Absorption
Refrigeration
Cycle
Turbine
Inlet
Conditioning

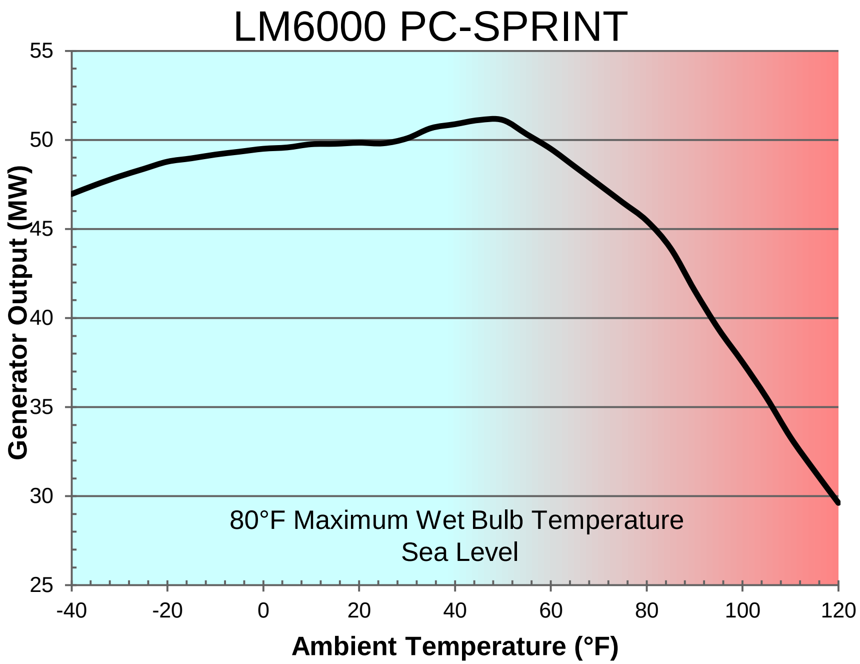
Luke Buntz
ARCTIC Engineer
Kiewit Power Engineers Co.

ARCTIC Overview

The Problem

Why chill?

- Increased fuel efficiency (fewer emissions)
- Power production capability and turbine efficiency increase as inlet temperature decreases
- Electricity demand is highest on the hottest days, but as ambient temperature increases air becomes less dense, therefore less power can be produced
    - **Power is also the most valuable at these times so recovering power lost due to high ambient provides a significant Return on Investment**



Why heat?

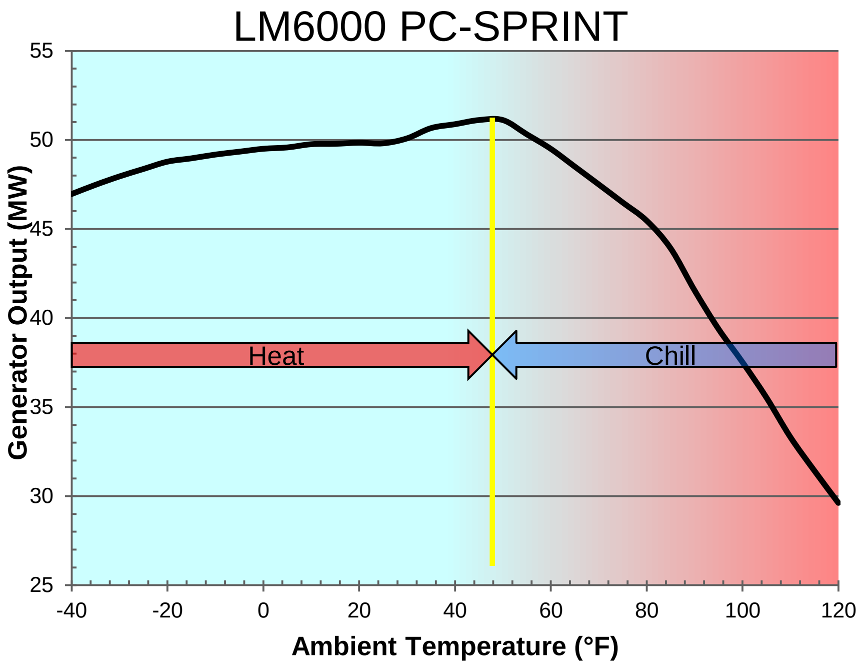
- Anti-icing is required in icing conditions to prevent damage to turbine blades
- Aero-derivatives:
    - Anti-ice systems typically heat air 10 degrees F above ambient temperature, however power capability decreases as temperature decreases below the "sweet spot" so additional heating enables higher power output
    - **At part load, heating of the inlet air improves heat rate and emissions**
- Frames:
    - Anti-icing is typically accomplished by using bleed air from the compressor. This results in a two-fold power reduction:
        1. As inlet temperature increases, power production capability decreases
        2. Bleed heat robs valuable compressed air from the combustor (**ARCTIC eliminates this need**)

The Solution

Why ARCTIC?

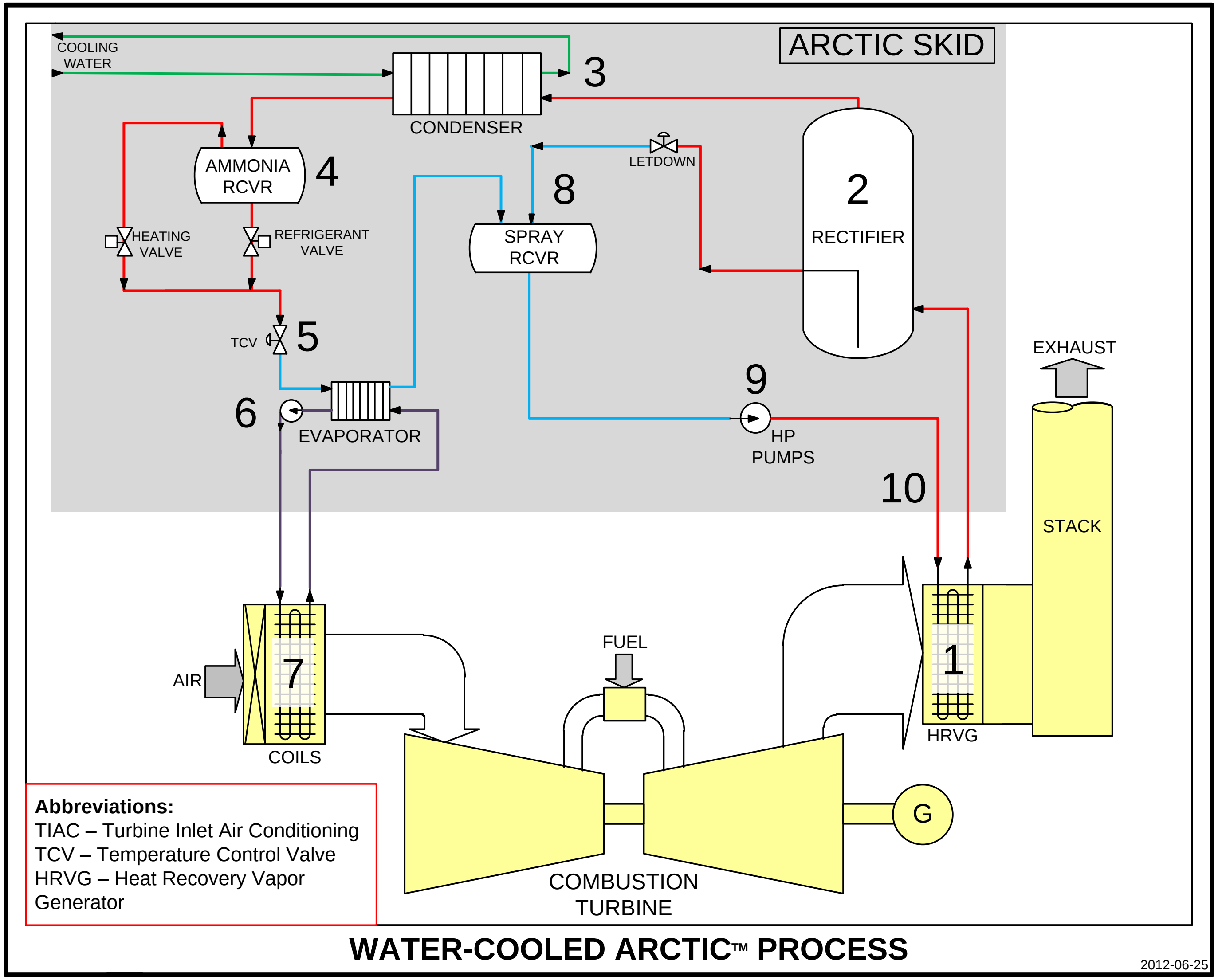
Operational Flexibility:

- Fast Start Capability:
  - On Aero units ARCTIC can be fully chilling or fully heating within 10 minutes of turbine fire
- Dispatch order:
  - By optimizing the heat rate at the desired power level, plant can be dispatched sooner when preference is given to heat rate
- Peaking profile:
  - Summer – Chill to enable maximum power
  - Winter – Heat (beyond anti-icing) to enable maximum power



- Load following:
  - Varies inlet air temperature to optimize output and heat rate, regardless of ambient temperature
  - Can enable maximum turndown to maintain a lb/hr emissions limitation
  - Ability to improve heat rate/emissions at part load conditions
- Base load:
  - Constant, maximum power across broad ambient temp range
- Dry Low Emissions:
  - Reduced fuel mapping (constant inlet temperature)
- Emissions reduction ("Green" Plants)
  - For same NET power production as unit with mechanical chiller, less lb of NOx and CO2 produced
  - For same emissions as unit with mechanical chiller, more NET power available

How Does ARCTIC Work?

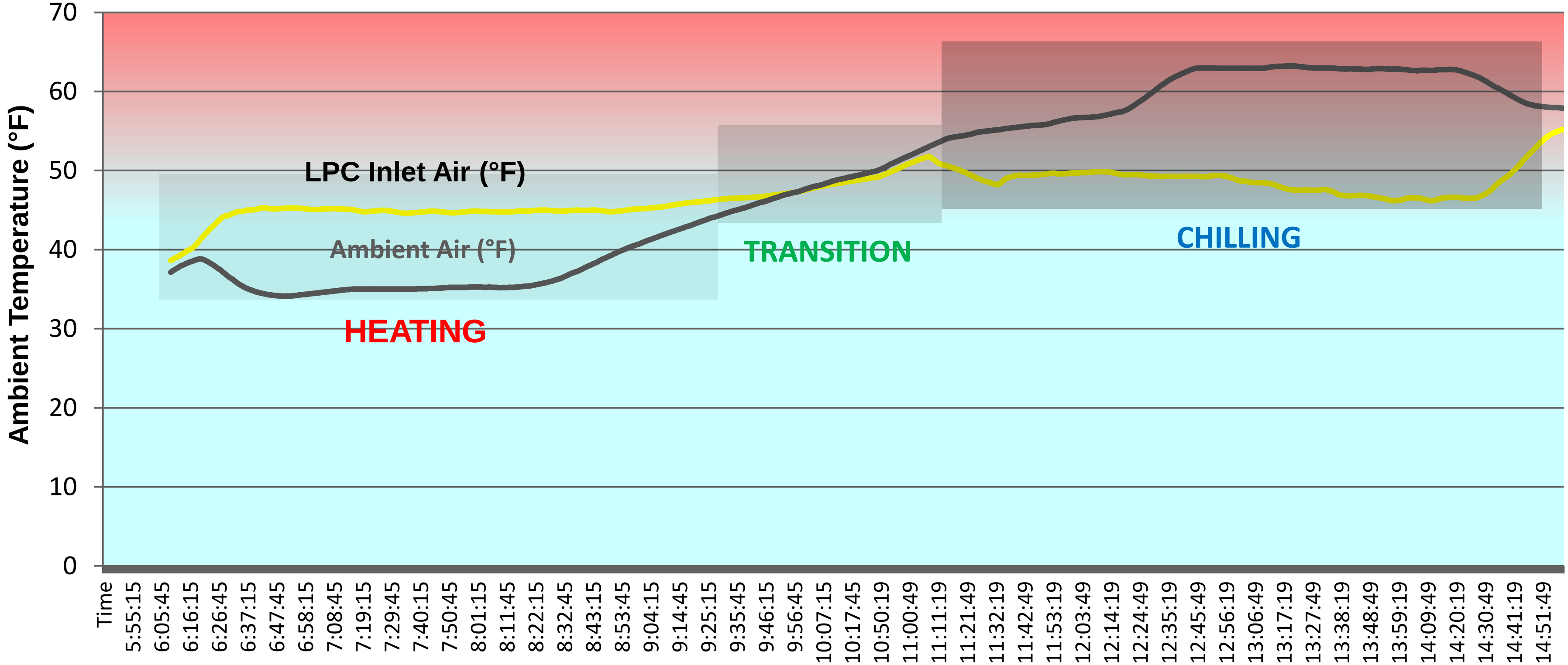


1. Ammonia-water solution is vaporized in the HRVG
2. The rectifier separates vapor ammonia out the top and liquid water to the bottom
3. The condenser turns the vapor ammonia to liquid
4. The liquid ammonia gathers in the ammonia receiver
5. The high pressure liquid ammonia is expanded in the TCV
6. The ammonia is evaporated, chilling the water-glycol mixture
7. The water-glycol mixture passes through the TIAC coils, chilling the inlet air
8. The vapor ammonia is recombined with the water from the rectifier
9. The ammonia-water solution is pumped back into the HRVG
10. The cycle repeats

Going Green

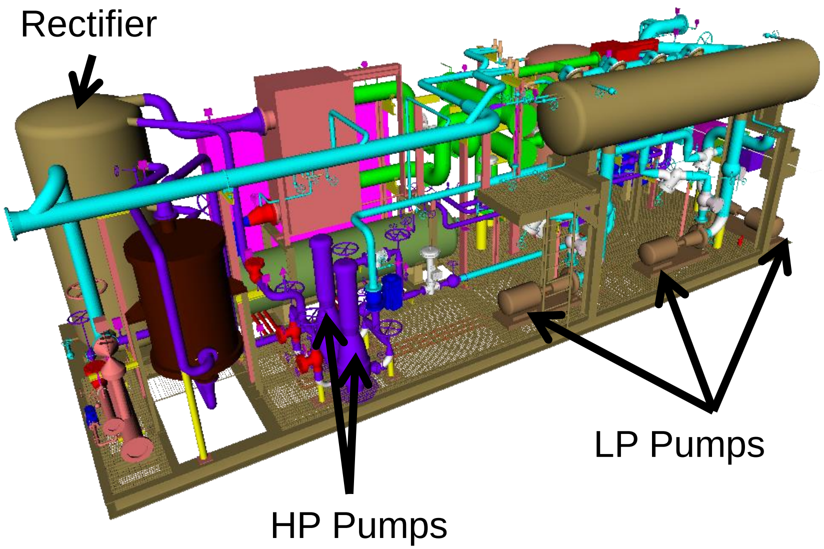
- Reuses waste product (exhaust energy)
- For same NET power as mechanical chiller, less lb of NO_x and CO_2
- Ammonia is naturally occurring, readily available, and inexpensive
- Ammonia is environmentally friendly:
  - Ozone Depletion Potential (ODP) = zero
    - R-134a = 0
    - R-123 = 0.02
  - Global Warming Potential (GWP) = zero
    - R-134a = 1300
    - R-123 = 90
- Better heat rate = more efficient use of fuel
- Water recovery from inlet coil condensate

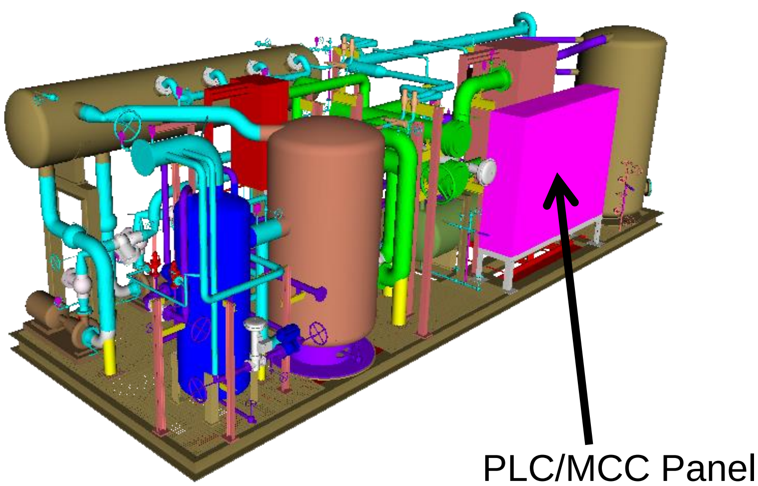
Mode Transition



- Morning Ambient Temperature: 34°F
- Afternoon Ambient Temperature: 64°F
- **Although the ambient temperature increased 30°F, compressor inlet temperature only varied 6°F**
- Skid changes modes based on ambient temperature
- Hands-off, automated transition
- **Only system available that performs both inlet conditioning functions**

ARCTIC Skid – 2000 Ton Unit

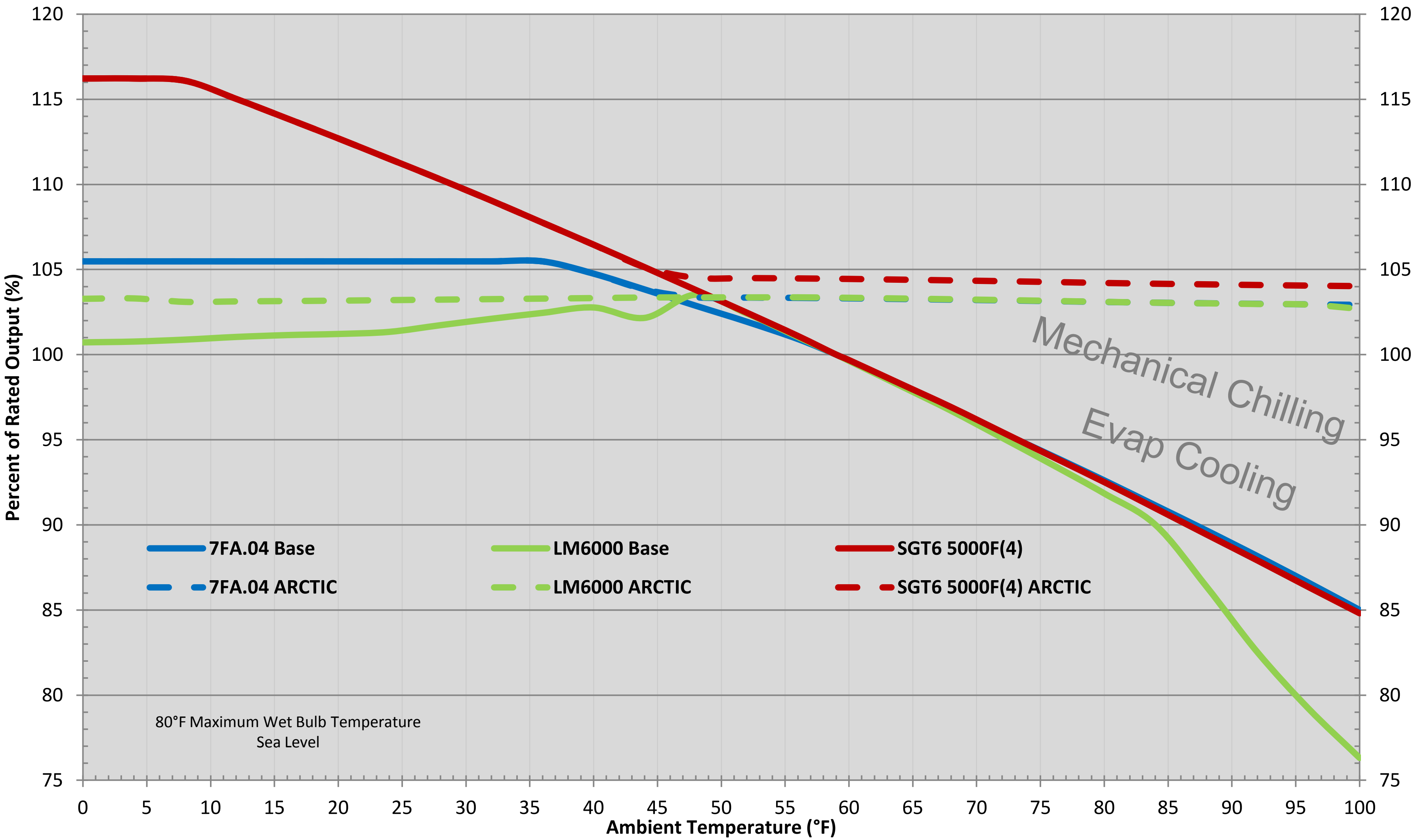




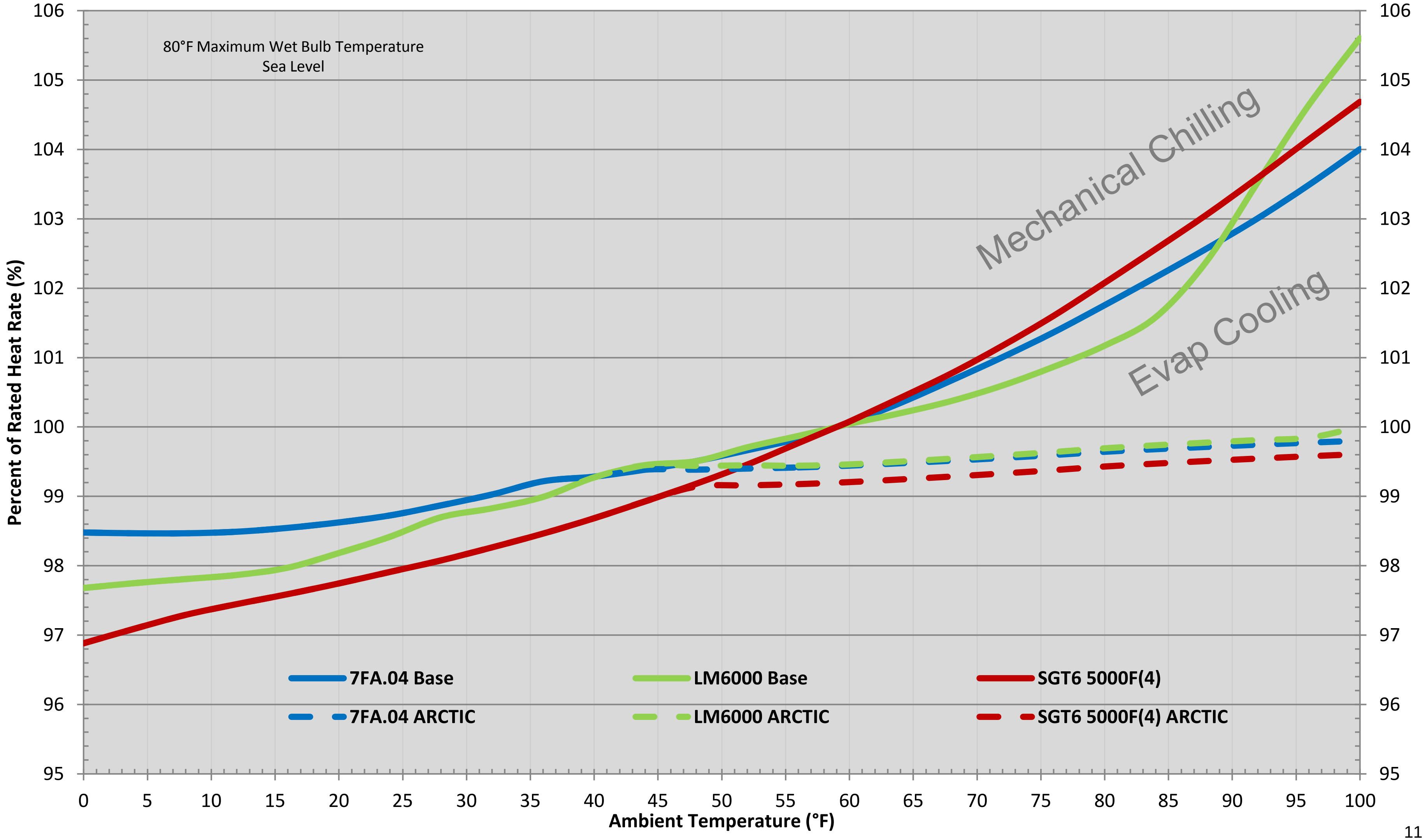
- Skid mounted PLC/MCC
- Closed-loop
- Redundant pumps
- 40’ long x 14’ wide
- No large components or compressors (eliminating 4160V switchgear)
- Low maintenance/operation costs

Simple Cycle Units

Simple Cycle – ARCTIC Output



Simple Cycle – ARCTIC Heat Rate



GE Frame Simple Cycle Summary

Legend
Worst
Better
Best

		Base	Evaporative Cooling	Mechanical Chiller	ARCTIC
7FA.04	Output Gain	158,107	8.7%	14.8%	21.1%
	Heat Rate Reduction*	10,310	-0.1%	3.2%	-2.2%
	Efficiency Improvement	33.1%	0.0%	-1.0%	0.8%
7FA.05	Output Gain	192,594	7.9%	10.6%	16.1%
	Heat Rate Reduction*	10,085	-1.2%	2.1%	-2.8%
	Efficiency Improvement	33.8%	0.5%	-0.8%	1.1%
7EA	Output Gain	75,360	8.3%	15.0%	22.6%
	Heat Rate Reduction*	11,812	-1.8%	1.8%	-4.5%
	Efficiency Improvement	28.9%	0.6%	-0.6%	1.5%

* Heat rates based on fuel HHV

- Based on a 100°F day with 35% Relative Humidity
- Mechanical Chiller parasitic load is based on 1.6 kW/ton
- ARCTIC parasitic load is based on 0.11 kW/ton

GE Aero Simple Cycle Summary

Legend
Worst
Better
Best

		Base	Evaporative Cooling	Mechanical Chiller	ARCTIC
LM6 PCS	Output Gain	37,606	20.3%	28.1%	35.6%
	Heat Rate Reduction*	9,868	-4.6%	-0.2%	-5.7%
	Efficiency Improvement	34.6%	1.8%	0.1%	2.3%
LM6 PGS	Output Gain	43,887	13.8%	24.7%	32.1%
	Heat Rate Reduction*	9,793	-2.7%	2.5%	-3.2%
	Efficiency Improvement	34.9%	1.1%	-0.9%	1.3%
LM6 PHS	Output Gain	41,653	7.7%	17.3%	25.1%
	Heat Rate Reduction*	9,713	-1.9%	1.8%	-4.5%
	Efficiency Improvement	35.1%	0.7%	-0.7%	1.8%
LMS PA	Output Gain	93,917	4.0%	8.4%	10.8%
	Heat Rate Reduction*	9,011	-1.1%	-0.7%	-2.8%
	Efficiency Improvement	37.9%	0.5%	0.3%	1.2%
LMS PB	Output Gain	83,912	4.4%	11.2%	16.8%
	Heat Rate Reduction*	8,997	-1.3%	0.4%	-4.4%
	Efficiency Improvement	37.9%	0.6%	-0.2%	2.0%
LM25 +G4	Output Gain	26,006	13.7%	22.1%	30.2%
	Heat Rate Reduction*	10,373	-3.1%	0.6%	-5.7%
	Efficiency Improvement	32.9%	1.1%	-0.2%	2.2%

* Heat rates based on fuel HHV

ARCTIC Contacts

Chris Mieckowski
ARCTIC Product Line Manager
913.928.7304
Chris.Mieckowski@Kiewit.com

Luke Buntz
ARCTIC Engineer
913.689.3931
Luke.Buntz@Kiewit.com