

Day 1: Exploration of system technology and performance

Rio room readout

May 23, 2014



Feedback on overall ARPA-E system vision

- ▶ Should look closely at the staging of the components from a system point of view.
- ▶ May work out that the components that are viewed as supplemental cooling could/should also be used upstream of air HX
- ▶ May want to extend design space box to include condenser also. If you directly air cool main condenser, then you buy yourself some delta T
- ▶ May pay to bundle the supplemental cooling metrics rather than specify for each

Air heat exchanger

- ▶ Debate on $5X St_{\text{louvered}}$ target – group thinks we'd be lucky to get $2X$
 - Almost inventing a new physics – look at turbulent flow. If you increase heat transfer, you're going to get higher f
 - Some approaches for higher HT
 - Vortex generation, needs for vortex generation
 - Impingement cooling and short flow path lengths so avoid establishment of thermal boundary layer
- ▶ Using St vs f as the metric dooms the problem - traditional first step in HX design. But, what you really care about is UA vs pressure drop
 - Otherwise, just focusing on one aspect (surface transfer) of the problem. But opportunities/challenges exist elsewhere
- ▶ Develop/incorporate high conductivity material?

Polymer heat exchangers

- ▶ Need to refine metrics to allow these, but there is a lot of space here
- ▶ Survival is a challenge – 3 or 4 years max before you need replacement
 - Temperature and moisture will affect the durability
- ▶ Going thin (100-150 microns) with embedded reinforcement material allows you to avoid extra thermal resistance
- ▶ Polymer HX avoids fouling. And, shown that surface structuring lowers rate of fouling by 10X.
- ▶ Metal + polymer hybrid HX's? – additive manufacturing may make this possible

Absorption/Adsorption cooling

- ▶ COP of 2 requires thermal COP of >2 (maybe 2.5 or 2.6) because of parasitics for dealing with heat being dumped
- ▶ COP of 2 requires the invention of a new materials pair.
- ▶ Complexity required appears daunting
 - Triple effect is the highest COP at ~ 1.2 and would be more complicated than power plant itself.
- ▶ Advantage here is that system only has to do a few degrees cooling. So, perhaps COP can be higher than nominal values.
- ▶ Alternative: Instead of absorption cooling, with all of the heat transfer steps, desiccant cooling may be easier, but would be lower COP. Or, water recovery may also make sense

Radiative cooling

- ▶ Group generally agreed that there is a lot of whitespace/opportunity.
- ▶ Data presented from Stanford is promising, especially considering low TRL.
- ▶ Challenges:
 - Going to require large real estate
 - Daunting to get 5 degrees out of the radiative
 - Long term reliability with fouling and dusting, etc
 - Convective flows must be avoided/managed, but this is done in other applications.
- ▶ Consider radiative cooling with reservoir (thermal mass)

Fans

- ▶ Performance is already pretty good
- ▶ Simple pitch control achievable, but costs need to be reduced
- ▶ Shape changing could also be helpful
- ▶ Could be opportunities in performance of 3 phase motors

Alternative Systems/Concepts

- ▶ Use water but recover as much as possible and use waste heat to regenerate
- ▶ Use of geothermal cooling, perhaps incorporating heat pipes
- ▶ Alternative, low cost tower designs
- ▶ Very tall natural draft towers painted black
- ▶ Using other liquid besides water – secondary loop
 - Non-volatile fluid in direct contact HX
 - Low temp molten salts
- ▶ Temporal management
 - Thermal storage to act as capacitor, rather than or in tandem with supplemental cooling
 - Use cheap electricity at night to recharge cooling system, or precool
- ▶ Utilize low grade waste heat to produce power economically Integration with thermal storage

Other

- ▶ New manufacturing techniques = new HX design space. But, many (1000's) of degrees of freedom in design. Mathematics problem – no one has any idea what the optimal solution is. Key enabler would be multivariate optimization tool that allows us to find optimal design – then we can decide how to manufacture it.
- ▶ Supply chain limitations sometimes limit design/performance
 - Limitation on metal foam – only 1-2 suppliers of Al foam in US