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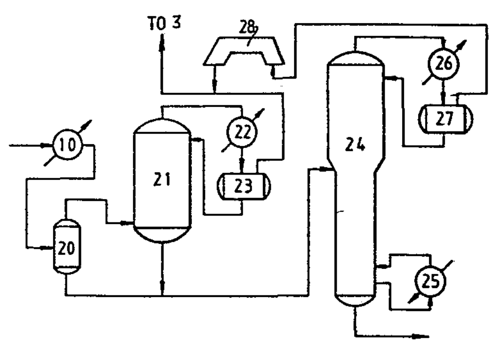
(54) A method of separating light ends from a mixed hydrocarbon feed, and apparatus for carrying out the method.

(57) Fouling during separation of light ends from a mixed hydrocarbon feed in a fractionating tower, particularly in the depropanizer in ethylene separation from steam cracked naphtha, is reduced by fractionating the vapour portion of the feed in a first tower (21) before fractionating the liquid portion of the feed together with the bottoms from the first tower in a second tower (24) operating at a lower pressure than the first. The bottoms temperature of second fractionation is thereby reduced which reduces fouling. Energy consumption is reduced by decreased refrigeration and heating requirements.

FIG. 3.



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A METHOD OF SEPARATING LIGHT ENDS FROM A MIXED HYDROCARBON FEED, AND APPARATUS FOR CARRYING OUT THE METHOD

This invention relates to a method and apparatus for fractionating a hydrocarbon feed to remove light ends, and is particularly but not exclusively concerned with a fractionating method which has a reduced tendency for fouling the fractionation tower and which generally has a lower energy consumption than the conventional method.

It is desirable to run continuous fractionation processes for as long as possible between shut-downs. One major limitation on the length of time for which a fractionation can be run is the tendency of the fractionation tower to foul - that is, for unwanted deposits to accumulate in the tower, so making the fractionation less effective and increasing the energy consumed in the separation process. A principal cause of fouling in light ends fractionating towers is the formation therein of solid deposits which result from the polymerization of certain components contained in the feedstock which is delivered to the towers. This unwanted polymerization is generally caused by high bottoms temperatures in the tower. Thus, it is desirable to be able significantly to reduce the temperature in the tower, and hence to reduce the fouling.

Bottoms temperature can be reduced by lowering the pressure within the tower, but a significant lowering of tower pressure is required in order to achieve a significant temperature reduction. Any reduction in tower pressure reduces overhead temperature, which results in a greater energy expenditure for refrigeration. A large reduction in tower pressure may cause the tower to flood and become inoperative, i.e. the vapour expands and its velocity increases to a point where heavy ends are entrained and carried off overhead. Therefore, simply lowering tower pressure is not an acceptable solution to tower fouling.

One proposed modification ("Hydrocarbon Processing", 58(8), 1979, pp 101-7) for deethanizers which results in a reduced bottoms temperature comprises first passing the hydrocarbon feed to an absorber/stripper which separates the C_{2-} from the feed as overhead, with the bottoms being fed to the deethanizer. The deethanizer overhead is totally condensed and fed to the absorber-stripper as reflux. Although an energy saving is claimed for this scheme, the deethanizer feed must be free of hydrogen and methane so that the overhead can be totally condensed, and this requires a high bottoms temperature in the absorber/ stripper. If the need for high bottoms temperature in the absorber/stripper could be eliminated, additional energy could be saved. This modification is particularly unattractive when the major part of the feed is vapor. In this case, some of the feed to the first tower has to be condensed so that enough reflux can be provided to the first tower by the second.

It has now been found that an energy efficient fractionation of hydrocarbon feeds may be achieved at a reduced bottoms temperature in the tower by first removing the major part of the lighter materials from only the vapour portion of the feed, in a first, relatively "coarse" fractionation. Thus, according to one aspect of the invention there is provided a method of separating light ends from a mixed hydrocarbon feed comprising liquid and vapour portions, in which method the vapour portion of the feed is fractionated in a first tower so as to provide the desired light ends cut as the vapour distillate thereof, and the bottoms of the first tower and the liquid portion of the feed are fractionated in a second tower operating at a lower pressure than the first to provide a further amount of the desired light ends cut as the vapour distillate.

In one particular embodiment there is provided a method of separating C_{3-} materials from a steam cracked naphtha in the production of ethylene characterised in that the steam cracked naphtha feed is depropanized by delivering the vapour portion of the feed to a first tower to give a vapour distillate containing the majority of the C_{3-} materials from the feed, combining the bottoms of the first tower and the liquid from the feed, fractionating the combined bottoms and liquid in a second tower operating at a lower pressure than the first tower to separate the remaining C_{3-} materials as the vapour distillate of the second tower, compressing the vapour distillate from the second tower and combining it with the vapour distillate from the first tower to form a feed for the subsequent stages of ethylene recovery.

According to another aspect of the invention there is provided apparatus for separating light ends from a mixed hydrocarbon feed containing liquid and vapour portions by fractionation to obtain a light end cut and bottoms, which apparatus comprises.

(a) means for separating the feed into its respective liquid and vapour portions;

(b) a first tower operable at a first pressure for fractionating said vapour portion into the desired light end cut as vapour distillate, and bottoms;

(c) means for delivering said vapour portion from said separating means to said first tower;

(d) a second tower operable at a pressure which is lower than said first pressure for fractionating the bottoms of the first tower and the liquid portion of the feed to provide a further amount of the desired light end cut as vapour distillate; and

(e) means for delivering the bottoms of the first tower and the liquid portion of the feed to said second tower.

The method of the invention is generally applicable to mixed hydrocarbon feeds where it is desired to remove the light ends. The method has been found to have particular energy saving advantages in relation to a depropanizer, and will be described principally in that connection. However, it is to be understood that the method is of more general applicability: for example it may be used in deethanizers and debutanizers with considerable energy savings under certain preferred conditions discussed hereinafter.

The mixed hydrocarbon feed fractionated in accordance with the invention may be taken from a wide variety of products resulting from the steam cracking or catalytic cracking of the range of feedstocks from ethane and propane through to naphtha and gas oil. The method has particular application to the separation of steam cracked naphtha in the production of ethylene.

The feed to be treated in accordance with the method is in liquid and vapour portions. Separation into these portions may be achieved in a conventional separation apparatus such as a flash drum, with a preceding cooling stage if necessary.

The principle of the method is that by separating light materials (C_{3-} in the case of a depropanizing operation) from the vapour in the first tower, the loading on the second tower is reduced relative to that of the conventional single fractionation tower; thus the light material (e.g. hydrogen and methane) in the second tower is reduced, which means that the pressure therein may be reduced without flooding (due to gas expansion) and reduced overhead temperature becoming problems. Thus, in accordance with the invention, only the bottoms from the first tower and the liquid portion of the feed is fractionated in the second tower. The second tower produces a further amount of light materials as vapour distillate since not all of the desired light end cut is removed in the first tower (this light end cut being C_{3-} in the case of a depropanizer). Because of the lower pressure in the second tower the bottoms temperature is lower than in a conventional single tower so that hot water (condensate) may be used in the reboiler instead of steam (an expensive primary heat source), with savings in energy. Moveover, and importantly, the lower temperature means less polymerization and hence less fouling. Further energy savings may result from an increase in the overhead temperature of the second tower which may allow a higher temperature refrigerant to be used in the condenser and from the increase in efficiency due to a greater number of trays in two towers than one conventional tower.

In a preferred embodiment of the invention the first tower is operated at a pressure of from 150 to 180, say 165 psia; the bottoms temperatures may be, say 39°F, whilst the overheads temperature in the first tower may be from -30 to -15°F. The second tower preferably operates at a pressure of 150 psia or less, for example from 75 to 150 psia. It is preferred to operate the second tower at a bottoms temperature of up to 180°F (which is the temperature of the heating water in the reboiler), more preferably from 130 to 170°F, say 150°F. The overheads temperature in the second tower is preferably some 35 degrees F greater than in the first, say 5 to 20°F, for example 10°F.

The overheads from the first and second towers may be combined, but to do this the second tower distillate needs compression since the second tower operates at a lower pressure than the first. However, the overheads stream from the second tower is of relatively smaller volume than the higher pressure overheads from the first tower, so the additional energy required for this compression stage is minor.

In general, to achieve an energy saving over a conventional single tower fractionation in addition to the considerable advantage of reduced fouling, the method of the invention is advantageously applied to a system wherein the major portion of the desired light end (e.g. C_{3-}) is separated in the first tower; the overhead temperature of the first tower exceeds the refrigerant temperature used in the conventional system; and the overhead temperature of the second tower is increased, and/or the bottoms temperature is reduced.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:-

Figure 1 is a schematic flowsheet of a separation process in ethylene recovery, using a front-end depropanizer;

Figure 2 is a schematic diagram of a conventional depropanizer using a single fractionating tower; and

Figure 3 is a schematic diagram of a depropanizer circuit embodying the method of this invention.

In the separation process shown in Figure 1 a feedstock containing hydrogen and C_1 to C_{10} hydrocarbons is compressed at 1, to separate some C_5-C_{10} hydrocarbons. The remaining H_2-C_8 mixture is fed to depropanizer 2, which produces a H_2-C_3 mixture overhead which is fed to compression and acetylene conversion stage 3. The C_4-C_8 bottoms from depropanizer 2 is fed to debutanizer 4 and further separated into C_4 hydrocarbons (overhead) and C_5-C_8 (bottoms).

The product of stage 3 is chilled and demethanized at 5 to give an H_2/CH_4 mixture overhead and C_2/C_3 bottoms. The latter is then fed to deethanizer 6 where the C_3 hydrocarbons are removed as bottoms, and finally the C_2 hydrocarbons are separated in ethylene fractionator 7 to yield ethylene (C_2H_4) and ethane (C_2H_6).

A depropanizer such as is conventionally used in a circuit such as the one outlined above is shown in Figure 2. Thus conventionally the feed is chilled in a heat exchanger 10 using 4.5°C propylene before being fed to a single tower 11, in which it is fractionated to yield C_{3-} overhead and C_4+ bottoms. The overhead is passed to a heat exchanger 12 where it is condensed using -37.8°C propylene, and then fed to reflux drum 13, from which part is refluxed back to the tower and part is fed to the compression and acetylene conversion stage 3 (Figure 1). A steam heated reboiler 14 is provided to heat the feed and so produce the necessary vapour in the tower. Typically the depropanizer would have to be operated at a pressure in the range 9-13 bar, for example at 11.4 bar (11.6 x 10^4 kgm^{-2}, 165 psia) with a bottom temperature of 98°C.

The method of the invention utilizes the arrangement shown in Figure 3 in which the feed is again cooled in heat exchanger 10, but then separated into vapour and liquid components in a flash drum 20. The vapour, which may be for example some 90% of the total, is fed to a first tower 21 where it is separated into a C_{3-} overhead and bottoms containing C_2-C_4 with some H_2 and CH_4. The overhead is cooled in a heat exchanger 22 with -37.8°C propylene and fed to a reflux drum 23, from which some is refluxed through the first tower 21, and some is taken off to the compression and acetylene conversion stage 3 (Figure 1). The bottoms of the first tower 21 is combined with the liquid portion of the feed from flash drum 20 and fed to the second tower 24, in this embodiment a depropanizer, in which it is separated into C_{3-} overhead and C_{4+} bottoms. The second tower 24 typically operates at 6.7 kgm^{-2} (96 psia) with a bottoms temperature of 63°C, a considerably lower temperature resulting in considerably less fouling. The second tower 24 is provided with a reboiler 25 which need only be heated by hot water rather than steam because of the lower pressure and bottoms temperature at which the tower is operated. The overhead from tower 24 is cooled in a heat exchanger 26 using -18°C propylene and fed to a reflux drum 27 from which some is returned to the tower, and some is fed via a compressor 28 to the next stage 3 (Figure 1).

With specific reference to the arrangment described with regard to Figure 3, a considerable overall energy saving may be achieved over the conventional arrangement shown in

Figure 2, as well as a significant reduction in fouling. Thus the reduced bottoms temperature resulting from the lower pressure operation of the second tower (permitted by the at least partial removal of H_2 and CH_4 in the first tower) means less polymerisation and hence less fouling. Moreover, the tower operating temperature permits the use of a cheap secondary heat source (hot water) in the reboiler, rather than the hitherto necessary use of the expensive primary heat source, steam. Further the overhead from the second tower is condensed using higher temperature, and hence cheaper, propylene refrigeration. The reduced pressure of the overheads does, though, mean that compression is required before the overheads of the first and second towers can be combined.

CLAIMS

1. A method of separating light ends from a mixed hydrocarbon feed containing liquid and vapour portions by fractionation to obtain a light end cut and bottoms, characterised in that the vapour portion of the feed is fractionated in a first tower so as to provide the desired light end cut as the vapour distillate thereof, and the bottoms of the first tower and the liquid portion of the feed are fractionated in a second tower operating at a lower pressure than the first tower to provide a further amount of the desired light end cut as vapour distillate.

2. A method as claimed in claim 1 characterised in that the light end cut comprises C_3 hydrocarbons and lighter materials.

3. A method as claimed in claim 1 or 2 characterised that the mixed hydrocarbon feed is a steam cracked naphtha.

4. A method as claimed in claim 1, 2 or 3 characterised in that the vapour distillate of the second tower is combined with that of the first tower after being compressed to the same pressure as the vapour distillate of the first tower.

5. A method as claimed in any of the preceding claims characterised in that the first tower is operated at a pressure of from 150 to 180 psia.

6. A method as claimed in any of the preceding claims characterised in that the second tower is operated at a pressure of from 75 to 150 psia.

7. A method as claimed in any of the preceding claims characterised in that the vapour distillate temperature in the first tower is from -30°F to -15°F.

8. A method as claimed in any of the preceding claims characterised in that the vapour distillate temperature in the second tower is from 5 to 20°F.

9. A method of separating C_{3-} materials from a steam cracked naphtha in the production of ethylene characterised in that the steam cracked naphtha feed is depropanized by delivering the vapour portion of the feed to a first tower to give a vapour distillate containing the majority of the C_{3-} materials from the feed, combining the bottoms of the first tower and the liquid from the feed, fractionating the combined bottoms and liquid in a second tower operating at a lower pressure than the first tower to separate the remaining C_{3-} materials as the vapour distillate of

the second tower, compressing the vapour distillate from the second tower and combining it with the vapour distillate from the first tower to form a feed for the subsequent stages of ethylene recovery.

10. Apparatus for separating light ends from a mixed hydrocarbon feed containing liquid and vapour portions by fractionation to obtain a light end cut and bottoms, which apparatus comprises.

(a) means for separating the feed into its respective liquid and vapour portions;

(b) a first tower operable at a first pressure for fractionating said vapour portion into the desired light end cut as vapour distillate, and bottoms;

(c) means for delivering said vapour portion from said separating means to said first tower;

(d) a second tower operable at a pressure which is lower than said first pressure for fractionating the bottoms of the first tower and the liquid portion of the feed to provide a further amount of the desired light end cut as vapour distillate; and

(e) means for delivering the bottoms of the first tower and the liquid portion of the feed to said second tower.

FIG.1.

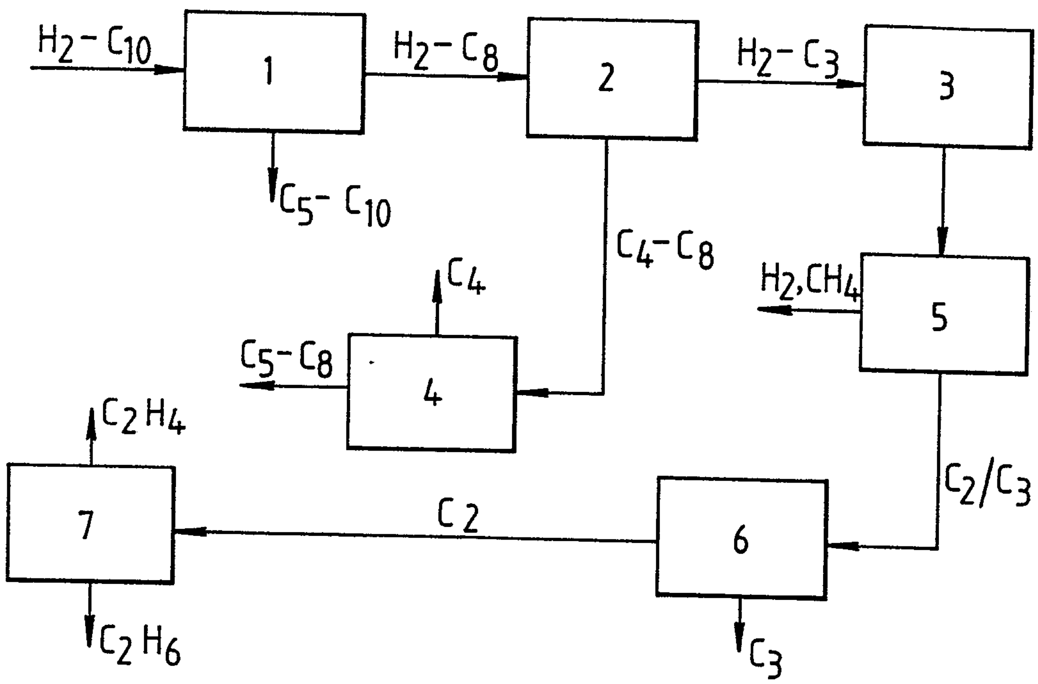
H2 - C10
1
H2 - C8
2
H2 - C3
3
C5 - C10
C4 - C8
C4
H2,CH4
5
C5 - C8
4
C2 H4
7
C 2
6
C2/C3
C2 H6
C3

FIG. 2.

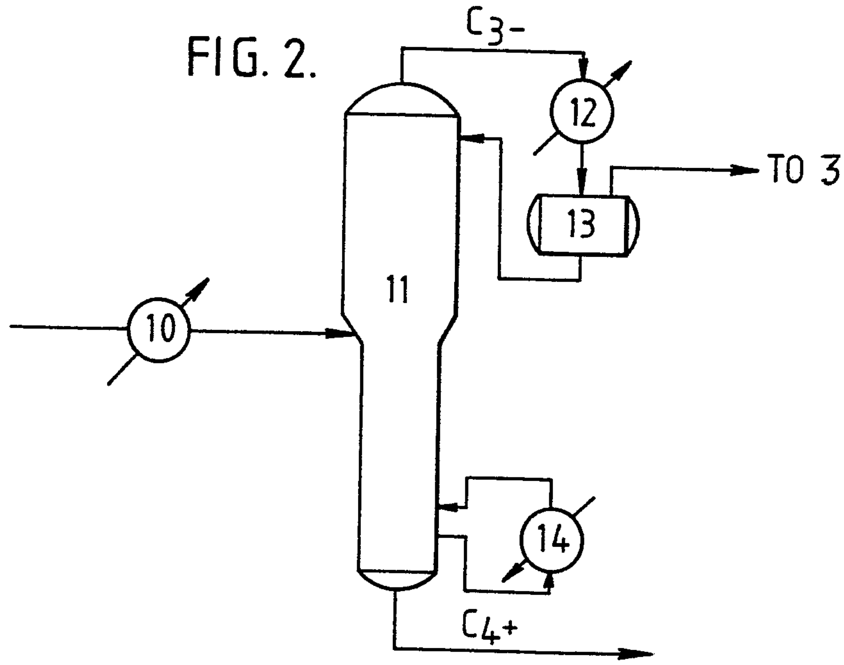
C3-
12
TO 3
13
11
10
14
C4+

FIG. 3.