

**IMPROVING CAPACITY AND PERFORMANCE OF PROCESS COLUMNS BY
OVERHEAD HEAT RECOVERY INTO AN ORGANIC RANKINE CYCLE FOR
POWER GENERATION**

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to U.S. Provisional Patent Application No. 61/390,388, entitled "Improving Capacity And Performance Of Distillation Columns By Overhead Heat Recovery Into An Organic Rankine Cycle For Additional Power Generation" and filed on October 6, 2010, in the name of John David Penton *et al*, the entire disclosure of which is hereby fully incorporated herein by reference.

TECHNICAL FIELD

[0002] The present application generally relates to heat recovery and utilization. More particularly, the present application relates to the utilization of process heat by-product from process columns to generate electricity and/or mechanical power through the use of an organic Rankine cycle.

BACKGROUND

[0003] Efforts to capture and/or reclaim waste heat in refineries are known (See, for example, Badenhausen, United States Patent No. 2,335,727). That said, there is not a universal waste heat recovery strategy for all refinery types, and for all of the heat-generating processes performed within such refineries. Accordingly, much of said effort has been directed at finding cumulative benefits from the harnessing of waste heat from a plurality of refinery processes using a variety of techniques, of which organic Rankine cycle systems are often part (See, for example, Carson, United States Patent No. 4,109,469).

[0004] In many refineries, the hydraulic capacity of process columns can be increased by installing high capacity trays. Reboiler input can usually be increased due to the availability of extra heating medium (often steam) and the excellent heat transfer provided by phase changes on either side of the associated exchanger. Overhead cooling capacity in such systems can be more problematic, however, often limited by ambient conditions and the large amount of space required by their associated air cooling cells.

[0005] Waste heat has also been recovered through the use of organic Rankine cycles within the geothermal industry. The waste heat temperatures from a geothermal process are

closely aligned to that found in process column overheads. However, the main obstacle to further utilizing the organic Rankine cycle technology in this type of application is that the current organic Rankine cycle designs are highly dependent on stable process conditions. Additionally, the existing equipment utilized within the current designs is more prone to fouling or corrosion issues which would be prevalent in process column applications. Another obstacle would be the increased design complexity in integrating an organic Rankine cycle system into an existing column operation.

[0006] In view of the foregoing, any process or enhancement directed to the recovery of such overhead heat from such above-mentioned process columns would be deemed beneficial from a waste heat recovery/reclamation perspective, as well as from a process efficiency standpoint.

SUMMARY

[0007] The present invention is directed to processes for heat recovery in refineries, wherein such heat recovery is realized by channeling thermal energy from an overhead stream of a process column to an organic Rankine cycle—from which electricity can be derived through a turbine-driven generator. The present invention is also directed to systems for implementing such processes.

[0008] In one aspect of the invention, a process for reclaiming heat from a process column unit includes two sub-processes that occur simultaneously and that are linked via a heater or heat exchanger. In the first sub-process, an overhead stream from the process column unit is directed to a heater and is utilized to heat a working fluid stream of an organic Rankine cycle to produce a reduced heat overhead stream and a heated working fluid stream. The overhead stream thermally contacts the working fluid stream to transfer heat to the working fluid stream. The reduced heat overhead stream is directed to another heat exchanger to produce a cooled intermediate. The cooled intermediate then enters a separator, where it is separated into a vapor stream, a light liquid stream, and a heavy liquid stream. The light liquid stream is passed through a pump to form a reflux fluid that can then be directed into the process column. In the second sub-process, the working fluid stream is heated by the overhead stream in the heater to form a heated working fluid stream. In certain aspects, the heated working fluid stream is vaporized. The heated working fluid stream is passed through a turbine-generator set to form an expanded working fluid stream and produce electricity and/or mechanical power. The expanded working fluid stream is then directed to another heat exchanger to form a condensed working fluid stream. The condensed working

fluid stream is then passed through a pump to form the working fluid stream that enters the heater of the organic Rankine cycle.

[0009] In another aspect of the invention, a process for reclaiming heat from a process column unit includes three sub-processes that occur simultaneously. The first and second sub-processes are linked via a first heater, and the second and third sub-processes are linked via a second heater. In the first sub-process, an overhead stream from the process column unit is directed to the first heater and is utilized to heat a first working fluid stream to produce a reduced heat overhead stream and a heated working fluid stream. The overhead stream thermally contacts the first working fluid stream to transfer heat to the first working fluid stream. The reduced heat overhead stream is directed to another heat exchanger to produce a cooled intermediate. The cooled intermediate then enters a separator, where it is separated into a vapor stream, a light liquid stream, and a heavy liquid stream. The light liquid stream is passed through a pump to form a reflux fluid that can then be directed into the process column. In the second sub-process, the first working fluid stream is heated by the overhead stream in the first heater to form a first heated working fluid stream. The first heated working fluid stream is directed to the second heater, and is utilized to heat a working fluid stream of an organic Rankine cycle to produce a cooled working fluid stream and a second heated working fluid stream. The first heated working fluid stream thermally contacts the working fluid stream of the organic Rankine cycle to transfer heat to the working fluid stream of the organic Rankine cycle. The cooled working fluid stream is then passed through a pump to form the first working fluid stream. In the third sub-process, the working fluid stream of the organic Rankine cycle is heated to form the second heated working fluid stream. In certain aspects, the second heated working fluid stream is vaporized. The second heated working fluid stream is passed through a turbine-generator set to form an expanded working fluid stream and produce electricity and/or mechanical power. The expanded working fluid stream is then directed to another heat exchanger to form a condensed working fluid stream. The condensed working fluid stream is then passed through a pump to form the working fluid stream that enters the heater of the organic Rankine cycle.

[0010] In yet another aspect of the invention, a system for reclaiming heat from a process column unit includes an overhead stream from the process column unit, an overhead conduit in connectivity with the process column unit for receiving the overhead stream, one or more air coolers for receiving and cooling the overhead stream to produce a cooled intermediate, a separator for receiving and separating the cooled intermediate into a vapor product and a liquid product, a fluid conduit for returning the liquid product to the process

column unit, and an organic Rankine cycle subsystem. In certain aspects, the organic Rankine cycle subsystem includes a heat exchanger in thermal communication with the overhead conduit prior to the overhead stream being directed to the one or more air coolers, an organic Rankine cycle flow line having a working fluid, whereby the flow line is in thermal communication with the heat exchanger, and whereby the heat exchanger transfers thermal energy from the overhead stream to the working fluid so as to heat the working fluid to form a heated working fluid, a turbine-based generator for generating electricity and/or mechanical power from the heated working fluid passing through, one or more condensers for condensing the heated working fluid to form a condensed working fluid, and a pump for pumping the condensed working fluid to a higher pressure to form the working fluid that enters the heat exchanger.

[0011] The features of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] For a more complete understanding of the exemplary embodiments of the present invention and the advantages thereof, reference is now made to the following description in conjunction with the accompanying drawings, which are briefly described as follows.

[0013] FIG. 1 is a schematic diagram of a heat recovery system for direct utilization of process heat by-product from a process column, according to an exemplary embodiment.

[0014] FIG. 2 is a schematic diagram of a heat recovery system for direct utilization of process heat by-product from a process column, according to another exemplary embodiment.

[0015] FIG. 3 is a schematic diagram of a heat recovery system for indirect utilization of process heat by-product from a process column, according to an exemplary embodiment.

[0016] FIG. 4 is a schematic diagram of a heat recovery system for indirect utilization of process heat by-product from a process column, according to another exemplary embodiment.

DETAILED DESCRIPTION

[0017] Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. One of ordinary skill in the art will appreciate that in the development of any such actual

embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0018] The present invention may be better understood by reading the following description of non-limitative embodiments with reference to the attached drawings wherein like parts of each of the figures are identified by the same reference characters. The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, for example, a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special meaning, for example, a meaning other than that understood by skilled artisans, such a special definition will be expressly set forth in the specification in a definitional manner that directly and unequivocally provides the special definition for the term or phrase. Moreover, various streams or conditions may be referred to with terms such as "hot," "cold," "cooled," "warm," etc., or other like terminology. Those skilled in the art will recognize that such terms reflect conditions relative to another process stream, not an absolute measurement of any particular temperature.

[0019] The present application is directed to processes for heat recovery and utilization of process heat by-product from process columns in refineries, wherein such heat recovery is realized by channeling or otherwise directing thermal energy (using a heat exchanger) from a process column overhead stream to an organic Rankine cycle—from which electricity can be derived using a turbine-driven generator. The present application is also directed to systems for implementing such processes. Generally, the present invention utilizes organic Rankine cycle technology within an enhanced heat recovery design to overcome the aforementioned issues with current systems.

[0020] Referring now to FIG. 1, a heat recovery system 100 for directly utilizing process heat by-product of an overhead stream 101 from a process column 102 is shown. Suitable examples of process columns include, but are not limited to, distillation columns and strippers. In certain exemplary embodiments, the overhead stream 101 has a temperature in the range of from about 170 to about 320 degrees Fahrenheit (°F). In certain exemplary

embodiments, the overhead stream 101 is a vapor and exits the process column 102 through an overhead vapor conduit. A portion 101a of the overhead stream 101 can be utilized to heat a working fluid stream 103 of an organic Rankine cycle. In certain exemplary embodiments, the working fluid stream 103 includes an organic fluid. In other embodiments, the working fluid stream 103 includes a refrigerant. One having ordinary skill in the art will recognize that the present invention may employ any number of working fluids in the organic Rankine cycle. Suitable examples of working fluids for use in the organic Rankine cycle include, but are not limited to, ammonia (NH₃), bromine (Br₂), carbon tetrachloride (CCl₄), ethyl alcohol or ethanol (CH₃CH₂OH, C₂H₆O), furan (C₄H₄O), hexafluorobenzene or perfluorobenzene (C₆F₆), hydrazine (N₂H₄), methyl alcohol or methanol (CH₃OH), monochlorobenzene or chlorobenzene or chlorobenzol or benzene chloride (C₆H₅Cl), n-pentane or normal pentane (nC₅), i-hexane or isohexane (iC₆), pyridene or azabenzene (C₅H₅N), refrigerant 11 or freon 11 or CFC-11 or R-11 or trichlorofluoromethane (CCl₃F), refrigerant 12 or freon 12 or R-12 or dichlorodifluoromethane (CCl₂F₂), refrigerant 21 or freon 21 or CFC-21 or R-21 (CHCl₂F), refrigerant 30 or freon 30 or CFC-30 or R-30 or dichloromethane or methylene chloride or methylene dichloride (CH₂Cl₂), refrigerant 115 or freon 115 or CFC-115 or R-115 or chloro-pentafluoroethane or monochloropentafluoroethane, refrigerant 123 or freon 123 or HCFC-123 or R-123 or 2,2-dichloro-1,1,1-trifluoroethane, refrigerant 123a or freon 123a or HCFC-123a or R-123a or 1,2-dichloro-1,1,2-trifluoroethane, refrigerant 123b1 or freon 123b1 or HCFC-123b1 or R-123b1 or halothane or 2-bromo-2-chloro-1,1,1-trifluoroethane, refrigerant 134A or freon 134A or HFC-134A or R-134A or 1,1,1,2-tetrafluoroethane, refrigerant 150A or freon 150A or CFC-150A or R-150A or dichloroethane or ethylene dichloride (CH₂ClCH₂Cl), thiophene (C₄H₄S), toluene or methylbenzene or phenylmethane or toluol (C₇H₈), water (H₂O), carbon dioxide (CO₂), and the like. In certain exemplary embodiments, the working fluid may include a combination of components. For example, one or more of the compounds identified above may be combined or with a hydrocarbon fluid, for example, isobutene. However, those skilled in the art will recognize that the present invention is not limited to any particular type of working fluid or refrigerant. Thus, the present invention should not be considered as limited to any particular working fluid unless such limitations are clearly set forth in the appended claims.

[0021] The portion 101a of the overhead stream 101 and the working fluid stream 103 enter a heat exchanger 105 where they are thermally contacted to produce a heated working fluid stream 106 and a reduced heat overhead stream 108. As used herein, the phrase

“thermally contact” generally refers to the exchange of energy through the process of heat, and does not imply physical mixing or direct physical contact of the streams. Generally, heat from the overhead stream 101 is utilized to heat the working fluid stream 103 by thermally contacting the two streams such that heat is transferred from the overhead stream 101 to the working fluid stream 103. The heat exchanger 105 is a part of the organic Rankine cycle. The heat exchanger 105 may be any type of heat exchanger capable of transferring heat from one fluid stream to another fluid stream. Suitable examples of heat exchangers include, but are not limited to, heaters, vaporizers, economizers, and other heat recovery heat exchangers. For example, the heat exchanger 105 may be a shell-and-tube heat exchanger, a plate-fin-tube coil type of exchanger, a bare tube or finned tube bundle, a welded plate heat exchanger, and the like. Thus, the present invention should not be considered as limited to any particular type of heat exchanger unless such limitations are expressly set forth in the appended claims. In certain exemplary embodiments, the working fluid stream 103 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 106 has a temperature in the range of from about 160 to about 310 °F. In certain exemplary embodiments, the heated working fluid stream 106 is vaporized, superheated, or supercritical. In certain exemplary embodiments, the reduced heat overhead stream 108 has a temperature in the range of from about 90 to about 210 °F. In certain exemplary embodiments, a portion 101b of the overhead stream 101 is diverted through a bypass valve 109 and then combined with the reduced heat overhead stream 108 to produce an intermediate overhead stream 110. In certain exemplary embodiments, the intermediate overhead stream 110 has a temperature in the range of from about 90 to about 215 °F. In certain exemplary embodiments, the overhead stream 101 is entirely directed through the heat exchanger 105.

[0022] In certain exemplary embodiments, a portion 110a of the intermediate overhead stream 110 is directed to one or more heat exchangers. In certain exemplary embodiments, the one or more heat exchangers are air-cooled condensers 112. In certain exemplary embodiments, two air-cooled condensers 112 are present in series. In certain exemplary embodiments, each of the air-cooled condensers 112 is controlled by a variable frequency drive 113. In certain exemplary embodiments, the air-cooled condensers 112 cool the intermediate overhead stream 110 to form a condensed intermediate stream 114. In certain exemplary embodiments, the condensed intermediate stream 114 has a temperature in the range of from about 85 to about 215 °F. In certain exemplary embodiments, a portion 110b of the intermediate overhead stream 110 is diverted through a bypass valve 115 and

then combined with the condensed intermediate stream 114 to produce an intermediate stream 116. In certain exemplary embodiments, the intermediate stream 116 has a temperature in the range of from about 85 to about 215 °F. In certain exemplary embodiments, the intermediate overhead stream 110 is entirely directed through the air-cooled condensers 112.

[0023] The intermediate stream 116 is then directed to a separator 120. In certain embodiments, the separator 120 is a reflux drum, an overhead receiver, or an accumulator. In certain embodiments, the separator 120 separates the intermediate stream 116 into a vapor product and a liquid product. In certain exemplary embodiments, the separator 120 separates the intermediate stream 116 into a vapor product stream 121, a light liquid product stream 122, and a heavy liquid product stream 123. In certain exemplary embodiments, the vapor product stream 121 is then directed to either a fuel gas system or to a light hydrocarbon recovery system (not shown). In certain exemplary embodiments, the heavy liquid product stream 123 is then directed to a pump 126 that pumps the heavy liquid product stream 123 to a higher pressure to produce a heavy liquid product stream 127 that is directed to a process water system (not shown). In certain exemplary embodiments, the light liquid product stream 122 is directed to a reflux pump 130. In certain exemplary embodiments, the reflux pump 130 is controlled by a variable frequency drive 131. The reflux pump 130 pumps the light liquid product stream 122 to a higher pressure to produce a reflux product stream 133. In certain embodiments, a portion 133a of the reflux product stream 133 is directed to the process column 102 through a fluid conduit. In certain embodiments, a portion 133b of the reflux product stream 133 is directed to a light hydrocarbon, for example, naptha or gasoline, recovery system (not shown). In certain embodiments, the reflux product stream 133 is entirely directed the process column 102.

[0024] At least a portion 106a of the heated working fluid stream 106 is then directed to a turbine-generator system 150 where the portion 106a of the heated working fluid stream 106 is expanded to produce an expanded working fluid stream 151 and generate power. In certain exemplary embodiments, the expanded working fluid stream 151 has a temperature in the range of from about 80 to about 300 °F. In certain embodiments, a portion 106b of the heated working fluid stream 106 is diverted through a bypass valve 152 and then combined with the expanded working fluid stream 151 to produce an intermediate working fluid stream 155. In certain exemplary embodiments, the intermediate working fluid stream 155 has a temperature in the range of from about 80 to about 305 °F.

[0025] The intermediate working fluid stream 155 is then directed to one or more air-cooled condensers 157. The air-cooled condensers 157 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 157 in series. In certain exemplary embodiments, each of the air-cooled condensers 157 is controlled by a variable frequency drive 158. The air-cooled condensers 157 cool the intermediate working fluid stream 155 to form a condensed working fluid stream 159. In certain exemplary embodiments, the condensed working fluid stream 159 has a temperature in the range of from about 80 to about 150 °F.

[0026] The condensed working fluid stream 159 is then directed to a pump 160. The pump 160 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 160 is controlled by a variable frequency drive 161. The pump 160 returns the condensed working fluid stream 159 to a higher pressure to produce the working fluid stream 103 that is directed to the heat exchanger 105.

[0027] FIG. 2 illustrates a heat recovery system 200 for directly utilizing process heat by-product of an overhead stream 101 from a process column 102, according to another exemplary embodiment. The heat recovery system 200 is the same as that described above with regard to heat recovery system 100, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 2, the intermediate working fluid stream 155 is directed to one or more water-cooled condensers 257. The water-cooled condensers 257 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 257 in series. The water-cooled condensers 257 cool the intermediate working fluid stream 155 to form a condensed working fluid stream 259. In certain exemplary embodiments, the condensed working fluid stream 259 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 259 is then directed to the pump 160 and is returned to a higher pressure to produce the working fluid stream 103 that is directed to the heat exchanger 105.

[0028] FIG. 3 illustrates a heat recovery system 300 for indirectly utilizing process heat by-product of an overhead stream 301 from a process column 302, according to an exemplary embodiment. A portion 301a of the overhead stream 301 can be utilized to heat an intermediate working fluid stream 303. The portion 301a of the overhead stream 301 thermally contacts the intermediate working fluid stream 303 to transfer heat from the overhead stream 301 to the intermediate working fluid stream 303. Suitable examples of the intermediate working fluid stream 303 include, but are not limited to, water, glycols,

therminol fluids, alkanes, alkenes, chlorofluorocarbons, hydrofluorocarbons, carbon dioxide (CO₂), refrigerants, and mixtures of other hydrocarbon components. Those skilled in the art will recognize that the present invention is not limited to any particular type of intermediate working fluid. Thus, the present invention should not be considered as limited to any particular intermediate working fluid unless such limitations are clearly set forth in the appended claims. The portion 301a of the overhead stream 301 and the intermediate working fluid stream 303 enter a heat exchanger 305 to produce a heated intermediate working fluid stream 306 and a reduced heat overhead stream 308. Generally, heat from the overhead stream 301 is utilized to heat the intermediate working fluid stream 303. In certain exemplary embodiments, the intermediate working fluid stream 303 has a temperature in the range of from about 85 to about 155 °F. In certain exemplary embodiments, the heated intermediate working fluid stream 306 has a temperature in the range of from about 165 to about 315 °F. In certain exemplary embodiments, the reduced heat overhead stream 308 has a temperature in the range of from about 90 to about 210 °F. In certain exemplary embodiments, a portion 301b of the overhead stream 301 is diverted through a bypass valve 309 and then combined with the reduced heat overhead stream 308 to produce an intermediate overhead stream 310. In certain exemplary embodiments, the intermediate overhead stream 310 has a temperature in the range of from about 90 to about 215 °F. In certain exemplary embodiments, the overhead stream 301 is entirely directed through the heat exchanger 305.

[0029] In certain exemplary embodiments, a portion 310a of the intermediate overhead stream 310 is directed to one or more heat exchangers. In certain exemplary embodiments, the one or more heat exchangers are air-cooled condensers 312. In certain exemplary embodiments, two air-cooled condensers 312 are present in series. In certain exemplary embodiments, each of the air-cooled condensers 312 is controlled by a variable frequency drive 313. In certain exemplary embodiments, the air-cooled condensers 312 cool the intermediate overhead stream 310 to form a condensed intermediate stream 314. In certain exemplary embodiments, the condensed intermediate stream 314 has a temperature in the range of from about 85 to about 215 °F. In certain exemplary embodiments, a portion 310b of the intermediate overhead stream 310 is diverted through a bypass valve 315 and then combined with the condensed intermediate stream 314 to produce an intermediate stream 316. In certain exemplary embodiments, the intermediate stream 316 has a temperature in the range of from about 85 to about 215 °F. In certain exemplary

embodiments, the intermediate overhead stream 310 is entirely directed through the air-cooled condensers 312.

[0030] The intermediate stream 316 is then directed to a separator 320. In certain exemplary embodiments, the separator 320 separates the intermediate stream 316 into a vapor product stream 321, a light liquid product stream 322, and a heavy liquid product stream 323. In certain exemplary embodiments, the heavy liquid product stream 323 is then directed to a pump 326 that pumps the heavy liquid product stream 323 to a higher pressure to produce a heavy liquid product stream 327. In certain exemplary embodiments, the light liquid product stream 322 is directed to a reflux pump 330. In certain exemplary embodiments, the reflux pump 330 is controlled by a variable frequency drive 331. The reflux pump 330 pumps the light liquid product stream 322 to a higher pressure to produce a reflux product stream 333. In certain embodiments, a portion 333a of the reflux product stream 333 is directed to the process column 302. In certain embodiments, a portion 333b of the reflux product stream 333 is directed to a light hydrocarbon recovery system (not shown). In certain embodiments, the reflux product stream 333 is entirely directed the process column 302.

[0031] The heated intermediate working fluid stream 306 is then directed to a heat exchanger 335 to heat a working fluid stream 336 of an organic Rankine cycle to produce a heated working fluid stream 337 and a reduced heat intermediate working fluid stream 338. The heated intermediate working fluid stream 306 thermally contacts the working fluid stream 336 to transfer heat from the heated intermediate working fluid stream 306 to the working fluid stream 336. In certain exemplary embodiments, the working fluid stream 336 includes an organic fluid or a refrigerant. In certain exemplary embodiments, the working fluid stream 336 has a temperature in the range of from about 80 to about 150 °F. In certain exemplary embodiments, the heated working fluid stream 337 has a temperature in the range of from about 160 to about 310 °F. In certain exemplary embodiments, the heated working fluid stream 337 is vaporized, superheated, or supercritical. In certain exemplary embodiments, the reduced heat intermediate working fluid stream 338 has a temperature in the range of from about 85 to about 155 °F.

[0032] The reduced heat intermediate working fluid stream 338 is then directed to a pump 342. In certain exemplary embodiments, the pump 342 is controlled by a variable frequency drive (not shown). The pump 342 returns the reduced heat intermediate working fluid stream 338 to a higher pressure to produce the intermediate working fluid stream 303 that enters the heat exchanger 305.

[0033] At least a portion 337a of the heated working fluid stream 337 is then directed to a turbine-generator system 350, which is a part of the organic Rankine cycle. The portion 337a of the heated working fluid stream 337 is expanded in the turbine-generator system 350 to produce an expanded working fluid stream 351 and generate power. In certain exemplary embodiments, the expanded working fluid stream 351 has a temperature in the range of from about 80 to about 300 °F. In certain embodiments, the turbine-generator system 350 generates electricity or electrical power. In certain other embodiments, the turbine-generator system 350 generates mechanical power. In certain embodiments, a portion 337b of the heated working fluid stream 337 is diverted through a bypass valve 352 and then combined with the expanded working fluid stream 351 to produce an intermediate working fluid stream 355. In certain exemplary embodiments, the intermediate working fluid stream 355 has a temperature in the range of from about 80 to about 305 °F.

[0034] The intermediate working fluid stream 355 is then directed to one or more air-cooled condensers 357. The air-cooled condensers 357 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two air-cooled condensers 357 in series. In certain exemplary embodiments, each of the air-cooled condensers 357 is controlled by a variable frequency drive 358. The air-cooled condensers 357 cool the intermediate working fluid stream 355 to form a condensed working fluid stream 359. In certain exemplary embodiments, the condensed working fluid stream 359 has a temperature in the range of from about 80 to about 150 °F.

[0035] The condensed working fluid stream 359 is then directed to a pump 360. The pump 360 is a part of the organic Rankine cycle. In certain exemplary embodiments, the pump 360 is controlled by a variable frequency drive 361. The pump 360 returns the condensed working fluid stream 359 to a higher pressure to produce the working fluid stream 336 that is directed to the heat exchanger 335.

[0036] FIG. 4 illustrates a heat recovery system 400 for indirectly utilizing process heat by-product of an overhead stream 301 from a process column 302, according to another exemplary embodiment. The heat recovery system 400 is the same as that described above with regard to heat recovery system 300, except as specifically stated below. For the sake of brevity, the similarities will not be repeated hereinbelow. Referring now to FIG. 4, the intermediate working fluid stream 355 is directed to one or more water-cooled condensers 457. The water-cooled condensers 457 are a part of the organic Rankine cycle. In certain exemplary embodiments, the organic Rankine cycle includes two water-cooled condensers 457 in series. The water-cooled condensers 457 cool the intermediate working fluid stream

355 to form a condensed working fluid stream 459. In certain exemplary embodiments, the condensed working fluid stream 459 has a temperature in the range of from about 80 to about 150 °F. The condensed working fluid stream 459 is then directed to the pump 360 and is returned to a higher pressure to produce the working fluid stream 336 that is directed to the heat exchanger 335.

[0037] The present application is generally directed to direct and indirect heat recovery systems and methods for producing electrical and/or mechanical power by utilizing heat by-product in an overhead stream from a process column with an organic Rankine cycle. The exemplary systems may include an overhead stream from a process column, a heater or heat exchanger, a turbine-generator set, a condenser heat exchanger, and a pump. The overall efficiency of the systems of the present invention is increased over conventional systems because the overhead condenser duty normally rejected to the atmosphere (with the additional cost of running cooling fans) is now recovered as power. Also, by continuously operating some or all of the existing heat exchangers in series with the organic Rankine cycle condensers to increase the overall overhead cooling capacity of the column, the following advantages can be realized: (1) the throughput of the process column can be increased with sufficient hydraulic capacity of the trays, and (2) the process column overhead pressure can be reduced. With regard to this latter advantage, such pressure reduction generally increases the relative volatilities of the liquid components. This will improve the separation, allowing more valuable intermediate boiling liquid products to be withdrawn from column sidestreams, as typically found in refineries. Alternatively, the same liquid product split could be maintained at a lower reflux ratio, thereby saving energy in the form of reduced reboiler heat input. Similar benefits apply to petrochemical plant columns with only two liquid products. The purity of the products can be improved with the same column heat input, or energy can be saved by reducing reboiler heat input while maintaining existing product purity.

[0038] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this invention as defined by the appended claims. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the

particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. The terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

CLAIMS

What is claimed is:

1. A process for reclaiming heat from a process column unit in a refinery, comprising:
 - a first sub-process and a second sub-process, the first sub-process comprising the steps of:
 - a) directing at least a portion of an overhead stream from said process column unit to a heater;
 - b) thermally contacting in said heater the overhead stream with a working fluid to cool the overhead stream to form a reduced heat overhead stream;
 - c) passing at least a portion of the reduced heat overhead stream through at least one first heat exchanger to form a cooled intermediate;
 - d) directing the cooled intermediate into a separator, wherein the cooled intermediate is separated into a vapor stream and at least one liquid stream;
 - e) passing at least a portion of the at least one liquid stream through at least one first pump to form a reflux fluid; and
 - f) directing at least a portion of the reflux fluid into said process column unit;
 - and the second sub-process comprising the steps of:
 - g) heating in said heater the working fluid to form a heated working fluid;
 - h) passing the heated working fluid through a turbine to form an expanded working fluid, wherein said passing of the heated working fluid through the turbine drives a generator for production of one of electricity and mechanical power;
 - i) passing the expanded working fluid through at least one second heat exchanger to form a condensed working fluid; and
 - j) passing the condensed working fluid through at least one second pump to form said working fluid;
 - wherein the first and second sub-processes are linked via the heater, and wherein first and second sub-processes occur simultaneously.
2. The process of claim 1, wherein the second sub-process is a closed loop organic Rankine cycle.
 3. The process of claim 1, wherein the working fluid is an organic working fluid.

4. The process of claim 1, wherein the working fluid is a refrigerant.
5. The process of claim 1, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid.
6. The process of claim 1, wherein the step of heating the working fluid to form the heated working fluid comprises vaporizing the working fluid within a supercritical process.
7. The process of claim 1, wherein the at least one first heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.
8. The process of claim 1, wherein the at least one second heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.
9. The process of claim 1, wherein the at least one liquid stream comprises a heavy liquid stream and a light liquid stream, and wherein the light liquid stream is passed through the at least one first pump to form the reflux fluid.
10. A process for reclaiming heat from a process column unit in a refinery, comprising:
 - a first sub-process, a second sub-process, and a third sub-process, the first sub-process comprising the steps of:
 - a) directing at least a portion of an overhead stream from said process column unit to a first heater;
 - b) thermally contacting in said first heater the overhead stream with a first working fluid to cool the overhead stream to form a reduced heat overhead stream;
 - c) passing at least a portion of the reduced heat overhead stream through at least one first heat exchanger to form a cooled intermediate;
 - d) directing the cooled intermediate into a separator, wherein the cooled intermediate is separated into a vapor stream and at least one liquid stream;
 - e) passing at least a portion of the at least one liquid stream through at least one first pump to form a reflux fluid; and
 - f) directing at least a portion of the reflux fluid into said distillation unit;
 - the second sub-process comprising the steps of:

- g) heating in said first heater the first working fluid to form a first heated working fluid;
 - h) directing the first heated working fluid to a second heater;
 - i) thermally contacting in said second heater the first heated working fluid with a second working fluid to cool the first heated working fluid to form a first cooled working fluid; and
 - j) passing the first cooled working fluid through a second pump to form said first working fluid; and
- the third sub-process comprising the steps of:
- k) heating in said second heater the second working fluid to form a second heated working fluid;
 - l) passing the second heated working fluid through a turbine to form an expanded working fluid, wherein said passing of the second heated working fluid through the turbine drives a generator for production of one of electricity and mechanical power;
 - m) passing the expanded working fluid through at least one second heat exchanger to form a condensed working fluid; and
 - n) passing the condensed working fluid through at least one second pump to form said second working fluid;
- wherein the first and second sub-processes are linked via the first heater, wherein the second and third sub-processes are linked via the second heater, and wherein first, second, and third sub-processes occur simultaneously.

11. The process of claim 10, wherein the second working fluid is an organic working fluid.

12. The process of claim 10, wherein the second working fluid is a refrigerant.

13. The process of claim 10, wherein the step of heating the second working fluid to form the second heated working fluid comprises vaporizing the second working fluid.

14. The process of claim 1, wherein the step of heating the second working fluid to form the second heated working fluid comprises vaporizing the second working fluid within a supercritical process.

15. The process of claim 10, wherein the at least one first heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.

16. The process of claim 10, wherein the at least one second heat exchanger is selected from the group consisting of air-cooled condensers and water-cooled condensers.

17. The process of claim 10, wherein the at least one liquid stream comprises a heavy liquid stream and a light liquid stream, and wherein the light liquid stream is passed through the at least one first pump to form the reflux fluid.

18. A system for reclaiming heat from a process column unit in a refinery, comprising:

- a) a process column unit having an overhead stream;
- b) an overhead conduit in connectivity with the process column unit;
- c) one or more air coolers for receiving the overhead stream through the overhead conduit and cooling the overhead stream to form a cooled intermediate;
- d) a separator for receiving the cooled intermediate and separating the cooled intermediate into a vapor product and a liquid product;
- e) a fluid conduit for returning at least a portion of the liquid product to the process column unit; and
- f) an organic Rankine cycle subsystem, the subsystem comprising:
 - i) a heat exchanger in thermal communication with the overhead conduit prior to the overhead stream being directed to the one or more air coolers;
 - ii) an organic Rankine cycle flow line comprising a working fluid, wherein said flow line is in thermal communication with the heat exchanger, and wherein the heat exchanger transfers thermal energy from the overhead stream to the working fluid so as to heat the working fluid to form a heated working fluid;
 - iii) a turbine-based generator, the turbine of which the heated working fluid passes through so as to generate one of electricity and mechanical power; and
 - iv) one or more condensers for condensing the heated working fluid to form a condensed working fluid.

19. The system of claim 18, wherein the subsystem further comprises a pump for receiving the condensed working fluid to form said working fluid.

20. The system of claim 18, wherein the liquid product comprises a heavy liquid stream and a light liquid stream, and wherein the light liquid stream is passed through the fluid conduit.