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(54) Title: IMPROVED HEAT PUMP DISTILLATION FOR <50% LIGHT COMPONENT IN FEED

(57) Abstract: A process is presented for the separation of a hydrocarbon mixture having less than 50% of the light component in the feedstream. The process provides an energy efficiency through drawing off a vapor stream from the rectifying section of a distillation column, and using re-compression of the vapor to provide a portion of the heat for reboiling a portion of the bottoms stream exiting the stripping section of the distillation column.

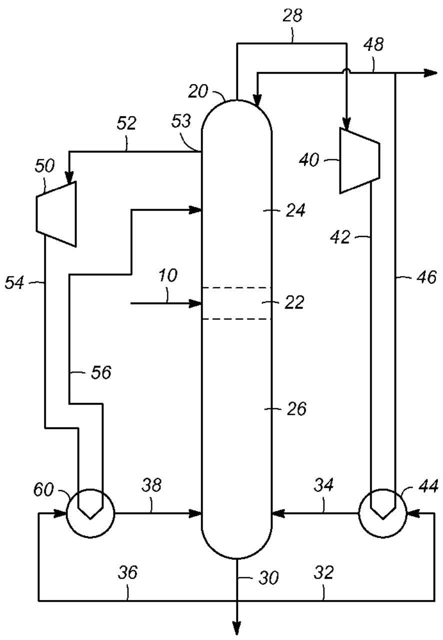

FIG. 1

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IMPROVED HEAT PUMP DISTILLATION FOR <50% LIGHT COMPONENT IN FEED

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application No. 61/359,869 filed on June 30, 2010.

FIELD OF THE INVENTION

[0002] The field of the invention relates to the separation of hydrocarbons. Specifically, the invention relates to improving the energy usage for the separation of hydrocarbon components that have similar boiling points through distillation.

BACKGROUND OF THE INVENTION

[0003] The separation of hydrocarbons is a basic process in the petroleum industry. Petroleum is a mixture of many hydrocarbon compounds and the compounds are separated and used for different purposes, such as fuel, lubricants, feedstock to polymer plants, etc. One method of separation in the petroleum industry is distillation. Distillation is a method of separation that is based on a difference in the relative volatilities of the components in a mixture, and therefore differences in the composition between a liquid mixture and a vapor formed from the liquid mixture. In a standard continuous distillation process involving multiple stages, the differences in composition allows for partial separation at each stage. The liquid and vapor phases are passed to different stages, and further produce new liquid and vapor phases in each having different compositions. The standard distillation system comprises a tall column wherein vapor flows upward and contacts a liquid flowing downward. The vapor phase is formed by adding substantial heat to boil, or vaporize, the liquid when it reaches the bottom of the column, and vapor is condensed when it leaves the top of the column. The process expends a lot of energy to continuously process a stream of hydrocarbons, and frequently, multiple columns are used to separate a feedstream into multiple product streams.

[0004] A problem exists for distillation systems in that they are large consumers of energy and inefficient with respect to energy usage and consumption. Improvements in design can significantly reduce energy consumption. With increasing energy costs and with increasing pressures to reduce CO_2 emissions associated with energy consumption, there is a compelling need for more efficient distillation designs.

SUMMARY OF THE INVENTION

[0005] Energy efficiency is important for processes that are energy intensive. The separation of hydrocarbon compounds with distillation is energy intensive, and with close boiling point components the amount of energy can be significant. The present invention provides for the separation of hydrocarbons that improves the energy efficiency. The invention is a process for the separation of a light component from a hydrocarbon mixture. A hydrocarbon feedstream is passed to a distillation column at a position between the rectifying section and the stripping section, and where the feedstream comprises a mixture that has less than 50% light components. The distillation column has an overhead vapor stream which is passed to a first heat pump compressor, creating a compressed overhead vapor stream. The compressed overhead vapor stream is passed to the vapor side of a first reboiler heat exchanger. The compressed overhead vapor stream is at least partially condensed. The distillation column has a bottoms stream, and a first portion of the bottoms stream is passed to the liquid side of the first reboiler heat exchanger, and at least partially vaporized. The vapor is returned to the distillation column. The invention further includes drawing off a side vapor stream from the rectifying section at a draw off port, thereby creating a side draw stream. The side draw stream is passed to a second heat pump compressor, creating a compressed side draw stream. The compressed side draw stream is passed to the vapor side of a second reboiler heat exchanger, creating a cooled side draw stream. A second portion of the bottoms stream is passed to the liquid side of the second reboiler heat exchanger, where the second portion is at least partially vaporized. The vapor from the second portion of the second heat exchanger is returned to the distillation column, and the cooled side draw stream is returned to the rectifying section of the distillation column.

[0006] In one embodiment, the side draw stream is taken from the lower half of the rectifying section of the distillation column.

[0007] Additional objects, embodiments and details of this invention can be obtained from the following drawing and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figure 1 is a schematic of the heat pump design for reducing energy requirements in the separation of close boiling point liquids;

[0009] Figure 2 shows the temperature gradient across the distillation column as a function of tray number;

[0010] Figure 3 shows the column grand composite curve for a propane-propylene splitter of temperature v. enthalpy; and

[0011] Figure 4 shows the column grand composite curve for a propane-propylene splitter of stage number v. enthalpy.

DETAILED DESCRIPTION OF THE INVENTION

[0012] One of the problems with the separation of hydrocarbon compounds is that compounds having close boiling points are highly energy intensive. Distillation is one of the most common methods for the separation of hydrocarbon liquids into separate components. This usually is for liquids having a more narrow composition, but is also used for producing relatively pure individual components. Distillation is also very energy intensive, and involves billions of dollars of fuel costs each year. Heat pumps, or mechanical vapor recompression, can be used to reduce these energy costs. Heat pumps make efficient use of energy through mechanical recompression of vapor, and the heat transfer of the energy in the vapor to another fluid. This is a means of transferring thermal energy from the compressed vapor to a liquid, wherein the liquid is boiled and the compressed vapor is partially or wholly condensed. This is particularly true for the separation of close boiling point components in a hydrocarbon mixture. Any improvements to reduce the energy intensity can significantly affect the economics of the production of many hydrocarbon compounds.

[0013] The present invention is aimed at the separation of a light component from a mixture of hydrocarbons. In the case where the feed comprises less than 50%, by weight, of light components, the overhead vapor stream can be used to transfer heat to the reboiler alone. However, by taking a side draw stream, there is a lower compression ratio, and therefore less mechanical energy to boost the side draw to the second reboiler temperature, thereby improving the efficiency of the column. The Figure 1 is illustrative of the new process. The process comprises passing a feedstream 10, having less than 50% light components, to a distillation column 20 at a position 22 between the rectifying section 24 and the stripping section 26. The distillation column generates an overhead vapor stream 28 and a bottoms liquid stream 30. The light components are the desired components that are separated from the hydrocarbon mixture that are recovered in the overhead vapor stream.

[0014] The overhead vapor stream 28 is passed to a first heat pump compressor 40, to create a compressed overhead vapor stream 42. The compressed overhead vapor stream is passed to the vapor side of a first reboiler heat exchanger 44, wherein the compressed overhead vapor stream is cooled and at least partially condensed 46. Preferably, the process is operated to completely condense the compressed overhead vapor stream. A portion of the condensed, compressed overhead vapor stream is passed back to the top of the rectifying section as reflux. A first portion of the bottoms liquid stream 32 is passed to the liquid side of the first reboiler heat exchanger 44. The first portion 32 is vaporized to a vapor stream 34 and passed back to the bottom of the stripping section 26 of the distillation column 20. A portion 48 of the condensed overhead stream 46 is passed to the top of the rectifying section 24 as reflux for the distillation process.

[0015] The process further includes drawing off a vapor side stream from the rectifying section 24, thereby creating a side draw stream 52, taken from a draw off port 53. The side draw stream 52 is compressed in a second heat pump compressor 50, to create a compressed side draw stream 54. The compressed side draw stream 54 is passed to the vapor side of a second reboiler heat exchanger 60, generating a cooled compressed side draw stream 56. The cooled side draw stream 56 is passed back to the rectifying section 24 of the distillation column 20. The cooled compressed side draw stream 56 can be either partially or wholly condensed. In one embodiment, the cooled side draw stream is passed back to the rectifying section, in a position near the draw off port 53. In one embodiment, the cooled and at least partially condensed side draw stream 56 is passed to a position in the rectifying section 24 below the draw off port 53.

[0016] A second portion 36 of the bottoms liquid stream is passed to the liquid side of the second reboiler heat exchanger 60. The second portion 36 is heated to a vapor phase 38 and passed to the bottom of the stripping section 26 of the distillation column 10.

[0017] The preferred position of the draw off port 53 is at a tray positioned within 10 trays of the tray having a relatively large temperature gradient in the rectifying section 24. A temperature gradient curve is shown in Figure 2 for propane-propylene splitter column. In one embodiment, the side draw port 53 is positioned at a tray proximate to the tray having the greatest temperature gradient in the rectifying section 24 of the column 20. In another embodiment, the side draw off port 53 is positioned at a tray in the bottom half of the rectifying section 24.

[0018] The flow of vapor to the reboilers would put the energy from the vapor into the reboilers. The flowscheme would split the vapor draws, and send some from a side draw. The side draw would have a smaller compression ratio requirement, and therefore would have some savings over just the compression of the rectifying overhead vapor compression.

[0019] Simulations were run using the thermodynamic data for propane and propylene. The feed comprised 35% propylene, with a nominal operating pressure of 170 psia (1172 kPa). The temperature of the feed at the inlet to the distillation column was 87°F (30.6°C). The feed tray was stage 114, or theoretical tray 114, for a column of 160 trays, with the first tray being the top most tray. The rectifying section 24 included trays 1 to 113, and the stripping section 26 included trays 115 to 160. The terms tray and theoretical stage are interchangeable for purposes of this discussion with respect to a distillation column.

[0020] A distillation column has a temperature gradient along the height of the column, which can be seen in Figure 2 for the example of a propane-propylene splitter. A distillation column also has a column grand composite curve (CGCC) which shows the temperature as a function of enthalpy deficit, as shown in Figure 3. This can also be shown as a column stage, or theoretical tray, as a function of enthalpy deficit. In the Figure 3, the enthalpy deficit curve has two parts: a first, or upper, part of the curve shows the enthalpy deficit in the stripping section 26 of the distillation column; and a second, or lower, part of the curve shows the enthalpy deficit in the rectifying section 24 of the distillation column. The enthalpy deficit is derived from the entropy effect leading to energy dissipation across a boundary in a nonequilibrium system. The position for the draw off stream, when the feed comprises less than 50% light ends, is in the rectifying section where the rate of change in the temperature is relatively large as a function of the enthalpy deficit across the rectifying section.

[0021] The enthalpy deficit can be plotted against the stage position in the distillation column, as shown in Figure 4. When looking for an appropriate tray to position the draw off port, the optimal position is near the position on the curve where enthalpy deficit turns relative to the stage number. In this simulation, the optimal position is near tray, or theoretical stage, 80.

[0022] Further simulations were performed for several columns having different stages for a typical commercial operation in the production of propylene. The simulations are for a commercial plant that produces 500 kMTA. The separation of propylene from propane is very energy intensive, and adding equipment can be readily offset by the savings in energy costs. The results for the simulation with a 160 theoretical stage column is shown in the following table. The base case is a standard set up without a side draw or the heat pump reboiler, and the case with a heat pump reboiler, or interstage reboiler.

Table: cost comparison

500 kMTA Propylene Production		
	Base Case	Improved Case
Feed to PP Splitter Olefin Concentration, mol%	34	34
Product Propylene Purity, mol%	99.5	99.5
Heat Pump Compressor Normal Load, KW/MT C3=	298.4	238.7
Utility Cost, $/year ($0.116/KWHr)	17344800	13875840
Difference, $/year		-3468960
Heat Pump Compressor Capital Cost, $	6226669	10000000
Capital Cost Difference, $		3773331
Payback (yr)		1.09

[0023] The simulations indicate a significant operating savings, with a payback on the order of 13 months. These simulations are all for the same product purity, with a propylene product stream having a 99.5% purity. The energy savings increases with increased product purity.

[0024] While the invention has been described with what are presently considered the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

CLAIMS:

1. A process for the separation of a light component from a mixture of hydrocarbons, comprising:

passing a feedstream to a distillation column at a position between the rectifying section and the stripping section, wherein the feed comprises less than 50% light components, and wherein the distillation column has an overhead vapor stream and a bottoms liquid stream;

passing the overhead vapor stream to a first heat pump compressor, thereby creating a compressed overhead vapor stream;

passing the compressed overhead vapor stream to the vapor side of a first reboiler heat exchanger, thereby creating a partially condensed overhead stream;

drawing off a side vapor stream from the rectifying section at a draw off port, thereby creating a side draw stream;

passing the side draw stream to a second heat pump compressor, thereby creating a compressed side draw stream;

passing the compressed side draw stream to the vapor side of a second reboiler heat exchanger, thereby creating a cooled compressed side draw stream;

passing a first portion of the bottoms liquid stream to the liquid side of the first reboiler heat exchanger, thereby creating a first vapor bottoms stream; and

passing a second portion of the bottoms liquid stream to the liquid side of the second reboiler heat exchanger.

2. The process of claim 1 wherein the compressed overhead stream is totally condensed.

3. The process of claim 1 further comprising passing a portion of the condensed overhead stream to the top of the rectifying section.

4. The process of claim 1 further comprising partially condensing the compressed side draw stream, thereby creating a partially condensed compressed side draw stream.

5. The process of claim 4 further comprising passing the partially condensed compressed side draw stream back to the rectifying section.

6. The process of claim 1 further comprising passing the cooled compressed side draw stream back to the rectifying section.

7. The process of claim 6 wherein the cooled compressed side draw stream is passed to below the draw off port.

8. The process of claim 1 wherein the side draw stream is drawn from a tray positioned within 10 trays to the tray having the greatest temperature gradient per tray in the rectifying section.

9. The process of claim 8 wherein the side draw stream is drawn from a tray proximate to the tray having the greatest temperature gradient per tray in the rectifying section.

10. The process of claim 1 wherein the side draw stream is drawn from the lower half of the rectifying section.

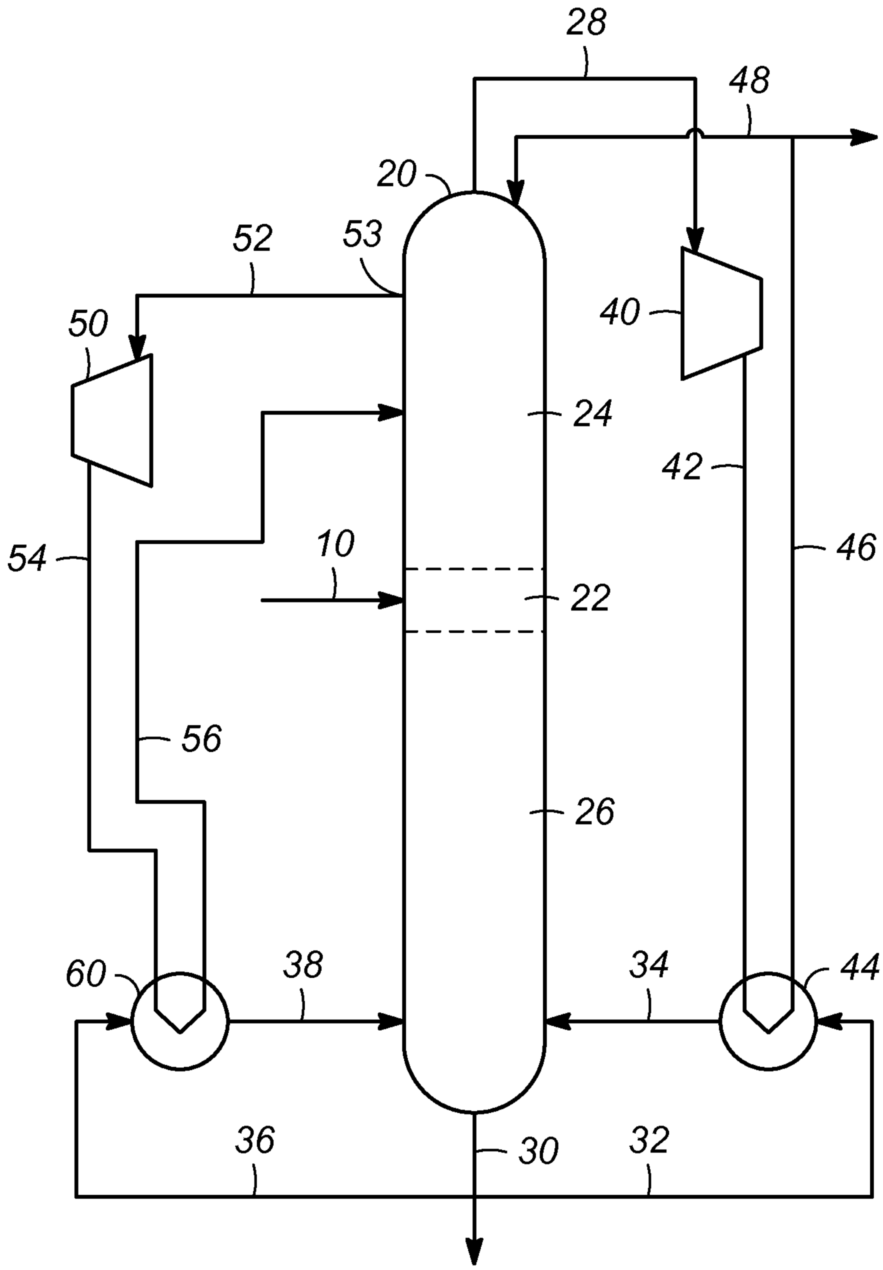
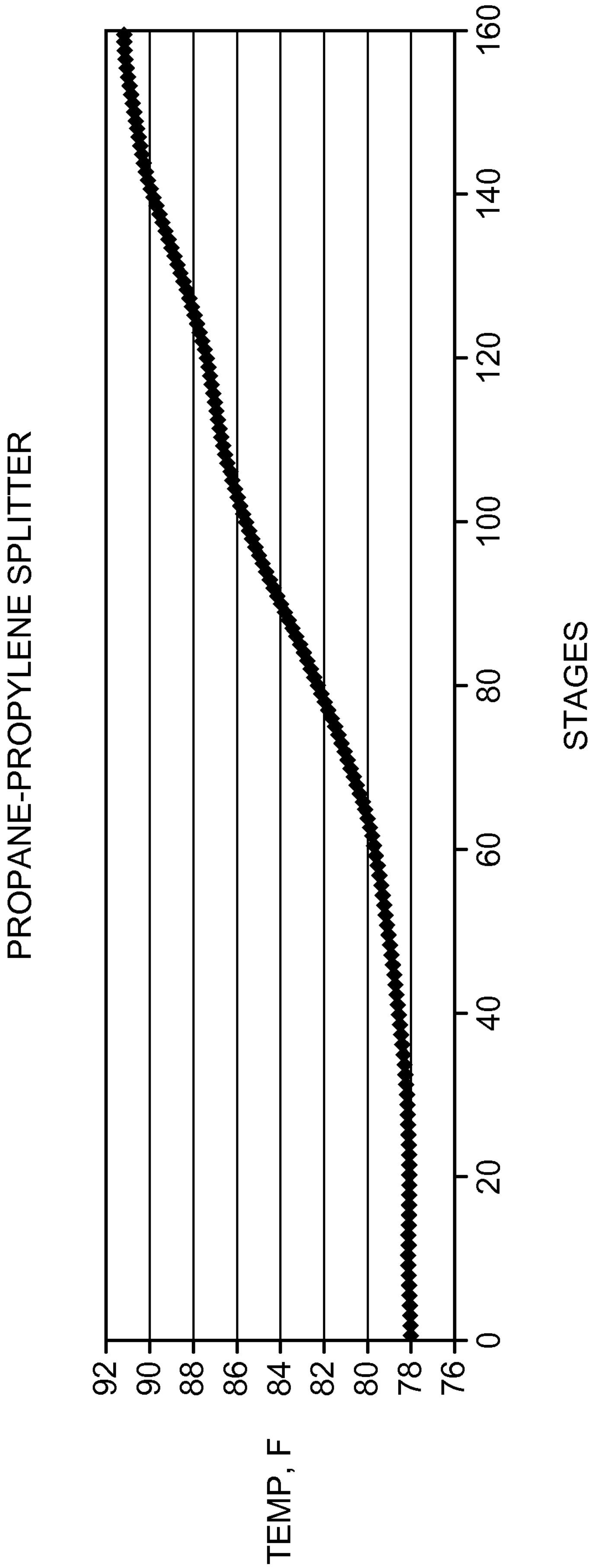


FIG. 1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TEMP, F
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90
88
86
84
82
80
78
76
STAGES
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20
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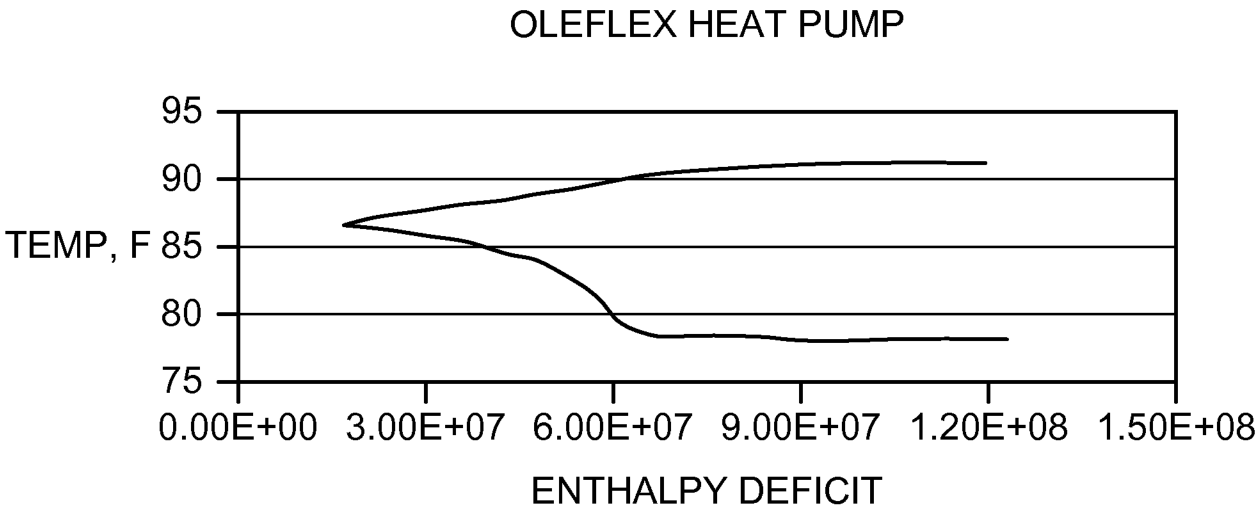
60
80
100
120
140
160

FIG. 2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90
TEMP, F 85
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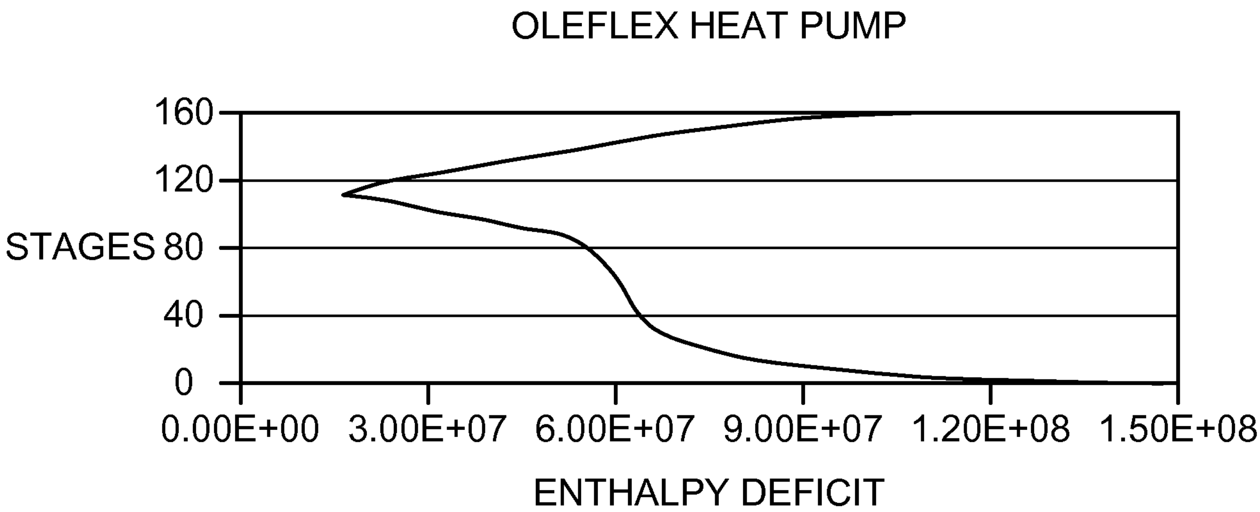
ENTHALPY DEFICIT

FIG. 3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9.00E+07
1.20E+08
1.50E+08
ENTHALPY DEFICIT

FIG. 4