SOLAR HEAT SINK FOR BATCH DISTILLATION

Adam Leibert, Jamie Skeie, Matthew Pesicka, Thomas Viggiano

Project Background

Project Opportunity:
Why is a waste product produced during cheese making processes. The lactose in whey can be fermented to produce 2-3% alcohol by volume (ABV). Alcohol concentrations this low require much larger energy input than traditional spirit distillation that starts around 8% ABV. Therefore, there is a need for a low energy cost distillation. One possible solution is to store thermal energy from the sun in molten salt by using a Fresnel lens.

Project Goals:
• Develop a prototype heat sink using lithium nitrate as a medium
• Complete a 4 L batch distillation using molten lithium nitrate as the heat source
• Heat lithium nitrate to 400 °C using a Fresnel lens
• Integrate the melting process powered by the Fresnel lens with the distillation

Lithium Nitrate Properties:
• Melting point- 255 °C
• Latent Heat- 373 kJ/kg
• Thermal Conductivity- 0.59 W/(m-K)
• Heat Capacity- Solid: 0.93 kJ/(kg-K)
• Heat Capacity- Liquid: 1.8 kJ/(kg-K)

For a 4 L batch distillation from 8 to 23% ABV, 1.17 kWh of energy is needed. This can be obtained using 23 kg of LiNO₃ initially at 400 °C assuming 30% efficiency.

Fresnel Lenses:
Fresnel lenses consist of a series of concentric grooves etched into a lens (think tree rings). They can be used to concentrate solar energy for heating in solar cookers, solar forges, and solar collectors used to heat water for domestic use.

General Equations:
Fresnel lens efficiency based on the sensible heat and temperature change of the aluminum block:

\[ E_{\text{eff}} = \frac{m_{\text{salt}}(\Delta H_{\text{fusion}} + C_p \text{liquid}(T_f - T_{\text{melt}}))}{m_{\text{water}}(C_p \text{water} - T_0) + \Delta H_{\text{boil}}} \]  

Energy Balance for lithium nitrate heating water with an assumed 30% efficiency:

\[ 30\% \cdot m_{\text{salt}}(\Delta H_{\text{fusion}} + C_p \text{liquid}(T_f - T_{\text{melt}})) = m_{\text{water}}(C_p \text{water} - T_0) + \Delta H_{\text{boil}} \]  

Fresnel Lens Testing:

Figure 1: Process overview. A Fresnel lens melts lithium nitrate using solar energy, and that molten salt is used to power a batch distillation.

Figure 2: Heating of 25 mL of water over time using 280 g of lithium nitrate with a starting temperature of 310 °C. Experimental configuration below.

Figure 3: Experimental set-up for lithium nitrate salt testing. Lithium nitrate was placed in an insulated vessel, then water was placed on top to heat.

Figure 4: Lid design for the lithium nitrate container made from stainless steel due to its corrosion resistance. Fins extending into the salt increase heat transfer between the salt and the still.

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