THERMO-CHEMICAL HEAT PUMP

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Summary

Reason for Technology Implementation: The thermo-chemical heat pump geothermal—based process should provide environmentally safe and renewable baseline electrical power at costs less than other technologies. It can be employed on a large scale. Utilization of heated water surfaced from Texas presently drilled oil and gas wells has potential to provide 2,000 megawatts electrical generating capacity. Further, the process may give economic life to wells that have past their fossil fuel delivery usefulness.

Technology: Lower temperature liquids from existent sources can be used to produce higher temperatures suitable for electricity generation. The liquids heat exchange with air thereby raising its temperature while the air is maintained saturated with water. Desiccant is employed to raise the temperature of the moisture-saturated air by its dehumidification. This air may be employed directly or exchange its heat with turbine loop fluids.

Technology Status: The technology has been advanced during the past 20 years with over 40 patents granted internationally and three additional including the heat pump are pending. All except one proprietary module of the thermo-chemical heat pump have had commercial application.

Commercialization: The patent pending technology is to be licensed to an entity with technology and commercial adequacies.

Why Geothermal Energy?

"Geothermal power – using the enormous heat generated in the earth's core by the radioactive decay of unstable elements - could prove to be the cleanest, greenest, and most abundant source of energy we have ever used."[1] "It currently produces 65 percent more power than solar and wind combined."[2] "In addition to the benefits, however, geothermal power also has some risks. The up-front investment required to start up a geothermal facility is very high, and the risk of the system's under-producing is non-trivial.[3]

Why Utilize Geothermal Water from Oil and Gas Wells?

Lower cost, risk reduction, and resource abundance. The wells are already drilled. Their characteristics have been plotted. The guess work of water flow and temperature has been removed. The USDOE Geothermal Technologies Program reports that more than 12 billion barrels of water are currently produced each year from oil and gas wells in Texas.[4] The *Oil and Gas Journal* reports the possibility of generating 500MW up to 2,000 MW of electricity from existing Texas oil and gas wells.[5] These studies are based on a minimum acceptable well head temperature. For example, a Southern Methodist University Geothermal Laboratory report limits review of geothermal electrical production from hydrocarbon wells to temperatures above 225°F.[6]

Why Elevate Geothermal Water Temperature?

First, the resource base is expanded. A plot of temperature-depth points from over 5,000 wells in eight Texas counties placed the highest concentration of wells with liquid temperatures between 160°F and 225°F [7]. Second, process efficiency is significantly improved. As discussed later, elevation of top process temperature from 225°F to 345°F increases theoretical efficiency by 60%. Together, resource expansion and temperature elevation should allow increased potential of geothermal fluids utilization for electricity production.

Electrical Supply

The need for electricity is projected to jump by 50% by 2030.[8] Present electricity production is dominated by coal, gas, and nuclear. Gas is not a long term option as the US Energy Information Administration reports natural gas to be supply limited with expected growth to be only two percent per year through 2030 with this growth derived from imports of LNG.[9] Nuclear expansion is uncertain. According to the Oxford Research Group "Another way of putting it is to say that if all the electrical energy used today were to be obtained from nuclear power, all known useful reserves of uranium would be exhausted in less than three years." [10] This leaves coal as the fall-back energy source. The "Christian Science Monitor" states the United States is on track to add 72 coal-fired plants in the next eight years and 1,200 300 megawatt power plants over the next 25 years.[11] This may not be an economical fix. There will probably be rulings regarding CO_2 capture that will drive up costs. An 800 megawatt plant consumes 2.5 million tons of coal per year leading to emission of 6 million tons of carbon dioxide.[12] The Electric Power Research Institute places the cost of power to be 60 to 80% higher as a result of CO_2 capture and sequester.[13] This is supported in a report by MIT which estimates expenditures of $30 per ton (America's utilities produce 1.5 billion tons a year) with the cost of coal-based electricity increasing from $0.05 to $0.08 per kilowatt hour.[14] Additionally, the price of coal is increasing. Merrill Lynch reports the 2008 contract price of coal for Asian utilities has increased from $55 per ton to $135 a ton in the past year.[15]

Electric power from renewable sources is either baseline such as hydro and geothermal or intermittent such as or wind or solar. In value to the electrical grid, baseline generation is worth three to four times the indefinite supplies. Beyond irregularity, wind peaks in the hour after midnight. “Transmission lines are rated for the peak load that a wind farm might produce… In Texas, wind farms use just 8% of their grid capacity because it’s often blowing at the wrong time.”[16] Photovoltaic or thermal solar power follows human living patterns but peaks nearly three hours before maximum summer grid loading.[17] Capital costs of wind and solar are based on “nameplate” capacity, where it appears that capital costs are similar to costs of a coal-fired plant. Recent reported price reductions for wind and solar towards $1.00 a kilowatt for equipment plus another $1.00 for installation[18] do not represent true capital costs. The reason is dictated by nature. Wind is effective 30% of the time[19] so real capital costs are not $2.00 but rather

This represents an improvement of 67% allowing a similar reduction in turbine and generation equipment size. Additionally, lower temperatures become practical. For instance, 185°F is calculated to increase to 345°F and 160°F to 275°F. The upward temperature increase has been limited by the desiccant presently employed and may be expanded in the future.

Adiabatic Processes

The heat pump is an offshoot of a very ancient technology. Hanging wetted sheets in air flows to reduce temperatures was documented in the Middle East some 4,500 years ago. This activity is now known as evaporative cooling and the exchange is referred to as “adiabatic” as there is no energy change in the air. In thermodynamics this process of changing moisture for heat is known to be reversible. Adding moisture to air will cause its temperature to reduce. Conversely, removing moisture from the air will cause its temperature to increase. In the first, air is subjected to water; in the second, air is in contact with a desiccant. The technology employed herein makes use of both but also changes energy content of the air by adding and taking away heat.

Heat Pump Structure

A process to utilize a range of low temperature resources (140 degrees to 225 degrees F) to produce elevated temperatures (to 345 degrees) suitable for electrical power generation is described. As seen in the following diagram, temperature elevation is accomplished by maintaining a saturated airflow while extracting energy from the low temperature resource. This higher temperature saturated air is subjected to a counter-current flow of liquid desiccant that provides an adiabatic exchange by absorbing moisture from saturated air thereby elevating its temperature.

The high temperature air exchanges heat with the second closed loop that supplies energy to the turbine. The air, with a reduced energy, is cycled to again contact the low temperature resource. An ambient air stream, once heated by the low temperature resource to reduce its relative humidity, is utilized to evaporate moisture from the desiccant.

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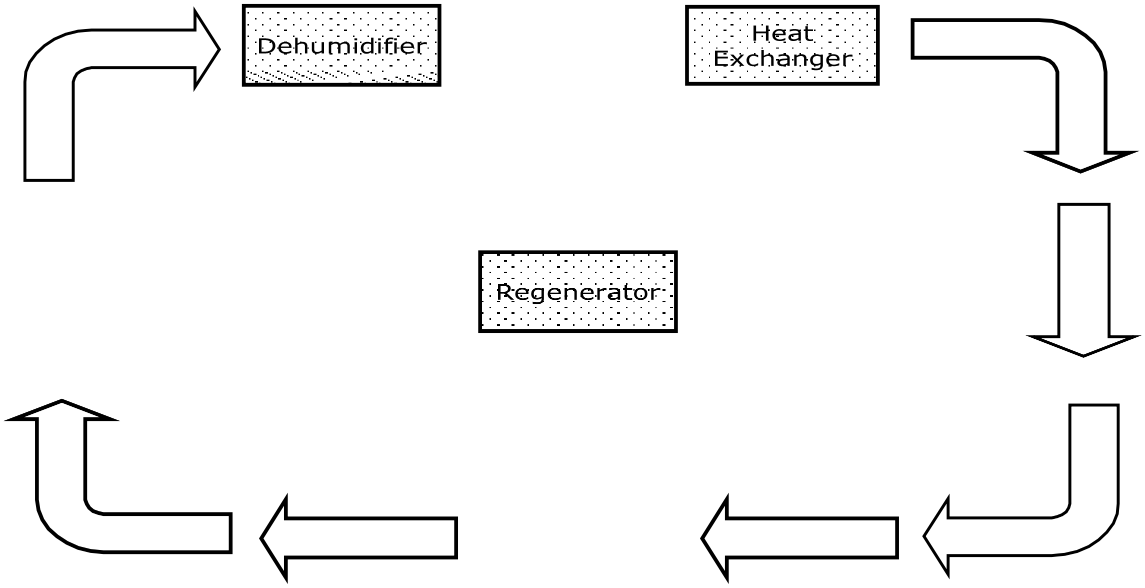
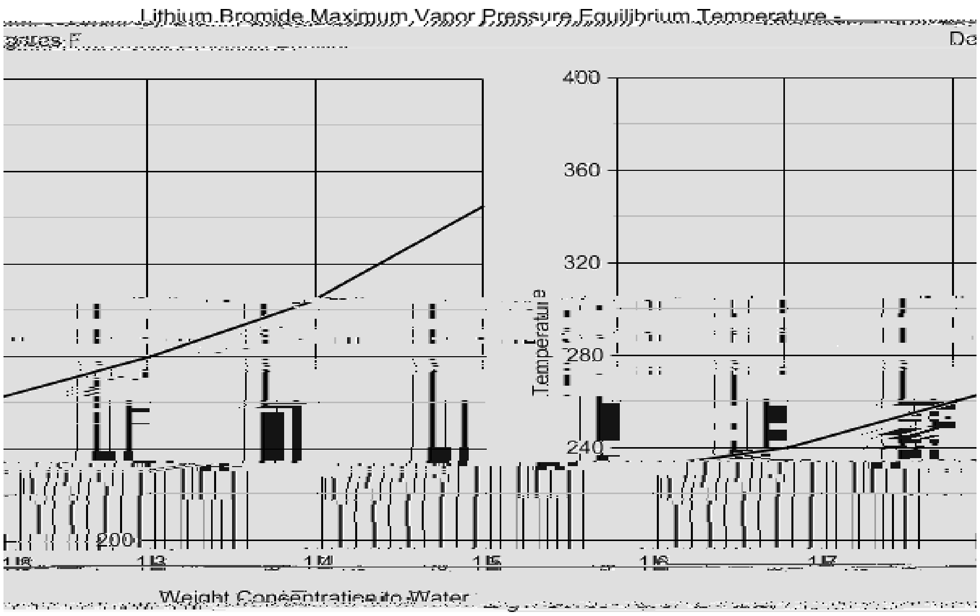
The thermo-chemical heat pump is projected to utilize 300 GPM to provide generation of 250 kW using a 185°F feed-stock elevated to 340°F (detailed in Appendix 1). A reduced temperature resource of 160°F allows the temperature increase to the turbine loop to 275°F The high temperature air exchanges heat with the second closed loop that supplies energy to the turbine. The air, with a reduced energy, is cycled to again contact the low temperature resource. An ambient air stream, once heated by the low temperature resource to reduce its relative humidity, is utilized to evaporate moisture from the desiccant. (Appendix 2) The resource flow rate can remain at approximately 300 gallons per minute for generation of 250 kW.



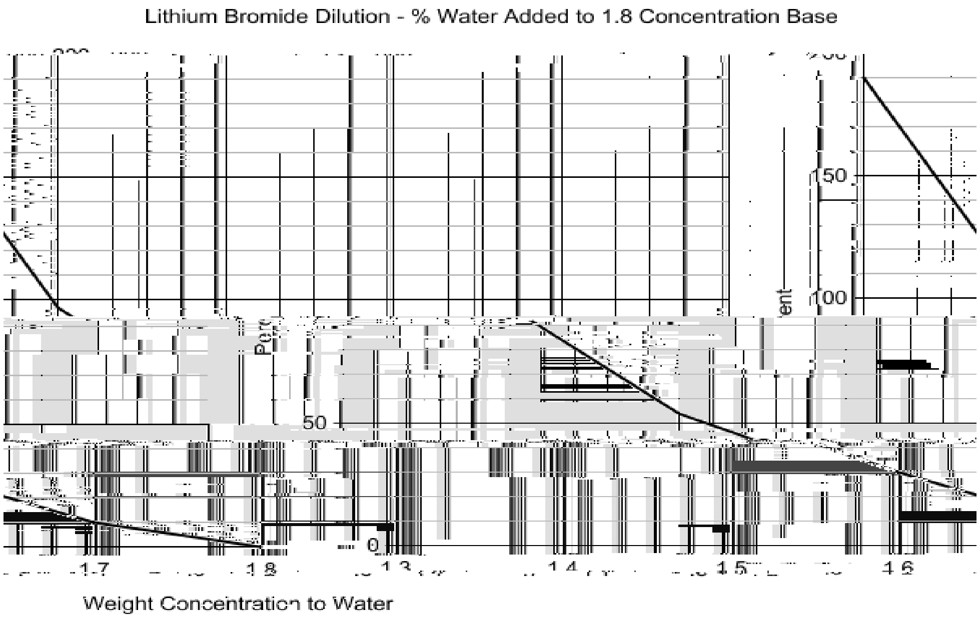
in this context is referred to as saturated when vapor pressure of the water in the air is at the equilibrium vapor pressure for water vapor at the temperature of the gas and generally overlooked in the literature. As seen in the graph just shown, at 180°F the enthalpy of a pound of air is nearly 800 Btu, a level that represents 70% the enthalpy contained in a pound of steam.

pressures of the gas and liquid. For instance, balance at a1.5 concentration is 260°F while at 1.8 balance exceeds 260°F.



Btu giving 112 Btu per pound

change of desiccant concentrations. When looking at lithium bromide, the amount of water absorbed greatly increases as the desiccant dilutes. Seen in the graph following,



movement from the 1.8 concentration (utilized as the measurement base) to a concentration of 1.7 causes the addition of only 11% more water whereas the dilution from 1.4 to 1.3 requires a dilution of 90%. Overall there is absorption of 190% when compared with an initial 1.8 concentration.

Partial removal of absorbed water from a dilute liquid desiccant may be accomplished by contacting the desiccant with a ambient air stream, especially in dryer climatic conditions. Supplemental heating of an ambient air stream significantly reduces the relative humidity levels. Using an earlier ex providing its temperature elevation and continual saturation. In the dehumidification module the air stream is directly contacted counter-currently by the desiccant. The module transferring heat to the turbine loop is more complicated as the high temperature and dry air is continually dehydrated as its temperature falls while giving up heat to the pressurized fluid within the turbine loop. The regenerator follows the same format. Size of modules is primarily dictated by air velocity through the media. The largest modules, the saturator and regenerator, would have an active face area 10 feet wide and 8 feet high with a media depth of 4 feet. These si

15. Coal seen rising 3 fold, to hit record