indirect exchange with the cracker effluent in a first TLE. As compared to a case wherein only 1 TLE is used to cool the effluent, in the above case the first TLE reduces the effluent temperature to a higher temperature which may be at least 220 °C or at least 260 °C and which may be at most 700 °C or at most 650 °C. Then in a next stage, at least a portion of the cracker effluent coming from the first TLE is sent to a next TLE arranged in series wherein at least a portion of the feed stream containing hydrocarbons is pre-heated, i.e. outside the cracker furnace which is in accordance with the present invention, by indirect heat exchange with said effluent from the first TLE. This advantageously results in a further reduction of fuel gas consumption in the cracker furnace.

Optionally, in another embodiment wherein two or more TLEs arranged in series are used, in a first TLE at least a portion of the feed stream containing hydrocarbons is pre-heated and in the next TLE pressurized steam is generated from water (i.e. from utility or boiler feed water), that is to say in the reversed order as in the above-mentioned preferred embodiment. In this optional embodiment, the steam generated in the second TLE may be saturated or unsaturated steam.

WO2018229267 and US4479869 describe the use of secondary TLEs in conventional steam crackers.

Optionally, in the present invention, in addition to pre-heating the feed stream containing hydrocarbons outside the cracker furnace, above-mentioned utility water may also be pre-heated outside the cracker furnace before pressurized steam is generated therefrom as described above. Such pre-heating of utility water may be carried out by an indirect heat exchange with one or more of the above-mentioned heat sources for pre-heating the feed stream containing hydrocarbons, such heat sources including "VHP", "HP", "MP" and "LP" steam. The pre-heated utility water may then be sent to a bank in the convection section of the cracker furnace, in which bank (often referred to as an "economiser" bank) an indirect heat exchange with the flue gas originating from the radiant section takes place. Advantageously, since the water fed to said "economiser" bank has already been pre-heated, less heat is extracted from flue gas in the convection section, resulting more heat further available to pre-heat combustion air and a further reduced fuel gas consumption.

The further heated water resulting from above-mentioned "economiser" bank may then be sent to a steam drum outside the cracker furnace and then to a TLE wherein indirect heat exchange with process effluent from the radiant section of the cracker furnace takes place. The resulting steam may then be sent to another bank in the convection section of the cracker furnace, which is positioned below the above-mentioned "economiser" bank, in which other bank (often referred to as a "steam superheat" or "SSH" bank) an indirect heat exchange with the flue gas originating from the radiant section takes place, which may result in superheated steam wherein substantially all of the water is in gaseous form.

The latter superheated steam is suitable as feed to a steam turbine.

Optionally, in the present invention, the fuel gas may be pre-heated before introduction into a burner in the radiant
5 section and before contacting with the pre-heated oxygen containing stream therein. Such fuel gas pre-heating may be achieved by indirect heat exchange outside the cracker furnace between flue gas from the convection section and the
10 fuel gas, or by indirect heat exchange inside the cracker furnace between flue gas in the convection section and the fuel gas.

The invention is further illustrated by the following Examples.

Examples

15 1. Definitions and procedure

In Table 1 below, a number of acronyms, abbreviations and terms used in the Reference Example (not according to the

invention) and Example A (according to the invention) is further described.

Table 1

BFW	Boiler Feed Water
APH-1 bank	Air Pre-Heat bank
APH-2 bank	Air Pre-Heat bank
DSSH bank	Dilution Steam Super-Heat bank
ECO bank	Economiser bank
HTC-2 bank	High Temperature Mixed Pre-Heat bank
HTC-3 bank	High Temperature Mixed Pre-Heat bank
LFPH bank	Lower Feed hydrocarbon Pre-Heat bank
MPH/HTC-1 bank	Mixed Pre-Heat bank
HPSS bank	High-Pressure Steam Superheat bank
TLE	Transfer Line Exchanger
UFPH bank	Upper Feed hydrocarbon Pre-Heat bank

5 In section 2 below, the Reference Example is described.
In section 3 below, Example A is described and compared with
the Reference Example. All of said Examples concern a process
for producing olefins from a feed stream containing saturated
hydrocarbons by pyrolytic cracking of the hydrocarbons in a
10 steam cracker furnace.

 In these Examples, the total duty to be provided by fuel
gas fed to the steam cracker furnace comprising a convection
section and a radiant section for pyrolytic cracking of the
hydrocarbons from above-mentioned feed stream, can be
15 calculated using commercially available KTI/Technip Energies
EFPS (Ethylene furnace program sets containing embedded
SpyroSuite® for reaction kinetics), which is a globally
accepted steam cracker furnace modelling and design software
tool. In these calculations, a number of cracking furnace
20 parameters was kept constant, including (but not limited to):
(i) the duty of the radiant section required for above-

mentioned pyrolytic cracking; (ii) the ratio of dilution steam to feed (i.e. hydrocarbons) in the radiant section; (iii) same air feed rate and same hydrocarbons feed rate; (iv) same temperature of (exhaust) flue gas in the stack of the convection section.

2. Reference Example

In the Reference Example (not according to the present invention), the set-up as shown in Figure 1 is applied in a process for producing olefins from a feed stream containing saturated hydrocarbons by pyrolytic cracking of the hydrocarbons in a steam cracker furnace, as further described below and in Tables 2-3.

Figure 1 shows a steam cracker furnace 1 comprising a convection section 2 and a radiant section 3, wherein convection section 2 comprises eight banks 4 to 11.

A feed stream 12a containing saturated hydrocarbons, said stream having a pressure of 10 bara and a temperature of 66 °C, is sent to an UFPH bank 4 wherein it is heated by indirect heat exchange with flue gas originating from radiant section 3, said flue gas having an inlet temperature of 140 °C and an outlet temperature of 100 °C. In this context, by "inlet" an inlet to the UFPH bank 4 is meant and by "outlet" an outlet from the UFPH bank 4 is meant.

The stream 12b exiting UFPH bank 4 is partially vaporized and is mixed with a 1st portion of superheated dilution steam (not shown in Figure 1) which dilution steam is supplied in to DSSH bank 9 (from an upstream dilution steam generator outside furnace battery limit (not shown in Figure 1) and is superheated by indirect heat exchange with flue gas having an inlet temperature of 955 °C and an outlet temperature of 860 °C) and which dilution steam has a pressure of about 5 to 6 barg and a temperature of about 700 °C, and sent to an LFPH bank 6 wherein it is further heated by indirect heat exchange

with flue gas having an inlet temperature of 360 °C and an outlet temperature of 250 °C. The stream 12c exiting LFPH bank 6 is fully vaporized and has a temperature of 300 °C.

Stream 12c is then mixed with a 2nd portion of
5 superheated dilution steam (not shown in Figure 1) from DSSH bank 9, and sent to MPH (or HTC-1) bank 7 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 630 °C and an outlet temperature of 360 °C. The stream 12d exiting MPH bank 7 is then sent to
10 HTC-2 bank 10 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 1025 °C and an outlet temperature of 955 °C. The stream 12e exiting HTC-2 bank 10 is then sent to HTC-3 bank 11 wherein it is further heated by indirect heat exchange with flue gas having
15 an inlet temperature of 1165 °C and an outlet temperature of 1025 °C.

The stream 12f exiting HTC-3 bank 11 has a temperature of 600 °C and is sent to radiant section 3 which comprises multiple burners (not shown in Figure 1) wherein air (fed via
20 stream 13) and a fuel gas comprising methane and hydrogen (fed via stream 14) are contacted, and the fuel gas is combusted resulting in the release of above-mentioned flue gas into radiant section 3. The air fed to said burners via stream 13 has a temperature of 27 °C. The temperature of the
25 flue gas leaving radiant section 3 and entering convection section 2 is 1165 °C. In radiant section 3, stream 12f is further heated to a temperature of 810 °C. At said temperature, saturated hydrocarbons from stream 12f are pyrolytically cracked and olefins are produced. The olefins
30 containing effluent which leaves radiant section 3 via stream 12g and which has a temperature of about 810 °C, is rapidly cooled in TLE 15 by indirect heat exchange as further described below. The cooled effluent in stream 12h having a

temperature of 450 to 500 °C is then sent to a work-up section (not shown in Figure 1) in which several products are separated from the effluent.

Further, BFW (utility water) having a pressure of 135
5 bara and a temperature of 117 °C is sent via stream 16a to an ECO bank 5 wherein it is heated and vaporised by indirect heat exchange with flue gas having an inlet temperature of 250 °C and an outlet temperature of 140 °C. The stream 16b exiting ECO bank 5 and having a temperature of 197°C is then
10 sent to a steam drum (not shown in Figure 1) and the steam from said steam drum is then sent to TLE 15 (the steam drum being thermally coupled to the TLE through a thermosyphon) wherein it is further heated by indirect heat exchange with above-mentioned effluent in stream 12g, resulting in a stream
15 16c containing superheated steam having a pressure of 115 bara and a temperature of 327 °C.

Stream 16c is then sent to HPSS bank 8 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 860 °C and an outlet temperature of
20 630 °C. Superheated steam having a temperature of 525 °C in the stream 16d exiting HPSS bank 8 is then used as feed to a steam turbine 17. In steam turbine 17, the steam is expanded in various stages, as represented by 17a, 17b, 17c and 17d in Figure 1, wherein HP steam (40 bara; 350 °C), MP steam (19
25 bara; 260 °C), LP steam (7 bara; 170 °C) and sub atmospheric steam (0.08 bara; 41 °C), respectively, are generated. By such steam expansion, power 18 is generated to drive compressors in above-mentioned work-up section.

The HP steam from HP stage 17a is sent completely to MP
30 stage 17b, and the MP steam from MP stage 17b is sent completely to LP stage 17c. The LP steam from LP stage 17c is split, and one portion in stream 16e is extracted from steam turbine 17 and another portion is sent to the final stage 17d

from which above-mentioned sub atmospheric steam is extracted into stream 16f which is sent to a steam turbine exhaust condenser 19. In condenser 19, stream 16f is cooled and condensed resulting in a stream 16g containing condensed
5 water and having a pressure of 0.1 bara and a temperature of 52 °C. Cooling water having ambient temperature 34 °C is provided to condenser 19 via stream 19a and warm cooling water is removed therefrom via stream 19b which may have to be discharged into the environment.

10 Streams 16e and 16g are combined and air is removed therefrom (not shown in Figure 1) and the resulting water stream having a pressure of 5 bara and a temperature of 115 °C is pressurized to a pressure of 135 bara and sent as BFW (utility water) in stream 16a having a temperature of 117 °C
15 to convection section 2 of cracker furnace 1, as described above.

3. Example A

In Example A (according to the present invention), the procedure of the Reference Example is followed except that
20 the set-up as shown in Figure 2 is applied as further described below and in Table 2, wherein the differences between Example A and the Reference Example are as follows.

An air stream 13a having a temperature of 27 °C is sent to an APH-1 bank 4 wherein it is pre-heated by indirect heat
25 exchange with flue gas originating from radiant section 3, said flue gas having an inlet temperature of 210 °C and an outlet temperature of 100 °C.

The air stream 13b exiting APH-1 bank 4, and having a temperature of about 150 °C, is sent to an APH-2 bank 6
30 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 305 °C and an outlet temperature of 270 °C. The stream 13c exiting APH-2 bank 6,

and having a temperature of 200 °C, is fed to the burners as comprised in radiant section 3.

A pre-heated feed stream 12a containing saturated hydrocarbons, said stream having a pressure of 10 bara and a
5 temperature of 66 °C, is sent to an "feed heating in a conventional TEMA heat exchangers where it is preheated to 192 °C, and then sent to a UFPH bank 5 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 270 °C and an outlet temperature of 210
10 °C.

The stream 12b exiting UFPH bank 5 is partially vaporized and is mixed with a 1st portion of superheated dilution steam generated in DSSH bank 9 (from a water feed stream and by indirect heat exchange with flue gas having an inlet
15 temperature of 915 °C and an outlet temperature of 800 °C) and which dilution steam has a pressure of 5 to 6 Bara and a temperature of 700 °C and sent to an MPH (or HTC-1) bank 7 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 500 °C and an outlet
20 temperature of 300 °C. The stream 12c exiting MPH bank 7 is fully vaporized and has a temperature of about 410 °C.

Stream 12c is then mixed with a 2nd portion of superheated dilution steam from DSSH bank 9, and sent to HTC-2 bank 10 wherein it is further heated by indirect heat
25 exchange with flue gas having an inlet temperature of 1000 °C and an outlet temperature of 915 °C. The stream 12d exiting HTC-2 bank 10 is then sent to HTC-3 bank 11 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 1160 °C and an outlet temperature of
30 1000 °C.

The stream 12e exiting HTC-3 bank 11 has a temperature of 625 °C and is sent to radiant section 3. The temperature of the flue gas leaving radiant section 3 and entering

convection section 2 is 1160 °C. In radiant section 3, stream 12e is further heated to a temperature of 810°C. The olefins containing effluent in stream 12f has a temperature of about 803 °C and is rapidly cooled in TLE 15 by indirect heat exchange as further described below. The cooled effluent in stream 12g having a temperature of about 450 to 500 °C is then sent to the work-up section.

Further, pre-heated BFW (utility water) having a pressure of 135 bara and a temperature of 250 °C is sent via stream 16a to the steam drum and the saturated BFW from said steam drum is then sent to TLE 15 wherein it is further heated by indirect heat exchange with above-mentioned effluent in stream 12f, resulting in a stream 16b containing superheated steam having a pressure of about 115 bara and a temperature of 327 °C.

Stream 16b is then sent to HPSS bank 8 wherein it is further heated by indirect heat exchange with flue gas having an inlet temperature of 800 °C and an outlet temperature of 500 °C. Superheated steam having a temperature of 525 °C in the stream 16c exiting HPSS bank 8 is then used as feed to steam turbine 17.

The HP steam from HP stage 17a (of steam turbine 17) is split, and one portion in stream 16d1 is extracted from steam turbine 17 and another portion in stream 16d2 is sent to MP stage 17b. The MP steam from MP stage 17b is also split, and one portion in stream 16e1 is extracted from steam turbine 17 and another portion in stream 16e2 is sent to LP stage 17c. Stream 16e1 is further split into streams 16e1a and 16e1b. Further, stream 16f is further split into streams 16f1 and 16f2. The LP steam from LP stage 17c is also split, and one portion in stream 16f is extracted from steam turbine 17 and another portion is sent to the final stage 17d from which the sub-atmospheric steam is extracted into stream 16g which is

sent to steam turbine exhaust condenser 19. In condenser 19, stream 16g is cooled and condensed resulting in a stream 16h containing condensed water and having a pressure of 0.1 bara and a temperature of 52 °C.

5 Streams 16f1 and 16h are combined and air is removed therefrom and the resulting water stream having a pressure of 5 bara and a temperature of 115 °C is pressurized to a pressure of 135 bara and sent as BFW (utility water) in stream 16i having a temperature of 117°C to a 1st heat
10 exchanger 20 wherein it is pre-heated by indirect heat exchange with MP steam from stream 16e1a, resulting in BFW stream 16j having a temperature of 205 °C. BFW stream 16j is then sent to a 2nd heat exchanger 21 wherein it is further heated by indirect heat exchange with HP steam from stream
15 16d1, resulting in BFW stream 16a having a temperature of 250 °C which is sent to TLE 15, as described above. The heat exchangers 20-23 outside of the cracker furnace can be conventional TEMA (Tubular Exchanger Manufacturers Association) classified heat exchangers, or alternative non-
20 tubular technology as for example plate and frame type.

A feed stream 12' containing saturated hydrocarbons, said stream having a pressure of 10 bara and a temperature of 66 °C, is sent to a 1st heat exchanger 22 wherein it is pre-heated by indirect heat exchange with LP steam from stream
25 16f2, resulting in stream 12'' having a temperature of 156 °C. Stream 12'' is then sent to a 2nd heat exchanger 23 wherein it is further heated by indirect heat exchange with MP steam from stream 16e1b, resulting in stream 12a having a

temperature of 192 °C which is sent to convection section 2 of cracker furnace 1, as described above.

The heat-exchanged streams resulting from streams 16d1, 16ela, 16elb and 16f2 are combined with streams 16f1 and 16h
5 before air is removed therefrom (now shown in Figure 2).

In Table 2 below, Example A and the Reference Example are compared in terms of energy savings.

Table 2 – Reference Example and Example A

Cracking furnace parameters	Ref	A
Temperature (°C) flue gas in stack 2a	100	100
Temperature (°C) BFW in stream 16a (Ref. Ex.) or 16i (Ex. A)	117	117
Temperature (°C) BFW in stream 16b (Ref. Ex.) or 16a (Ex. A) to TLE 15	197	250
Duty (MW) heating BFW upstream of TLE 15, i.e. duty ECO bank 5 (Ref. Ex.) and combined duty heat exchangers 20 and 21 (Ex. A)	4.4	5.5
Temperature (°C) air in stream 13 (Ref. Ex.) or 13a (Ex. A)	27	27
Temperature (°C) air fed in stream 13 (Ref. Ex.) or 13c (Ex. A) to burners in radiant section 3	27	200
Temperature (°C) hydrocarbon feed in stream 12a (Ref. Ex.) or 12' (Ex. A)	66	66
Temperature (°C) hydrocarbon feed fed in stream 12a (Ref. Ex. and Ex. A) to convection section 2	66	192
Feed rate (10 ³ kg/hr) hydrocarbons in stream 12a (Ref. Ex. and Ex. A)	49.0	49.0
Feed rate (10 ³ kg/hr) hydrocarbons + 1 st portion of dilution steam	53.9	53.9
Feed rate (10 ³ kg/hr) hydrocarbons + 2 nd portion of dilution steam	68.6	68.6
BFW flow rate (10 ³ kg/hr)	45.5	51.5

Cracking furnace parameters	Ref	A
Duty (MW) heating hydrocarbon feed in convection section 2 upstream of MPH (or HTC-1) bank 7, i.e. combined duty UFPH bank 4 and LFPH bank 6 (Ref. Ex.) or duty UFPH bank 5 (Ex. A)	6.15	2
Duty (MW) heating hydrocarbon feed upstream of convection section 2, i.e. combined duty heat exchangers 22 and 23 (Ex. A)	0	4.05
Combined duty (MW) MPH (or HTC-1) bank 7, HTC-2 bank 10 and HTC-2 bank 11 (Ref. Ex. and Ex. A)	22.2	17.3
Duty (MW) DSSH bank 9 (Ref. Ex. and Ex. A)	4.6	4.6
Duty (MW) HPSS bank 8 (Ref. Ex. and Ex. A)	10.8	11.7
Combined duty (MW) APH-1 bank 4 and APH-2 bank 6	0	5
Duty (MW) TLE 15	22.6	22.5
Duty (MW) convection section 2, i.e. combined duty banks 4-11	48.15	40.6
Duty (MW) radiant section 3	33.85	33.85
Flow rate (tonne/hr) superheated steam in stream 16d (Ref. Ex.) or 16c (Ex. A) to steam turbine 17.	45	51
Flow rate (tonne/hr) condensed water in (exhaust) stream 16g (Ref. Ex.) or 16h (Ex. A) from steam turbine 17	45	30
Reduction in flow rate condensed water in exhaust stream from steam turbine		33.3%
Total duty (MW) to be provided by fuel gas, i.e. combined duty convection section 2 and radiant section 3	86.8	72.7
Reduction in amount of fuel gas needed		16.2%
Turbine condenser duty loss to stream 19b (MW)	25.6	17.0

Cracking furnace parameters	Ref	A
Reduction in turbine condenser duty loss		33.6%
Turbine shaft power delivered (MW)	13.5	11.5
Reduction in turbine shaft power delivered		14.8%

Upon comparing the total required fuel gas duties for the steam cracker furnace between the Reference Example and Example A in Table 2 above, it can be seen that in Example A, wherein in accordance with the present invention (i) the hydrocarbons feed stream is pre-heated outside the cracker furnace (in specific, in heat exchangers 22 and 23 in Fig. 2), i.e. before entering the convection section of the cracker furnace, and (ii) the air feed stream is pre-heated (in specific, in APH-1 bank 4 and APH-2 bank 6 in Fig. 2), i.e. before entering burners in the radiant section of the cracker furnace, surprisingly and advantageously, the total fuel gas duty required to produce the same amount of the same chemicals (including olefins) from the same amount of the same saturated hydrocarbons in the feed, in Example A is reduced as compared to the Reference Example. Accordingly, the amount of fuel gas needed is likewise reduced in Example A to the same extent as compared to the Reference Example.

Further, advantageously, the above-mentioned comparison has shown that in addition to above-mentioned pre-heating of the hydrocarbons feed stream outside the cracker furnace and pre-heating the air feed stream, also pre-heating the utility water outside the cracker furnace (in specific, pre-heating BFW in heat exchangers 20 and 21 in Fig. 2) before pressurized steam is generated therefrom (in specific, in TLE 15 in Fig. 2), even further reduces above-mentioned total required fuel gas duty and accordingly amount of fuel gas

needed, by a total reduction percentage of 16.2% (see Table 2 above).

Still further, advantageously, the above-mentioned comparison has shown that not only the total required fuel gas duty is reduced by the present invention, thereby reducing the amount of fuel gas needed and also reducing the amount of carbon dioxide emitted into the atmosphere e.g. in case such fuel gas comprises methane, but simultaneously the amount of warm cooling water (in specific, in stream 19b in Fig. 2) produced by cooling the sub-atmospheric steam in the exhaust stream (in specific, stream 16g in Fig. 2) from the steam turbine coupled to the steam cracker furnace, wherein pressurized steam (utility water) from the steam cracker furnace is used to provide power through expansion of that steam, is also reduced so that the amount of warm cooling water that may have to be cooled in cooling towers is likewise reduced, because part of the expanded steam is extracted from the steam turbine in order to provide a heat source for above-mentioned pre-heating of the hydrocarbons feed stream and utility water outside the cracker furnace. The reduction in the amount of warm cooling water (in specific, in stream 19b in Fig. 2) is substantial as indicated by the 33.3% reduction in the flow rate of condensed water in the exhaust stream from the steam turbine (see Table 2 above). Indeed, as is also shown in Table 2 above, less power is delivered in Example A as compared to the Reference Example, because in Example A, a relatively large part of the steam is not used to provide turbine shaft power, but to pre-heat furnace hydrocarbons feed and utility water. However, this loss in power provided by the steam turbine is, surprisingly and advantageously, only relatively small (i.e. 14.8% less; see Table 2 above). Furthermore, such relatively small power loss can easily be compensated for by

also using an electrically driven motor (so-called "e-motor") wherein the electrical power may be provided by renewable, non-fossil energy resources, in addition to above-mentioned steam turbine.

C L A I M S

1. A process for producing olefins from a feed stream containing hydrocarbons by pyrolytic cracking of the hydrocarbons in a cracker furnace, said process comprising:
 - pre-heating the feed stream outside the cracker furnace;
 - 5 feeding the pre-heated feed stream to a tube in the convection section of the cracker furnace;
 - further pre-heating the feed stream in the convection section;
 - feeding the further pre-heated feed stream to a tube in
 - 10 the radiant section of the cracker furnace;
 - pre-heating an oxygen containing stream;
 - contacting the pre-heated oxygen containing stream with a fuel gas in a burner in the radiant section; and
 - pyrolytic cracking the feed stream in the radiant section
 - 15 resulting in an effluent containing olefins.
2. The process according to claim 1, wherein the feed stream containing hydrocarbons is pre-heated outside the cracker furnace to a temperature which is at least 75 °C, preferably
- 20 at least 150 °C, and which is at most 550 °C, preferably at most 450 °C.
3. The process according to claim 1 or 2, wherein one or more of the following heat sources is or are used in pre-heating
- 25 the feed stream containing hydrocarbons outside the cracker furnace through indirect heat exchange between the feed stream and such heat source or heat sources: (i) very high pressure steam having a pressure of from greater than 70 bara to 130 bara; (ii) high pressure steam having a pressure of
- 30 from greater than 30 bara to 70 bara; (iii) medium pressure steam having a pressure of from greater than 10 bara to 30

bara; (iv) low pressure steam having a pressure of from greater than atmospheric pressure to 10 bara; and (v) another heat source having a temperature of from greater than 50 °C to 100 °C.

5

4. The process according to claim 1 or 2, wherein the olefins-containing effluent from the radiant section is used to provide pressurized steam through indirect heat exchange, in a first transfer line exchanger, between said effluent
10 from the radiant section and utility water, and at least a portion of the cracker effluent coming from the first transfer line exchanger is sent to a next transfer line exchanger arranged in series wherein at least a portion of the feed stream containing hydrocarbons is pre-heated by
15 indirect heat exchange with said effluent from the first transfer line exchanger, and wherein a transfer line exchanger is a system which comprises one or more indirect heat exchangers.

20 5. The process according to any one of claims 1 to 4, further comprising:

pre-heating utility water outside the cracker furnace;
and

generating pressurized steam from the pre-heated utility
25 water through indirect heat exchange with effluent from the radiant section.

6. The process according to any one of claims 1 to 5, wherein the oxygen containing stream is pre-heated to a
30 temperature which is at least 70 °C, preferably at least 100 °C, and which is at most 550 °C, preferably at most 400 °C.

7. The process according to any one of claims 1 to 6,
wherein the oxygen containing stream is pre-heated inside the
cracker furnace through indirect heat exchange between the
oxygen containing stream and flue gas in the convection
5 section.

8. The process according to any one of claims 1 to 7,
wherein the feed stream containing hydrocarbons is not pre-
heated in the convection section of the cracker furnace
10 before pre-heating the feed stream outside the cracker
furnace.