SYSTEM AND PROCESS FOR STORING COLD ENERGY

FIELD OF THE INVENTION

The present invention relates generally to thermodynamically stable energy storing systems and methods. More particularly, the invention relates to a system and process for storing cold energy.

BACKGROUND OF THE INVENTION

In the United Stated (U.S.), more than 90% of budding space cooling and refrigeration is provided by vapor compression (VC) based systems. Modern compressors are highly efficient, but are now approaching their theoretical and technological limits. In addition to the efficiency plateau, VC technology has environmental issues. For example, VC refrigerants such as hydrochlorofluorocarbons (HCFC) or halofluorocarbons (HFC) are a significant source of green house gas (GHG) emissions. Global warming potential (GWP) for VC refrigerants is as high as 1000 times that of CO_2. According to 2008 Buildings Energy Data, with VC as the dominate technology, building space cooling and refrigeration will consume 7.46 quads of primary electricity and generate 447 million metric tons (MMT) of CO_2 emissions by the year 2030. This will be equivalent to ~5% of primary energy consumption and ~5% of CO_2 emissions in the U.S. alone. As such, there is an urgent need to develop new and affordable cooling technologies to enhance overall energy efficiencies and reduces GHG emissions. A number of alternative technologies are under development including electrocaloric, magnetocaloric, thermoacoustic, and thermoelectric. Magnetocaloric cooling (MC) is currently considered a front runner among these technologies due to its higher efficiency and elimination of HCFC/HFC refrigerants. However, MC is inherently expensive because of the requirement for large magnetic fields and rare earth materials. Recently, an entirely new type of solid-state cooling based on reversible martensitic transformation was disclosed by a group of researchers at the University of Maryland. The new cooling technology is referred to as "elastocaloric cooling" (EC) which utilizes super-elastic transformation of austenite. Compared to other cooling technologies, EC has three advantages: 1) It is environment friendly. EC uses solid refrigerants, which completely eliminates the need for HCFC/HFC refrigerants, 2) EC has a high efficiency. It has been shown that the COP (coefficient of performance) of a jugular refrigerant is 5.8 with a ΔT of about 12° C., and 3) EC is cost-effective. EC does not require hydrostatic pressure. Therefore, there is no need for hermetic seals. In addition, the working materials are inexpensive. These advantages positioned EC to challenge VC as a dominate cooling technology. EC technology is new. And, key characteristics of the technology have yet to be fully understood, but differences associated with the physics from other cooling technologies are obvious. These differences enable different applications and different system designs. The present invention relates to a new application of the EC technology and corresponding systems.

SUMMARY OF THE INVENTION

The invention includes a system and a process for storing cold energy. The system includes: a chamber that defines an environment for storing energy, a regenerator system for storing and releasing energy, and a heat exchange system for moving the energy in and out of the system.

In one embodiment, the process includes: 1) deforming (stressing) a preselected solid state material (referred hereafter as "solid refrigerant") at a given temperature (T_0) from a first phase (referred as the high temperature phase) that is thermodynamically stable without the applied stress at (T_0) to a second phase (referred as the low temperature phase) that is thermodynamically stable without the applied stress at a temperature lower than (T_0) and is thermodynamically stable with the applied stress at (T_0). Transformation of the solid refrigerant from the first phase to the second phase results in the release of a preselected quantity of latent heat due to the difference between the total free energy ($\Delta G°$) of the first phase and the second phase of the solid refrigerant, 2) keeping the temperature of the solid refrigerant at the given temperature by exchanging the just generated heat with the ambient, 3) retaining the solid refrigerant in the second phase for a preselected time to keep the solid refrigerant ready to absorb previously released latent heat. This step is analogous to storing cold energy that is equal to the previously released latent heat, 4) undeforming the solid refrigerant by unloading the stress previously applied to the solid refrigerant to transform the second phase to the first phase. Transformation of the solid refrigerant from the second phase to the first phase results in the absorption of latent heat that was previously released. This step is analogous to generating cold energy that is equal to the released latent heat, 5) cooling the heat exchange medium with the cold refrigerant, and 6) distributing the cold medium to cool a preselected environment, volume, or space location to a desired or preselected temperature.

In another embodiment, the process includes: 1) inducing transformation of the solid refrigerant to transform it from the high temperature phase to the low temperature phase by exposing the solid refrigerant to an ambient environment when the ambient temperature is sufficiently low for the low temperature phase to exist without the bias of mechanical energy. For example, in a desert, the temperature difference between daytime and nighttime temperatures can exceed 70° C. Similarly, in some embodiments, the high temperature phase of the solid refrigerant may be thermodynamically stable in the daytime but not thermodynamically stable in the nighttime. Likewise, in some embodiments, the low temperature phase may be thermodynamically stable at nighttime but not thermodynamically stable during the daytime, 2) retaining the solid refrigerant in the second phase for a preselected time. This step is analogous to storing the cold energy provided by a cold ambient environment. As the ambient temperature increases with time, the solid refrigerant becomes stressed by the retaining mechanism, 4) releasing the stress on the solid refrigerant by removing (e.g., unlocking) the retaining mechanism. The transformation of the solid refrigerant from the second phase to the first phase results in the absorption of latent heat. This step is analogous to generating cold energy equal to the released latent heat, 5) cooling the heat exchange medium with the cold refrigerant, and 6) distributing the cold medium to cool a preselected environment, volume, or space location to a desired or preselected temperature.

In another embodiment, the process includes: 1) energizing a preselected solid refrigerant in a structured form releasing a quantity of heat therefrom to heat an exchange medium in a first location, 2) equilibrating the heated exchange medium between the first location at a higher temperature and a second location at a lower temperature to establish a temperature equilibrium between the first location and the second location, 3) storing cold energy in the solid refrigerant in the first location, 4) de-energizing the solid refrigerant absorbing a