

SYSTEMS AND METHODS FOR GENERATING POWER AND CHILLING USING UNUTILIZED HEAT

FIELD OF THE INVENTION

[0001] The present application relates to systems and methods employing sorbent materials to generate power and chilling using unutilized heat. In particular, the present invention relates to a system and method for the simultaneous generation of power and chilling utilizing waste heat.

BACKGROUND OF THE INVENTION

[0002] Petroleum refining and petrochemical processing operations are energy intensive. It is often necessary to conduct these operations at high temperatures using high temperature heat sources including, but not limited to, steam. After the steam or other hot streams have performed the intended functions, there remains unutilized energy. Refineries and petrochemical facilities typically utilize only 70% of the input energy and a large amount of energy loss occurs at lower temperatures, 450 °F or below. There is a strong need to recapture or utilize this energy. Potential uses of this energy include production of electric power, shaft power, or chilling of process streams. However, the cost of equipment to capture this heat can be a disincentive because of the low efficiencies of waste heat capture devices when the source of heat is at or below 450 °F. Electric power, shaft power, and chilling can be effectively utilized in refineries and petrochemical processes to increase the overall efficiency of the facility.

[0003] In an effort to increase efficiency, it is desirable to recover and utilize unutilized heat. One method described in U.S. Patent No. 5,823,003 to Rosser et

al. attempts to make use of waste heat and apply such heat to an adsorbent material in order to release an adsorbed gas at a higher pressure, which in turn can be used in a refrigeration cycle that contains an expansion valve. U.S. Patent No. 5,823,003 describes the use of a zeolite-water combination for a sorption refrigeration system.

[0004] Current methods to obtain refrigeration from sorbent materials in chemical process applications have their limitations. Often the sorbent materials and gases employed in sorption systems require processing equipment that is expensive to maintain, operate under vacuum, have a refrigeration temperature above water freezing point (32 F), unreliable, and requires a large allocation of space. Such limitations often render the recovery of unutilized heat economically unsustainable.

[0005] Accordingly, there remains a need to make unutilized heat recovery efforts more cost-effective by providing the opportunity to utilize lower (less than 450 °F) grades of unutilized heat and to reduce equipment and space requirements of the process. There also remains a need to provide other uses, besides refrigeration, of the fluid released from unutilized heat-charged sorbent materials.

SUMMARY OF THE INVENTION

[0006] One embodiment of the present application provides a sorption system for generating power and chilling including a first vessel containing a sorbent material in fluid communication with a working fluid and operatively connected to a heat source to yield a feed of working fluid at a supercritical state, a generator in fluid communication with the feed of working fluid at supercritical state to yield power and a feed of working fluid in an at least partially condensed state, and an evaporator in fluid communication with the

feed of working fluid in the at least partially condensed state to yield chilling and a feed of uncondensed working fluid. In one embodiment, the heat source is an unutilized heat source.

[0007] The present application also provides a process for generating power and chilling including adsorbing a working fluid onto a sorbent material, heating the sorbent material to desorb the working fluid from the sorbent material at a supercritical state, directing the desorbed fluid to drive a generator to generate power and to at least partially condense the desorbed working fluid, and evaporating the at least partially condensed desorbed fluid to yield chilling and a feed of uncondensed working fluid. In one embodiment, the heating is provided by unutilized heat from one of a refining operation and chemical processing operation.

[0008] The present application also provides a sorption system for generating both power and chilling that includes an absorber to absorb a working fluid in a liquid sorbent, a pump in fluid communication with the absorber to yield a feed of pressurized liquid sorbent and absorbed working fluid, a heat source to heat the feed of pressurized liquid sorbent and absorbed working fluid to yield a feed of working fluid at a supercritical state, a generator in fluid communication with the feed of working fluid at a supercritical state to yield power and a feed of working fluid in an at least partially condensed state, and an evaporator in fluid communication with the feed of working fluid in the at least partially condensed state to yield chilling and uncondensed working fluid. The heat source may be an unutilized heat source.

[0009] The present application also provides a process for generating both power and chilling that includes absorbing a working fluid into a liquid sorbent to yield a liquid sorbent and absorbed working fluid, pressurizing the liquid

sorbent and absorbed working fluid to increased pressure, heating the pressurized liquid sorbent and absorbed working fluid to desorb the working fluid from the sorbent material in a supercritical state, directing the desorbed working fluid to drive a generator to generate power and to at least partially condense the desorbed working fluid, and evaporating the at least partially condensed desorbed working fluid to yield chilling and uncondensed working fluid. In one embodiment, the heating is provided by unutilized heat from one of a refining operation and chemical processing operation.

[0010] In accordance with another aspect of the present invention, a sorption system for generating power is disclosed. The sorption system includes a first vessel in fluid communication with a working fluid and a liquid sorbent material such that the working fluid is adsorbed in the liquid sorbent in the first vessel to yield a feed of liquid sorbent with an adsorbed working fluid. The working fluid is selected from carbon dioxide, methane, ethane, propane, butane, ammonia and chlorofluorocarbons. The feed of liquid sorbent with an adsorbed working fluid is fed to a heat source. The heat source may be an unutilized heat source which includes a vapor generator. The heat source disengages the liquid sorbent from the adsorbed working fluid to create a feed of working fluid at a supercritical state and a feed of liquid sorbent. A first generator is in fluid communication with the feed of working fluid at supercritical state to yield power and a feed of working fluid in an at least partially condensed state which is in fluid communication with the first vessel. The first generator may be turbo expander. A second generator is in fluid communication with the feed of liquid sorbent to yield power and a feed of liquid sorbent in fluid communication with the first vessel. The second generator may be a twin screw expander.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention will now be described in conjunction with the accompanying drawings in which:

Figure 1 is a schematic of a sorption system for the generation of chilling in accordance with an aspect of the present invention.

Figure 2 is a Mollier Diagram annotated to show four points that correspond to four stages of the sorption system described in Figure 1.

Figure 3 is a Mollier Diagram annotated to show alternative process points based on the use of waste heat to achieve a temperature of about 450°F and alternative process points based on the use of higher sorbing pressures for use in connection with the generation of chilling.

Figure 4 is a schematic of an adsorption system for the generation of power and/or chilling in accordance with an embodiment of the present application.

Figure 5 is a schematic of an absorption system for the generation of power and/or chilling in accordance with an embodiment of the present application.

Figure 6 is a schematic of an absorption system for the generation of power in accordance with an embodiment of the present application.

DETAILED DESCRIPTION OF THE INVENTION

[0012] The present application will now be described in greater detail in connection with the figures and the following terms.

[0013] As used herein, the term “sorbent material” refers to a material that reversibly binds a working fluid. Sorbent materials include, but are not limited to, absorbents and adsorbents.

[0014] As used herein, the term “working fluid” refers to a liquid or gas that can reversibly bind to the sorbent material.

[0015] As used herein, the term “generator” refers to a turbine, shaft or other mechanism driven by a working fluid (e.g., a working fluid pressurized by an absorption or adsorption system) to generate power or work.

[0016] As used herein, the term “vessel” refers to a container suitable for containing a sorbent material and a working fluid under suitable conditions to permit sorption (e.g., absorption or adsorption) and/or desorption.

[0017] As used herein, the term “waste heat,” “unutilized heat” or “unutilized heat source” refers to the residual or remaining heat source (e.g., steam) following the processing operation after the heat source has been used for its primary purpose in the refining or petrochemical processing operation. Unutilized heat is also referred to as waste heat. The unutilized heat or unutilized heat source refers to a heat source that is no longer of any use in refining and/or petrochemical processing operations and would traditionally be discarded. The unutilized heat can be provided as an unutilized heat stream. For example, but not limitation, unutilized heat can include steam that was employed in a heat exchanger used in petroleum and petrochemical processing, and is of no value to current processes and is being discarded.

[0018] As used herein, the term “pump” refers to a physical device that assists in transporting fluids and/or pressurizing fluids to an increased pressure.

[0019] As used herein, the term “efficiency” in context of the present invention is defined as the power plus chilling generated over the heat input.

[0020] As used herein, the term “twin screw expander” in the context of the present invention is defined as a device driven by high pressure liquid or mixed phase sorbent liquid to generate power or shaft work.

[0021] For purposes of illustration and not limitation, a zeolite 13X/CO₂ adsorption system 100 is provided, as depicted schematically in Figure 1. A Mollier Diagram for carbon dioxide at various temperatures and pressures for this embodiment is shown in Figures 2 and 3 for reference. In this embodiment, two vessels 111 and 112 are maintained in an adsorption mode and a desorption mode, respectively. When one vessel is in the adsorption mode, the other vessel is in the desorption mode and vice versa. In this example, the sorbent material is zeolite 13X and the working fluid is CO₂. For the vessel in the adsorption mode, carbon dioxide is adsorbed by the zeolite 13X at a pressure of about 140 psi and a temperature of about 95°F. These conditions are denoted in Figure 2 as Stage 1.

[0022] After adsorption is complete, the adsorbent bed is isolated (e.g., by operating the relevant valve (e.g., valve 141 for vessel 111 or valve 142 for vessel 112)) and heated using unutilized heat from a petroleum refining or chemical process. The adsorption mode can last for several seconds (e.g., 10 seconds) to several minutes. The duration of the adsorption mode varies based upon the adsorbent material and fluid selected. Unutilized heat 121 or 122 is applied to the vessel in order to desorb the carbon dioxide, thus initiating the desorption mode. Using the unutilized heat, the vessel is heated to about 212°F in this particular embodiment. A pressurized stream is generated due to desorption of CO₂ from the 13X sorbent material as the adsorbent bed heats to 212°F. In response to operation of a back pressure regulator valve (e.g., valve 113 for vessel 111 or valve 114 for vessel 112), high pressure CO₂ is released

from the vessel to pressure damper or cooler 115 at a preset pressure (e.g., ~ 1400 psig), which is denoted in Figure 2 as stage 2. The temperature of the CO₂ is approximately 212°F.

[0023] The pressurized CO₂ stream is cooled in the pressure damper/cooler 115 to approximately 110°F, which is denoted as stage 3 in Figure 2. As a result, the pressure of the cooled CO₂ stream in the line 131 is approximately 1380psi and the temperature is approximately 110°F. The cooled working fluid stream is subsequently expanded adiabatically using an expansion valve 116 to about 140 psi and -40°F, which is denoted as stage 4 in Figure 2. The expansion valve 116 may be a flow restrictor or a needle valve to restrict but not stop flow. This cooled stream 132 can be used as a high quality refrigeration load for many different applications within refineries or similar facilities where unutilized heat is readily available. For example, the refrigerated CO₂ can be directed to a heat exchanger 118 to chill process streams within refineries and chemical plants.

[0024] After performing the refrigeration operation within the exchanger 118, the carbon dioxide of this representative embodiment can have a temperature of about 60°F to 100°F and a pressure of about 140psi. The carbon dioxide working fluid 133 is then recycled back to one of the vessels for use in a subsequent adsorption mode.

[0025] The CO₂/zeolite 13X system has a pressure index of greater than 3.5. The pressure index is determined in accordance with the procedure set forth below.

[0026] Alternatively, higher temperature heat can be applied to desorb more working fluid molecules from the adsorption bed. As shown in Figure 3, and for purposes of illustration and not limitation, stage 2 is now stage 2A, in which a

higher-temperature unutilized heat source is used to heat the bed to 450°F, instead of 212°F. The pressurized stream is to be cooled to 110°F before expansion. It, therefore, will require a much higher amount of cooling media at stage 2. The efficiency of this alternative system based on a 450°F heat source, using the selection of zeolite 13X and carbon dioxide, will be significantly different as it requires higher level of heating and cooling. It is understood, however, that a selection of sorbent material and fluid based on a higher level heat pressure index can produce a sorption system that is better suited for a higher quality of heat.

[0027] For purposes of the above discussion, each vessel can be a shell in tube-type configuration with adsorbents in the tube. The vessel can have an inner diameter of about 5 ft and contains tubes having a length of about 20 ft. Other suitable vessels can be used. Furthermore, exchanges other than shell-in-tube heat exchanges can be selected based on ordinary skill in the art.

[0028] This example is provided for illustrative purposes; other sorbent materials and fluids can be used in the place of, or in addition to, zeolite 13X and CO₂. Additional details of similar adsorption systems are disclosed in U.S. Patent Application No. 12/603,243 entitled, "System Using Unutilized Heat for Cooling and/or Power Generation," which is incorporated by reference in its entirety herein.

[0029] In accordance with one aspect of the present application, an adsorption system for generating power and chilling is provided. The adsorption system includes a first vessel containing a sorbent material in fluid communication with a working fluid and operatively connected to a heat source to yield a feed of working fluid at a supercritical state, a generator in fluid communication with the feed of working fluid at supercritical state to yield

power and a feed of working fluid in an at least partially condensed state, and an evaporator in fluid communication with the feed of working fluid in the at least partially condensed state to yield chilling and a feed of uncondensed working fluid. In one embodiment, the heat source is an unutilized heat source or stream. For example, the unutilized heat source is from a chemical processing or petrochemical refining operation.

[0030] The system can also include a second vessel containing sorbent material in fluid communication with the working fluid and operatively connected to a heat source to yield a second feed of working fluid at a supercritical state. Each of the first vessel and the second vessel has a sorption mode and a desorption mode, wherein in the desorption mode the working fluid is released from the sorbent material in response to the heat source, and wherein in the sorption mode, the working fluid is sorbed by the sorbent material, wherein when the first vessel is operating in the adsorption mode, the second vessel is operating in the desorption mode and, wherein when the first vessel is operating in the desorption mode, the second vessel is operating in the adsorption mode.

[0031] For the purpose of illustration and not limitation, an adsorption system 400 in accordance with one aspect of the present application is illustrated in Figure 4. The adsorption system 400 includes a first vessel 411, a second vessel 412, a generator 413, and an evaporator 414 for which cooling is desired. The first and second vessel 411 and 412 can be a shell-in-tube type configuration with the sorbent material in the tubes. For example, the first and second vessels can have an inner diameter of about 5 feet and contain tubes having a length of about 20 feet. Other vessel sizes are considered to be well within the scope of the present application. Furthermore, the present application is not limited to shell-in-tube heat exchangers, other exchangers and other vessels can be selected based on ordinary skill in the art and are considered to be well within the scope

of the present application including but not limited to the use of sorbent beds, structured adsorbents, and hollow fiber adsorbents.

[0032] An unutilized heat stream 431 passes through the first vessel 411. Unutilized heat contained in the stream 431 passes through the walls of the line containing the stream into the first vessel 411. An unutilized heat stream 432 passes through the second vessel 412. Unutilized heat contained in the stream 432 passes through the walls of the line containing the stream into the second vessel 412. The unutilized heat streams 431 and 432 can supply from the same unutilized heat source or separate unutilized heat sources. Alternatively or additionally, vessels 411 and 412 can also be adapted to receive a feed of cooling media to regenerate the adsorbents housed therein.

[0033] A valve assembly 441 is interposed between the first vessel 411 and the generator 413. In this embodiment, the valve assembly 441 functions as a back pressure regulator which permits the working fluid to escape from the first vessel 411 at a predetermined or pre-set pressure. The predetermined or pre-set pressure can range, for example, from about 500 psig to about 3000 psig, which is dependent upon the amount of sorbent material contained in the vessel and the temperature of the unutilized heat stream. A second valve assembly 442 is interposed between the second vessel 412 and the generator 413. Like the first valve assembly 441, the second valve assembly 442 functions as a back pressure regulator, which permits the working fluid in the second vessel to escape from the second vessel 412 at a pre-set pressure.

[0034] In operation, the first vessel 411 is in fluid communication with a feed of working fluid 421 fed to the first vessel at pressure ~100 psia and temperature ~100 F. A control valve 451 controls the flow of working fluid to the first vessel 411. Similarly, the second vessel 412 is in fluid communication

with a feed of working fluid 421 fed to the second vessel at pressure 100 psia and temperature 100 F. A control valve 452 controls the flow of fluid to the second vessel 412. When the working fluid 421 is fed to the first vessel 411, the working fluid is adsorbed onto a sorbent material contained in the first vessel 411. Similarly, when the working fluid is fed to the second vessel 412, the working fluid is adsorbed onto the sorbent material contained in the second vessel 412.

[0035] In one embodiment, the first and second vessels 411 and 412 operate in tandem. The working fluid 421 flows into the first vessel 411 when the valve 451 is open. The valve 451 remains open until equilibrium is established within the first vessel 411. The adsorption mode can last for several seconds (e.g., ~10 seconds) to several minutes. The duration of the adsorption mode varies based upon the adsorbent material and fluid selected. The unutilized heat stream 431 passes through the first vessel 411 such that the sorbent material and the working fluid are heated, which results in the desorption of the working fluid from the sorbent material. This increases the pressure of the working fluid contained in the first vessel 411. Once the pre-set pressure is reached, the working fluid is released from the first vessel 411 via the valve assembly 441, to yield a feed of working fluid at a super-critical state 422 at pressure ~1600 psia and temperature ~255 F.

[0036] The feed of working fluid at a supercritical state 422 is used to run to the generator 413 to generate power. The generator is run using a turbine, a turboexpander or any other suitable device to create shaft work to be able to run the generator for power. It is also contemplated that the generator may also be used to drive rotating equipment such as pumps or compressors to perform work on a process stream. Additionally, the device yields a feed of working fluid in an at least partially condensed state 423 at a pressure about 100 psia and temperature -58 F. In one embodiment, the feed of working fluid at supercritical

state 422 passes through the generator to either generate electricity or perform work by driving a shaft or other suitable mechanism. In accordance with an aspect of the present invention, the amount of power generated is 0.95 megawatts (MW) based on 60,000 lb/hr CO₂ flow rate. It is contemplated that the amount of power generated may vary based upon the system components.

[0037] The feed of working fluid in an at least partially condensed state 423 is fed to an evaporator 414 to provide chilling and a feed of uncondensed working fluid. The uncondensed working fluid 421 is then to be reintroduced to the first or second vessel. In an exemplary embodiment the working fluid in an at least partially condensed state 423 is processed through an evaporator to generate chilling by using the latent heat of vaporization as well as sensible heat of the working fluid, although other suitable vessels to create chilling can be utilized. The chilling generated can be used in many refinery processes. For example, the chilling can be used in a heat exchanger to cool a process stream for refining or petrochemical processing operations. In such an arrangement, the unutilized heat, which normally would be lost, is recaptured and used to perform cooling of another process stream. For example, chilling can be used to cool water to provide cooling water to an overhead condenser in a distillation tower. Chilling can be used to recover gas molecules from a fuel stream. The chilling can also be used in cooling the air intake of a gas turbine generator to improve power output.

[0038] The present application is not intended to be limited for use in process streams in refining and petrochemical processing applications. It is contemplated that the heat exchanger can be used in connection with a building cooling system located in one of the buildings located at the facility such that the unutilized heat can be used to cool one or more of the buildings. It is also contemplated that the system can be used in connection with air conditioning using exhaust heat from automobiles.

[0039] If tandem processing is desired through the second vessel, the valve 451 is closed such that after the passing through the evaporator 414, the working fluid at a pressure close to 100 psia and temperature ~100 F, is fed to the second vessel through open control valve 452. The valve 452 remains open until equilibrium is established within the second vessel 412. As mentioned above, the adsorption mode can last for several seconds (e.g., ~10 seconds) to several minutes. The duration of the adsorption mode varies based upon the adsorbent material and fluid selected. The unutilized heat stream 432 passes through the second vessel 412 such that the sorbent material and the working fluid are heated, which results in the desorption of the working fluid from the sorbent material. This increases the pressure of the working fluid contained in the second vessel 412. Once the pre-set pressure is reached, the working fluid is released from the second vessel 412 via valve assembly 442, to yield a feed of working fluid at a supercritical state 422. The working fluid passes through the system, as described above. After passing through the evaporator 414, the working fluid is returned to the first vessel 411.

[0040] In this manner, the first and second vessels 411 and 412 are operated in tandem such that one is operating in an adsorption mode when the other is operating in a desorption mode and vice versa. With such an arrangement, the first and second vessels 411 and 412 operate to provide a continuous supply of working fluid to the generator 413.

[0041] In one embodiment of this application, the working fluid is selected from carbon dioxide, methane, ethane, propane, butane, ammonia and chlorofluorocarbons (e.g., FreonTM), other refrigerants, or other suitable fluids. The sorbent material is selected from zeolites, metal organic frameworks (MOFs), zeolitic imidazolate frameworks (ZIFs), ionic liquids, silicagel,

adsorbing polymers, carbon, and activated carbon, and combinations thereof. In one embodiment the working fluid is carbon dioxide and/or the sorbent material is a zeolite. In one embodiment the working fluid is carbon dioxide and the zeolite is a zeolite X, preferably a zeolite 13X.

[0042] The present application also provides an adsorption process for generating both power and chilling. The process includes adsorbing a working fluid onto a sorbent material, heating the sorbent material to desorb the working fluid from the sorbent material at a supercritical state, directing the desorbed fluid to drive a generator to generate power or do shaft work and to at least partially condense the desorbed working fluid, and evaporating the at least partially condensed desorbed fluid to yield chilling and a feed of uncondensed working fluid. The process can use any of the features described above for the adsorption system. In one embodiment, the heating is provided by unutilized heat from one of a refining operation and chemical processing operation. For example, the unutilized heat can be at a temperature of 450 F or lower

[0043] It is of note that the adsorption system and process described herein do not require the use of a pump or additional components to facilitate movement of the working fluid through the system.

[0044] In accordance with the present invention, it has been discovered that the generation of power and chilling simultaneously is a more efficient and economical use of waste heat available in refineries compared to the generation of chilling or power alone. It is desirable to simultaneously integrate power and chilling generation using waste heat within refinery and petro-chemical plants (e.g. in a distillation column, chilling can be used to lower the overhead temperature to improve throughput and power can be used to pump feed to the distillation column reboiler). The integration of recovered waste heat back in to refinery and petrochemical processes improves the efficiency of the individual

process and the facility as a whole reducing the need to consume additional fuel. This may result in a reduction of carbon dioxide emissions.

[0045] The table below compares generation of power and chilling together with power or chilling alone. The examples are based on the use of a CO₂-Zeolite 13X combination. The adsorber/desorber bed is a shell and tube design with sorbent material packed inside the tube. This comparison is based on same amount of gas flow 60,000 lb/hr CO₂. The equipment size of adsorber/desorber beds is related with thermal swing time of the process. Each adsorber/desorber vessel may have an inner diameter of about 5 ft and contains tubes having a length of about 20 ft. The process scheme illustrated in Figure 1 can be used for the chilling only case. To generate both power and chilling, the process scheme illustrated in Figure 4 can be utilized. To generate power only, the process scheme is similar to Figure 4 without the evaporator.

	Waste Heat MW _{TH}	Chilling MW _C	Power MW _E	Efficiency %	Inlet Pressure (psia)	Outlet Pressure (psia)	Inlet Temp (F)	Outlet Temp. (F)
Chilling Only	6.45	1.38	0	21.4	1600	100	112	-58
Power Only	6.45	0.0	0.95	14.7	1600	100	255	-58
Chilling + Power	6.45	0.73	0.95	26.0	1600	100	255	-58

[0046] In accordance with another aspect of the present application, an absorption system for generating power and chilling is provided. The absorption system includes an absorber to absorb a working fluid in a liquid sorbent, a pump in fluid communication with the absorber to yield a feed of pressurized liquid sorbent and absorbed working fluid, a heat source to heat the feed of pressurized liquid sorbent and absorbed working fluid to yield a feed of working fluid at a supercritical state, a generator in fluid communication with the feed of

working fluid at a supercritical state to yield power and a feed of working fluid in an at least partially condensed state, and an evaporator in fluid communication with the feed of working fluid in the at least partially condensed state to yield chilling and uncondensed working fluid.

[0047] For the purpose of illustration and not limitation, an absorption system 500 in accordance with one aspect of the present application is illustrated in Figure 5. The absorption system 500 includes an absorber 511, a pump 512, a vapor generator 513, a generator 514, an evaporator 515, a cooler 516 and a cooler 517.

[0048] In operation, the absorber 511 is in fluid communication with a working fluid 521 fed to the absorber at a first pressure (~560 psia) and a first temperature (~100 F) and a liquid sorbent 522. In the absorber 511, the working fluid 521 is absorbed in the liquid sorbent 522 to yield a liquid sorbent with an absorbed working fluid 523. The absorber 511 can be an absorption column or any other suitable vessel. During absorption there is heat generated in the absorber that can be removed from the absorber using cooling water, or any other suitable means, to maintain the absorber at a temperature favorable for absorbing the working fluid.

[0049] The pump 512 pumps the liquid sorbent with an absorbed fluid 523 from the absorber to a higher pressure to yield a feed of pressurized liquid sorbent and absorbed working fluid 524. The pressurized liquid sorbent and absorbed working fluid 524 is at a higher pressure (~1400 psia) and a second temperature (~104 F), generally greater than (100 F). The present invention is not intended to be limited to the specified pressures and temperatures; rather, other temperatures and pressures are considered to be well within the scope of

the present invention provided such temperatures and pressures are suitable for the pressurized liquid sorbent and absorbed working fluid.

[0050] The feed of pressurized liquid sorbent and absorbed working fluid 524 is heated using a heat source which can include a vapor generator 513, e.g., a rectification column or any other suitable vessel. The heat source 531 can pass through the vapor generator, to disengage the working fluid from the liquid absorbent to yield a feed of working fluid at a supercritical state 525 and the liquid sorbent 527, which is fed to a cooler 516 before the liquid sorbent 522 is returned to the absorber 511. The cooler 516 can be in fluid communication with the vapor generator and can include cooling water. The feed of working fluid at a supercritical state 525 from the vapor generator 513 is passed through a cooler 517 to reduce the temperature from ~275 F to ~60F. The pressure remains at ~1400 psia. Other temperatures and pressures are considered to be well within the scope of the present invention. The unutilized heat stream or source 531 can be operatively connected to the vapor generator 513 such that unutilized heat from the unutilized heat source can be transferred to the liquid sorbent with an absorbed fluid contained within the vapor generator.

[0051] The feed of working fluid at a supercritical state 525 is used to run to a generator 514 to generate power. The generator can be a turbine, a turboexpander or any other suitable device to generate power or work. A working fluid is selected such that the generator yields a feed of working fluid in an at least partially condensed state 526 at a pressure about ~560 psia and a temperature ~43 F less than 100 F. The present invention is not intended to be limited to the pressures and temperatures stated herein; rather, other temperatures and pressures are considered to be well within the scope of the present invention provided such temperatures and pressures yield the partially condensed state 526. In one embodiment, the feed of working fluid at

supercritical state 525 passes through the generator to either generate power or perform work by driving a shaft or other suitable mechanism. If implemented at a refinery, the power generated can be supplied to the power grid for refinery use or for supplying a third party. The amount of power generated by the system in accordance with the present invention may vary based upon the design of the system and the selected components. For example, the system may generate ~32 kilo watts (KW) of power based on 45,000 lb/hr mixture of CO₂ and amyl acetate (stream 525). The molar concentration of amyl acetate in 525 is 3%. It is contemplated that the system may generate amounts in excess of 32 KW based upon the system design and other constraints.

[0052] The working fluid in an at least partially condensed state 526 is fed to an evaporator 515 to yield chilling and uncondensed working fluid 521 to be fed to the absorber 511. The evaporator 515 can be in fluid communication with the absorber 511. In an exemplary embodiment the working fluid in an at least partially condensed state 526 is processed through an evaporator 515 to generate chilling by using the latent heat of vaporization of the working fluid, although other suitable vessels to create chilling can be utilized. The chilling generated can be used in many refinery processes. For example, the chilling can be used in a heat exchanger to cool a process stream for refining or petrochemical processing operations. In such an arrangement, the unutilized heat, which normally would be lost, is recaptured and used to perform cooling of another process stream. Chilling can be used to cool water to provide cooling water to an overhead condenser in a distillation tower. Chilling can also be used to recover gas molecules from a fuel stream. The chilling can also be used in cooling the air intake of a gas turbine generator to improve power output.

[0053] In accordance with another aspect of the present application, an absorption system for generating power is provided. Power is generated using both gas phase expansion and liquid phase expansion. The absorption system

includes an absorber to absorb a working fluid in a liquid sorbent, a pump in fluid communication with the absorber to yield a feed of pressurized liquid sorbent and absorbed working fluid, a heat source to heat the feed of pressurized liquid sorbent and absorbed working fluid to yield a feed of working fluid at a supercritical state, at least one generator.

[0054] For the purpose of illustration and not limitation, an absorption system 600 in accordance with one aspect of the present application is illustrated in Figure 6. The absorption system 600 includes an absorber 611, a pump 612, a vapor generator 613, generators 614 and 615, a cooler 616 and a cooler 617.

[0055] In operation, the absorber 611 is in fluid communication with a working fluid 621 fed to the absorber at a first pressure (~600psia) and a first temperature (~127 F) and a liquid sorbent 622. In the absorber 611, the working fluid 621 is absorbed in the liquid sorbent 622 to yield a liquid sorbent with an absorbed working fluid 623. The absorber 611 can be an absorption column or any other suitable vessel. During absorption there is heat generated in the absorber that can be removed from the absorber using cooling water, or any other suitable means, to maintain the absorber at a temperature favorable for absorbing the working fluid.

[0056] The pump 612 pumps the liquid sorbent with an absorbed fluid 623 from the absorber to a higher pressure to yield a feed of pressurized liquid sorbent and absorbed working fluid 624. The pressurized liquid sorbent and absorbed working fluid 624 is at a higher pressure (~1200 psia) and a second temperature (~102 F). The present invention is not intended to be limited to the specified pressures and temperatures; rather, other temperatures and pressures are considered to be well within the scope of the present invention provided such

temperatures and pressures are suitable for the pressurized liquid sorbent and absorbed working fluid.

[0057] The feed of pressurized liquid sorbent and absorbed working fluid 624 is heated using a heat source which can include a vapor generator 613, e.g., a rectification column or any other suitable vessel. The heat source 631 can pass through the vapor generator, to disengage the working fluid from the liquid absorbent to yield a feed of working fluid at a supercritical state 625 and the liquid sorbent 627, which is fed to a cooler 616 and then to a generator 615 before the liquid sorbent 622 is returned to the absorber 611. The generator 615 is suitable for use in liquid phase expansion to generate. The generator 615 may be a twin screw expander, but other power generating assemblies are considered to be well within the scope of the present invention. The cooler 616 can be in fluid communication with the vapor generator 613 and can include cooling water. The feed of working fluid at a supercritical state 625 is at a pressure (~1200 psia) and a temperature (~450 F). Other temperatures and pressures are considered to be well within the scope of the present invention. The unutilized heat stream or source 631 can be operatively connected to the vapor generator 613 such that unutilized heat from the unutilized heat source can be transferred to the liquid sorbent with an absorbed fluid contained within the vapor generator.

[0058] The feed of working fluid at a supercritical state 625 is used to run to a generator 614 to generate power. The generator 614 can be a turbine, a turboexpander or any other suitable device to generate power or work. A working fluid is selected such that the generator yields a feed of working fluid 626 at a pressure about ~600 psia and a temperature ~398 F. The present invention is not intended to be limited to the pressures and temperatures stated herein; rather, other temperatures and pressures are considered to be well within the scope of the present invention.

[0059] The working fluid 626 is fed to a cooler 617. The reduced temperature working fluid 621 from the cooler 617 is then fed back to the absorber 611.

[0060] While described, solely for the sake of convenience, largely in the context of a refining and petrochemical operation, the present application is not intended to be limited thereto. It is contemplated that, for example, the heat exchanger can be used in connection with a building cooling system located in one of the buildings located at the facility such that the unutilized heat can be used to cool one or more of the buildings.

[0061] Thus the absorption system generates power and chilling by recovering unutilized heat from an unutilized heat stream or source. The unutilized heat source can be used heat from a heat exchanger, or other process area of a chemical processing plant or petrochemical refining plant.

[0062] The absorption system includes a liquid sorbent or a mixture of liquid sorbents and a working fluid or a mixture of working fluids.

[0063] In various embodiments, various combinations of liquid sorbents and working fluids are considered to be within the scope of the present application. It should be noted that a combination that is suitable for application with a higher temperature unutilized heat stream may not be applicable for a lower temperature unutilized heat stream.

[0064] The liquid sorbent in the absorption system has an average heat of sorption (Q) between about 2 kcal/mole and about 25 kcal/mole, or more preferably between about 3 kcal/mole and about 10 kcal/mole.

[0065] In one embodiment of the present application, the working fluid is a gas and is selected from carbon dioxide, methane, ethane, propane, butane, ammonia, chlorofluorocarbons (e.g., FreonTM), other refrigerants, or other suitable fluids. The liquid sorbent is selected from water, ethylene glycols, Triethylene glycol, polyethylene glycol, polyethylene glycol dimethyl ether, N-methyl-2-pyrrolidone, dimethylsulfoxide, potassium carbonate, amyl acetate, acetone, pyridine, ethyl alcohol, methyl alcohol, acetic acid, isobutyl acetate, acetic anhydride, ionic liquids, etc., or other suitable liquids and combinations thereof. In one embodiment, the working fluid is carbon dioxide and/or the liquid sorbent is N-methyl-2-pyrrolidone and ionic liquids.

[0066] In accordance with another aspect of the present application, a process for generating power and chilling is provided. The process includes absorbing a working fluid into a liquid sorbent to yield a liquid sorbent and absorbed working fluid, pressurizing the liquid sorbent and absorbed working fluid to increased pressure, heating the pressurized liquid sorbent and absorbed working fluid to desorb the working fluid from the sorbent material in a supercritical state, directing the desorbed working fluid to drive a generator to generate power and to at least partially condense the desorbed working fluid, and evaporating the at least partially condensed desorbed working fluid to yield chilling and uncondensed working fluid. The process can use any of the features described above for the absorption system. In one embodiment, the heating is provided by unutilized heat from one of a refining operation and chemical processing operation. For example, the unutilized heat is at a temperature of 450°F or lower.

Pressure Index

[0067] Embodiments of the present application employ a “pressure index” that can be determined at various desorbing temperatures, which is used to determine suitable combinations of a sorbent material and a working fluid. These combinations are especially adaptable to be used in the sorption process disclosed herein, since they collectively maximize pressurization of working fluid (ΔP) from available energy sources, which are often, but not necessarily, low grade heat sources primarily intended to be used for some other specific purpose (e.g., waste heat).

[0068] The pressure index is determined by the following method. One hundred (100) grams of sorbent material are placed in a 1 liter vessel designed to be isolated from associated equipment with existing valves on both ends of the vessel. The vessel also has indicators to measure the inside pressure and temperature. The vessel is flushed and filled with a pure fluid (e.g., CO_2) at one atmospheric pressure. The sorbent material adsorbs fluid and the sorbent may heat up. The vessel is equilibrated at 298 K (77 °F) and 1 atmospheric pressure, this sorbing pressure being defined as $P_I = 1.0$. The vessel is heated to a pre-selected desorbing temperature (e.g., 348 K i.e. 167 °F). When the vessel and sorbent material reach the pre-selected desorbing temperature, the internal vessel pressure is measured to determine P_F . The pressure index is defined as the ratio of P_F to P_I .

[0069] As noted above, embodiments of the present application make use of a lower temperature of unutilized heat. In order to select a sorbent material/fluid combination that is preferred for use with low level heat (e.g., sorption systems that utilize low grade unutilized heat), it is often desirable or necessary to

ascertain at least the low level heat pressure index, as determined above. A pressure index of at least 1.5 is generally appropriate for use in low level unutilized heat applications. Nevertheless, other embodiments of the present application can use high level heat sources. Thus in these embodiments, it is desirable to select a high level heat pressure index. In such cases, combinations of sorbent material and working fluid can have a pressure index as low as 1.2.

Sorbent Materials

[0070] As noted above, and as used in this application, the term “sorbent material” refers to a material that reversibly binds the working fluid. Sorbent materials include, but are not limited to, absorbents and adsorbents.

[0071] Absorbent materials that can be used in embodiments of the present application include, but are not limited to, water, glycols, amyl acetate, acetone, pyridine, ethyl alcohol, methyl alcohol, acetic acid, isobutyl acetate, acetic anhydride, ionic liquids, etc.

[0072] Adsorbent materials that can be used in embodiments of the present application include, but are not limited to, metal-organic framework-based (MOF-based) sorbents, zeolitic imidazole framework (ZIF) sorbent materials, zeolites and carbon.

[0073] MOF-based sorbents include, but are not limited to, MOF-based sorbents with a plurality of metal, metal oxide, metal cluster or metal oxide cluster building units. As disclosed in International Published Application No. WO 2007/111738, which is hereby incorporated by reference, the metal can be selected from the transition metals in the periodic table, and beryllium. Exemplary metals include zinc (Zn), cadmium (Cd), mercury (Hg), beryllium

(Be) and copper (Cu). The metal building units can be linked by organic compounds to form a porous structure, where the organic compounds for linking the adjacent metal building units can include 1,3,5-benzenetribenzoate (BTB); 1,4-benzenedicarboxylate (BDC); cyclobutyl 1,4-benzenedicarboxylate (CB BDC); 2-amino 1,4 benzenedicarboxylate (H₂N BDC); tetrahydropyrene 2,7-dicarboxylate (HPDC); terphenyl dicarboxylate (TPDC); 2,6 naphthalene dicarboxylate (2,6-NDC); pyrene 2,7-dicarboxylate (PDC); biphenyl dicarboxylate (BDC); or any dicarboxylate having phenyl compounds.

[0074] Specific materials MOF-based sorbent materials include: MOF-177, a material having a general formula of $\text{Zn}_4\text{O}(\text{1, 3, 5-benzenetribenzoate})_2$; MOF-5, also known as IRMOF-I, a material having a general formula of $\text{Zn}_4\text{O}(\text{1,4-benzenedicarboxylate})_3$; IRMOF-6, a material having a general formula of $\text{Zn}_4\text{O}(\text{cyclobutyl 1,4-benzenedicarboxylate})$; IRMOF-3, a material having a general formula of $\text{Zn}_4\text{O}(\text{2-amino 1,4 benzenedicarboxylate})_3$; and IRMOF-11, a material having a general formula of $\text{Zn}_4\text{O}(\text{terphenyl dicarboxylate})_3$, or $\text{Zn}_4\text{O}(\text{tetrahydropyrene 2,7-dicarboxylate})_3$; IRMOF-8, a material having a general formula of $\text{Zn}_4\text{O}(\text{2,6 naphthalene dicarboxylate})_3$; and Cu-BTC MOF, a material having a general formula of $\text{C}_{18}\text{H}_6\text{Cu}_3\text{O}_{12}$ (copper benzene-1,3,5-tricarboxylate).

[0075] Exemplary zeolitic imidazole framework (ZIF) sorbent materials include, but are not limited to, ZIF-68, ZIF-60, ZIF-70, ZIF-95, ZIF-100 developed at the University of California at Los Angeles and generally discussed in Nature 453, 207-211 (8 May 2008), hereby incorporated by reference in its entirety.

[0076] Zeolite adsorbent materials include, but are not limited to, aluminosilicates that are represented by the formula $\text{M}_{2/n}\text{O} \cdot \text{Al}_2\text{O}_3 \cdot y\text{SiO}_2 \cdot w\text{H}_2\text{O}$,

where y is 2 or greater, M is the charge balancing cation, such as sodium, potassium, magnesium and calcium, N is the cation valence, and w represents the moles of water contained in the zeolitic voids. Examples of zeolites that can be included in the methods and systems of the present application include natural and synthetic zeolites.

[0077] Natural zeolites include, but are not limited to, chabazite (CAS Registry No. 12251-32-0; typical formula $\text{Ca}_2[(\text{AlO}_2)_4(\text{SiO}_2)_8] \cdot 13\text{H}_2\text{O}$), mordenite (CAS Registry No. 12173-98-7; typical formula $\text{Na}_8[(\text{AlO}_2)_8(\text{SiO}_2)_{40}] \cdot 24\text{H}_2\text{O}$), erionite (CAS Registry No. 12150-42-8; typical formula $(\text{Ca}, \text{Mg}, \text{Na}_2, \text{K}_2)_{4.5}[(\text{AlO}_2)_9(\text{SiO}_2)_{27}] \cdot 27\text{H}_2\text{O}$), faujasite (CAS Registry No. 12173-28-3, typical formula $(\text{Ca}, \text{Mg}, \text{Na}_2, \text{K}_2)_{29.5}[(\text{AlO}_2)_{59}(\text{SiO}_2)_{133}] \cdot 235\text{H}_2\text{O}$), clinoptilolite (CAS Registry No. 12321-85-6, typical formula $\text{Na}_6[(\text{AlO}_2)_6(\text{SiO}_2)_{30}] \cdot 24\text{H}_2\text{O}$) and phillipsite (typical formula: $(0.5\text{Ca}, \text{Na}, \text{K})_3[(\text{AlO}_2)_3(\text{SiO}_2)_5] \cdot 6\text{H}_2\text{O}$).

[0078] Synthetic zeolites include, but are not limited to, zeolite A (typical formula: $\text{Na}_{12}[(\text{AlO}_2)_{12}(\text{SiO}_2)_{12}] \cdot 27\text{H}_2\text{O}$), zeolite X (CAS Registry No. 68989-23-1; typical formula: $\text{Na}_{86}[(\text{AlO}_2)_{86}(\text{SiO}_2)_{106}] \cdot 264\text{H}_2\text{O}$), zeolite Y (typical formula: $\text{Na}_{56}[(\text{AlO}_2)_{56}(\text{SiO}_2)_{136}] \cdot 250\text{H}_2\text{O}$), zeolite L (typical formula: $\text{K}_9[(\text{AlO}_2)_9(\text{SiO}_2)_{27}] \cdot 22\text{H}_2\text{O}$), zeolite omega (typical formula: $\text{Na}_{6.8}\text{TMA}_{1.6}[(\text{AlO}_2)_8(\text{SiO}_2)_{28}] \cdot 21\text{H}_2\text{O}$, where TMA is tetramethylammonium) and ZSM-5 (typical formula: $(\text{Na}, \text{TPA})_3[(\text{AlO}_2)_3(\text{SiO}_2)_{93}] \cdot 16\text{H}_2\text{O}$, where TPA is tetrapropylammonium).

[0079] Zeolites that can be used in the embodiments of the present application also include the zeolites disclosed in the Encyclopedia of Chemical Technology by Kirk-Othmer, Volume 16, Fourth Edition, under the heading “Molecular Sieves,” which is hereby incorporated by reference in its entirety.

[0080] Synthetic zeolite sorbent materials are commercially available, such as under the Sylosiv[®] brand from W.R. Grace and Co. (Columbia, Md.) and from Chengdu Beyond Chemical (Sichuan, P.R. China). For example, Sylosiv[®] A10 is one commercially available zeolite 13 X product.

Working Fluids

[0081] As noted above, the term fluid refers to a liquid or gas that reversibly binds to the sorbent material. Non-limiting examples of fluids that can be used in accordance with the present application include carbon dioxide, methane, ethane, propane, butane, ammonia, chlorofluorocarbons (e.g., Freon[™]), and other suitable fluids and refrigerants. In certain particular embodiments, any suitable fluid or refrigerant satisfying the above-described pressure index can be used.

Selection of Sorbent Materials and Fluids

[0082] In accordance with another aspect of the invention, a method is provided for selecting a sorbent material and a working fluid for use in combination in an unutilized-heat sorbent system within a chemical processing or petrochemical refining operation. The method generally includes identifying a sorbent that meets the pressure index criterion of at least 1.5. In one embodiment, the sorbent material and the working fluid for use in combination are selected if the measured internal pressure within the secured chamber is at least two times, or at least three times, or at least four times, or at least six times, or at least eight times the sorbing pressure. The sorption system can be used to generate power and chilling. The above-described method is not applicable to absorption systems.

Heat of Sorption

[0083] Preferably, the sorbent material and fluid couple has an average heat of sorption (Q) from about 2 kcal/mole to about 25 kcal/mole, and more preferably from about 4 kcal/mole to about 10 kcal/mole for heat sources up to 450 °F. The heat of sorption should be between 2 kcal/mole to about 40 kcal/mole if a higher temperature heat source (e.g., greater than 450 °F and up to 1700 °F) is available. The sorbent material should also have a high capacity for the working fluid.

Uses of Sorbent Systems of the Present Application

[0084] The adsorbent systems of the present application can be used in various applications provided the setting allows for the presence of a vessel that contains a sorbent material, a supply of working fluid, a heat supply and means to effectively direct the desorbed fluid to a generator to generate power and a evaporator to provide chilling. For example, the desorbed gas can be directed to a turboexpander to provide power.

[0085] The absorbent systems and methods of the present application can be used in various applications provided the setting allows for the presence of a absorber for absorbing a working fluid in a liquid sorbent and a vapor generator for desorbing the working fluid from the liquid sorbent, a supply of working fluid, a heat supply and a pump, and means to effectively direct the desorbed fluid to a generator to generate power and a evaporator to provide chilling thereto.

[0086] Possible applications for sorption systems of the present application include residential (for generating air conditioning in the summer and a heat

pump in the winter), vehicular (where the on-board air conditioning utilizes exhaust heat) and industrial (refining and chemical plants).

[0087] In one embodiment of the present application, the sorbent system or method is used within a chemical or petrochemical plant, and the desorbed fluid is used to generate power and to provide chilling to aid in other process areas, particularly areas that rely on temperature differences to separate components of a mixture. For example, the chilling can be used to recover liquefied petroleum gas (LPG, C³⁺) from flue gases going up a stack, or the chilling can be used to operate condensers to improve the effectiveness of vacuum distillation columns, particularly in the summer months.

[0088] By proper selection of the sorbent material and working fluid, the sorbent system or method can make effective use of lower grade heat than previously provided by sorption systems in the prior art. For example, in one embodiment of the present application, the heat supply is “unutilized heat” which has a temperature of from about 70°C (158 F) to about 300°C (572 F), more preferably from about 90°C (194 F) to about 180°C (356 F).

[0089] The present application is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

[0090] It is further to be understood that all values are approximate, and are provided for description.

[0091] Patents, patent applications, publications, product descriptions, and protocols are cited throughout this application, the disclosures of each of which is incorporated herein by reference in its entirety for all purposes.

CLAIMS:

1. A sorption system for generating power and chilling, comprising:
 - (a) a first vessel containing a sorbent material in fluid communication with a working fluid and operatively connected to a heat source to yield a feed of working fluid at a supercritical state;
 - (b) a first generator in fluid communication with the feed of working fluid at supercritical state to yield power and a feed of working fluid in an at least partially condensed state; and
 - (c) an evaporator in fluid communication with the feed of working fluid in the at least partially condensed state to yield chilling and a feed of uncondensed working fluid.
2. The sorption system of claim 1, wherein the sorbent material is selected from zeolites, metal organic frameworks (MOFs), zeolitic imidazolate frameworks (ZIFs), silicagel, adsorbing polymers, carbon, and activated carbon, and combinations thereof.
3. The sorption system of claim 2, wherein the sorbent material is a zeolite.
4. The sorption system according to anyone of the preceding claims, further comprising: a second vessel containing sorbent material in fluid communication with the working fluid and operatively connected to a heat source to yield a second feed of working fluid at a supercritical state.
5. The sorption system of claim 4, wherein each of the first vessel and the second vessel has a sorption mode and a desorption mode, wherein in the desorption mode the working fluid is released from the sorbent material in

response to the heat source, and wherein in the sorption mode, the working fluid is sorbed by the sorbent material, wherein when the first vessel is operating in the adsorption mode, the second vessel is operating in the desorption mode and, wherein when the first vessel is operating in the desorption mode, the second vessel is operating in the sorption mode.

6. A sorption system for generating power and chilling, comprising:
 - (a) an absorber to absorb a working fluid in a liquid sorbent;
 - (b) a pump in fluid communication with the absorber to yield a feed of pressurized liquid sorbent and absorbed working fluid;
 - (c) a heat source to heat the feed of pressurized liquid sorbent and absorbed working fluid to yield a feed of working fluid at a supercritical state;
 - (d) a first generator in fluid communication with the feed of working fluid at a supercritical state to yield power and a feed of working fluid in an at least partially condensed state; and
 - (e) an evaporator in fluid communication with the feed of working fluid in the at least partially condensed state to yield chilling and uncondensed working fluid.

7. The sorption system of claim 6, wherein the evaporator is in fluid communication with the absorber.

8. A sorption system for generating power, comprising:
 - (a) a first vessel in fluid communication with a working fluid and a liquid sorbent material, wherein the working fluid is adsorbed in the liquid sorbent in the first vessel to yield a feed of liquid sorbent with an adsorbed working fluid;
 - (b) a heat source in fluid communication with the feed of liquid sorbent with the adsorbed working fluid and a heat source, wherein the heat source disengages the liquid sorbent from the adsorbed working fluid to create a feed of working fluid at a supercritical state and a feed of liquid sorbent;

(c) a first generator in fluid communication with the feed of working fluid at supercritical state to yield power and a feed of working fluid in an at least partially condensed state in fluid communication with the first vessel; and

(d) a second generator in fluid communication with the feed of liquid sorbent to yield power and a feed of liquid sorbent in fluid communication with the first vessel.

9. The sorption system according to claim 8, wherein the second generator is a twin screw expander.

10. The sorption system according to any one of the preceding claims, wherein the first generator is a turbo expander.

11. The sorption system according to any one of the preceding claims, wherein the heat source is an unutilized heat source.

12. The sorption system of claim 11, wherein the heat source includes a vapor generator.

13. The sorption system of claim 12, further comprising a cooler in fluid communication with the vapor generator.

14. The sorption system of claim 13, wherein the cooler includes cooling water.

15. The sorption system according to any one of claims 11 to 14, wherein the vapor generator is a rectification column.

16. The sorption system according to any one of the preceding claims, wherein the working fluid is selected from carbon dioxide, methane, ethane, propane, butane, ammonia and chlorofluorocarbons.

17. The sorption system of claim 16, wherein the working fluid is carbon dioxide.

18. A process for generating power and chilling comprising:
adsorbing a working fluid onto a sorbent material;
heating the sorbent material to desorb the working fluid from the sorbent material at a supercritical state;
directing the desorbed fluid to drive a generator to generate power and to at least partially condense the desorbed working fluid; and
evaporating the at least partially condensed desorbed fluid to yield chilling and a feed of uncondensed working fluid.

19. The process of claim 18, wherein the sorbent material is selected from zeolites, metal organic frameworks (MOFs), zeolitic imidazolate frameworks (ZIFs), silicagel, adsorbing polymers, carbon, and activated carbon, and combinations thereof.

20. The process of claim 19, wherein the sorbent material is a zeolite.

21. A process for generating power and chilling comprising:
absorbing a working fluid into a liquid sorbent to yield a liquid sorbent and absorbed working fluid;
pressurizing the liquid sorbent and absorbed working fluid to increased pressure;
heating the pressurized liquid sorbent and absorbed working fluid to desorb the working fluid from the sorbent material in a supercritical state;

directing the desorbed working fluid to drive a generator to generate power and to at least partially condense the desorbed working fluid; and
evaporating the at least partially condensed desorbed working fluid to yield chilling and uncondensed working fluid.

22. A process for generating power, comprising:
absorbing a working fluid into a liquid sorbent to yield a liquid sorbent and absorbed working fluid;
pressurizing the liquid sorbent and absorbed working fluid to increased pressure;
heating the pressurized liquid sorbent and absorbed working fluid to desorb the working fluid from the liquid sorbent in a supercritical state;
directing the desorbed working fluid to drive a first generator to generate power and to at least partially condense the desorbed working fluid; and
directing the liquid sorbent to drive a second generator to generate power.

23. The process according to any one of claims 18 to 22, wherein the working fluid is selected from carbon dioxide, methane, ethane, propane, butane, ammonia and chlorofluorocarbons.

24. The process according to claim 23, wherein the working fluid is carbon dioxide.

25. The process according to any one of claims 18 to 24, wherein the heating is provided by unutilized heat from one of a refining operation and chemical processing operation.

26. The process according to claim 25, wherein the unutilized heat is at a temperature of 450 °F or lower.

27. The process according to any one of claims 18 to 26, wherein the generator is a turboexpander.