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Editorial

Renewable energy sources, including wind, solar, geothermal, biomass, and water power play an important and increasing role in our nation's energy combine. The Department of Energy (DOE) is committed to the development of renewable energy technologies and their rapid commercial adoption. The department invests in clean energy technologies that strengthen the economy and protect the environment by reducing carbon emissions and accelerates the development of solar technologies as energy sources for the nation and world. Of the many renewable energy sources, solar energy is the most abundant. The average daily solar radiation falling upon one acre in the continental United States is equivalent in total energy content to about eleven barrels of oil. Reusable energy of this quantity represents a huge, useful, and relatively unexploited energy supply. The intermittent character of solar energy requires a Thermal Energy Storage (TES) system for the most effective utilization of this energy source. The TES system serves as a reservoir of energy to collect and transfer thermal energy from the Heat Transfer Fluid (HTF) to storage media.

A wide variety of equipment is available to capture solar energy and use it for space and water heating, and for electricity generation. The three major components of solar thermal energy utilization systems are the solar collector, the energy storage system, and the steam generator used for the turbine-electric generator. Thermal energy is usually collected by a parabolic trough, transferred to thermal storage by a heat transfer fluid, and then transferred to a steam generator by storage media. For active thermal energy storage in a direct system, the heat transfer fluid collects the solar heat and also serves as storage medium. The solar energy system costs are strongly dependent on the properties of the thermal storage media and the heat transfer fluid.

For most industrial applications, water is the most popular heat transfer fluid. It has high latent thermal energy, high thermal conductivity, high specific heat, and high density with moderate viscosity. The primary drawback with water as a heat transfer fluid is the limited range of temperature over which it can be used. The theoretical liquid range of water is between 0 and 100 °C, but the practical temperature range for water used as heat transfer fluid is much less than 100 °C because of the high vapor pressure near the boiling point. Also, high pressure is needed to keep water at a liquid state when the temperature is over 100 °C, which results in high costs due to the related pressure vessels and pipes. Accordingly, high temperature water (over 100 °C) is unsuitable as a heat transfer fluid or thermal energy storage medium for solar energy power plants.

Thermal oils can maintain their liquid phase up to about 300 °C, and can be used as thermal storage media and heat transfer fluids, but their applications are limited by several intrinsic disadvantages such as low decomposition temperature, low density, flammability, high vapor pressure, fuming tendency, and low chemical stability. Santotherm 55 is common thermal oil used as thermal storage medium and heat transfer fluid. The main disadvantages of this thermal oil are low thermal capacity, and low decomposition temperature resulting in low energy storage. Ionic liquids which are salts having low melting points have emerged as novel thermal storage and heat transfer fluids for low to medium temperature applications. Their important properties include extremely low volatility in the liquid state, non-flammability, relatively wide temperature range, and large number of possible compositions allowing fine-tuning of ionic liquid properties for specific applications. For application as TES media, ionic liquids have a limited operating temperature range, limited cycle life and low decomposition temperatures although they have higher thermal storage density capacities.

From the entire gamut of materials researched for various properties, molten salts are a very specific group that have immense potential as thermal energy storage and heat transfer media for solar energy applications. Molten salts have been proposed as heat transfer fluids for high temperatures from 250 to 1000 °C. Low melting point (LMP) molten salts are a group of salts which remain liquid over a wide temperature range. Other important properties of LMP salts includes: good heat and electrical conductivity, high thermal and chemical stability, low viscosity, and environmental friendliness. The liquid range for an individual molten salt could be from 150 to 600 °C. By a combination of different LMP salts and the optimization of composition, the liquid temperature range is expected to increase significantly. Due to these properties, LMP molten salts could be excellent thermal storage media and heat transfer liquids in solar power plant systems. Current molten salt heat transfer fluid and thermal storage media are a mixture of 60% $NaNO_3$ and 40% KNO_3 [13]. The liquid temperature range is 220-600 °C. The main disadvantage of this salt mixture is the high melting point. The salt can freeze and block the pipeline during winter evenings. In order to overcome this problem, auxiliary facilities need to be installed, which could increase the investment and operational costs.

Research is underway to develop novel low melting point (LMP) molten salt mixtures that have large and stable liquid temperature range, high heat capacity, moderate density, viscosity and thermal conductivity and high thermal energy storage density. Additionally, common stainless steel should show appreciable corrosion resistance to these salt mixtures since they are used as piping material to hold the salt mixtures. Thermodynamic modeling can be used as a powerful tool to identify novel eutectic mixtures from a group of alkali and alkaline earth nitrate and nitrite salts. All the binary systems involving alkali nitrates and nitrites are simple eutectics. Thermodynamic principles can be utilized in developing novel eutectic mixtures by a combination of these salts to generate higher order eutectic systems. This technique will yield salt mixtures with lower melting points than that of the binary eutectic temperatures. Theoretically, additional of a low melting salt to a binary eutectic system will further lower the melting temperature by finding a potential new eutectic in the system. The validity of such a eutectic mixture can be further verified by experimental determination of the melting temperature of the potential new eutectic composition. These eutectic mixtures can be synthesized and characterized for the relevant properties to be projected as potential low melting point molten salt mixtures for thermal storage and heat transfer applications.

In summary, research efforts are improving in identifying novel molten salts for solar energy applications. However, the commercialization of these mixtures as thermal storage media will take some time. Efforts are also necessary towards the fundamental understanding of the phase equilibria and transport properties of novel eutectic molten salt mixtures. The challenge for developing suitable materials such as novel molten salts for tapping renewable energy sources such as solar energy has to be directed in generating thermodynamic and transport properties data of these systems. This will enhance our understanding of the properties of molten salts for their use in other technologies.

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