Hybrid Systems: Multi-Stage Turbine Inlet Cooling for Increased Efficiency

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June 19, 2013

Introductions

Annette Dwyer

Technical Product Manager

TICA Vice Chair

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Marcus Bastianen, PE

Director of Sales and Marketing

TICA Director

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Why Turbine Inlet Cooling?

- Turbine Inlet Cooling (TIC) provides a cost-effective, energy-efficient, and environmentally beneficial means to enhance power generation capacity and efficiency of combustion/gas turbines during hot weather.

Who is TICA

- The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling.
- The TICA website is one-stop source of TIC technical information.
- TICA is a non-profit organization.

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TICA Member Benefits

- Access to full/detailed version of TIC Installation Database
- Access to full/detailed version of the TIC Technology Performance Calculator
- GT Users get access to the TIC Forum
- Vendors get information space on the TICA Website and booths at various electric power trade shows

Become a Member **Today!!!**

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Turbine Inlet Cooling Technologies

Webinar Schedule

- August 22, 2012: Wetted-Media Evaporative Cooling
- October 18, 2012: Fogging
- December 19, 2012: Chiller Systems
- February 13, 2013: Thermal Energy Storage
- April 17, 2013: Wet Compression
- **June 19, 2013: Hybrid Systems**

All Webinars start at 1 PM (U.S. Central Time)

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Webinar Procedures

- To avoid background noise, we will mute participants
- Please submit questions during the presentations by typing them into the “chat” window area of the screen
- After the featured presentation is complete, we will answer your submitted questions
- Please complete the online survey immediately following the webinar

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June 19, 2013

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Outline

- Air Density and Gas Turbines
- Why a Hybrid System
- Psychrometrics 101
- How a Hybrid System Works
- Control and Water Management
- System Performance
- Installations

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Importance of Air Density

- Gas turbines are mass flow machines
- Lower air density results in less mass flow to the GT that results in:
  - Lower engine power output
  - Decreased engine efficiency and higher emissions (burn more fuel/kWh)
- Primary reasons for lower intake air density:
  - Ambient air temperatures rise (usually when power demand is greatest)
  - At higher elevations, air is less dense

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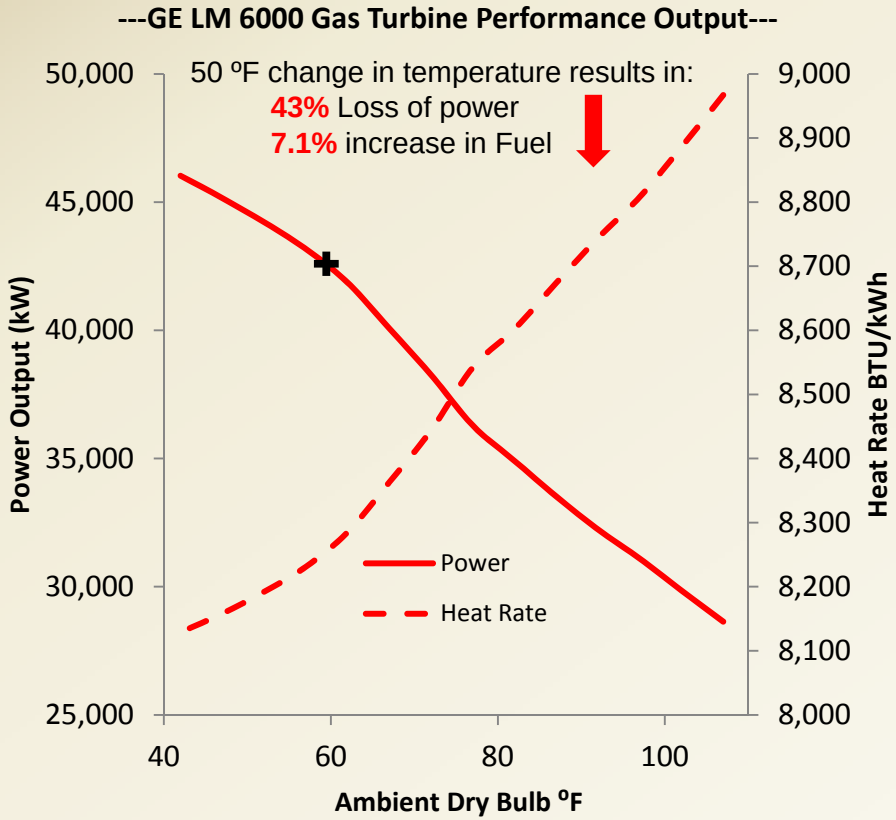
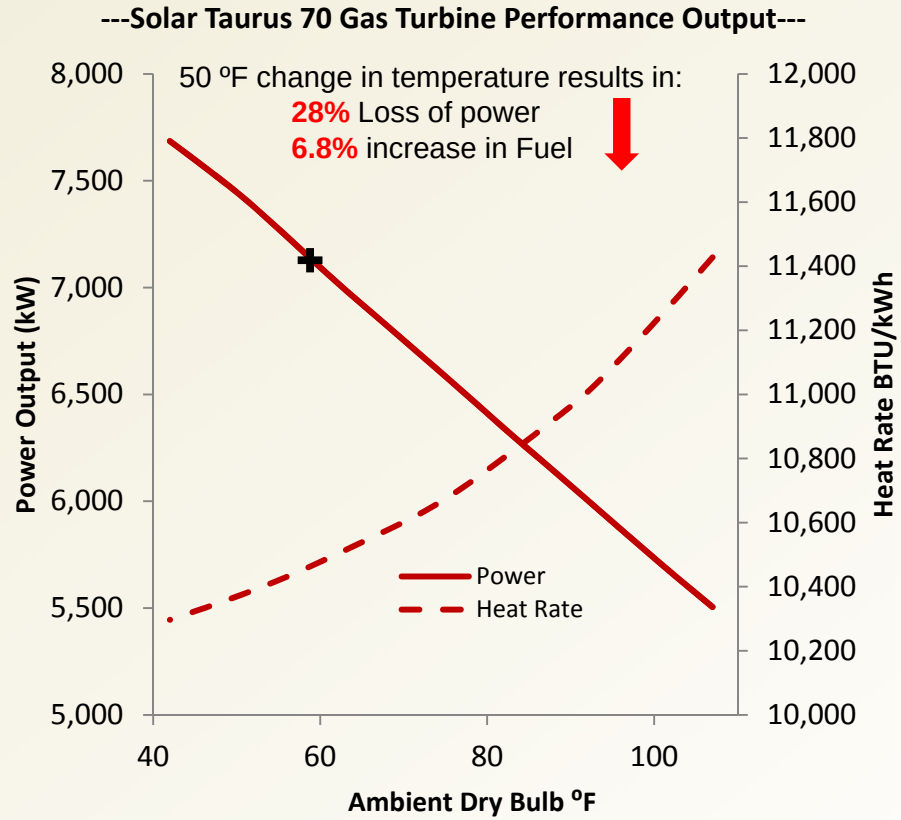
Air Density Effect of Engine Output



* Power and Heat Rate based on GE APPS book rated engine performance



* Power and Heat Rate based on Solar FASTE book rated engine performance

A 50 ºF change in air temperature ~ 8-10% change in air density (Sea Level)

Aero models and Non-Aero Models lose power and efficiency with less mass flow

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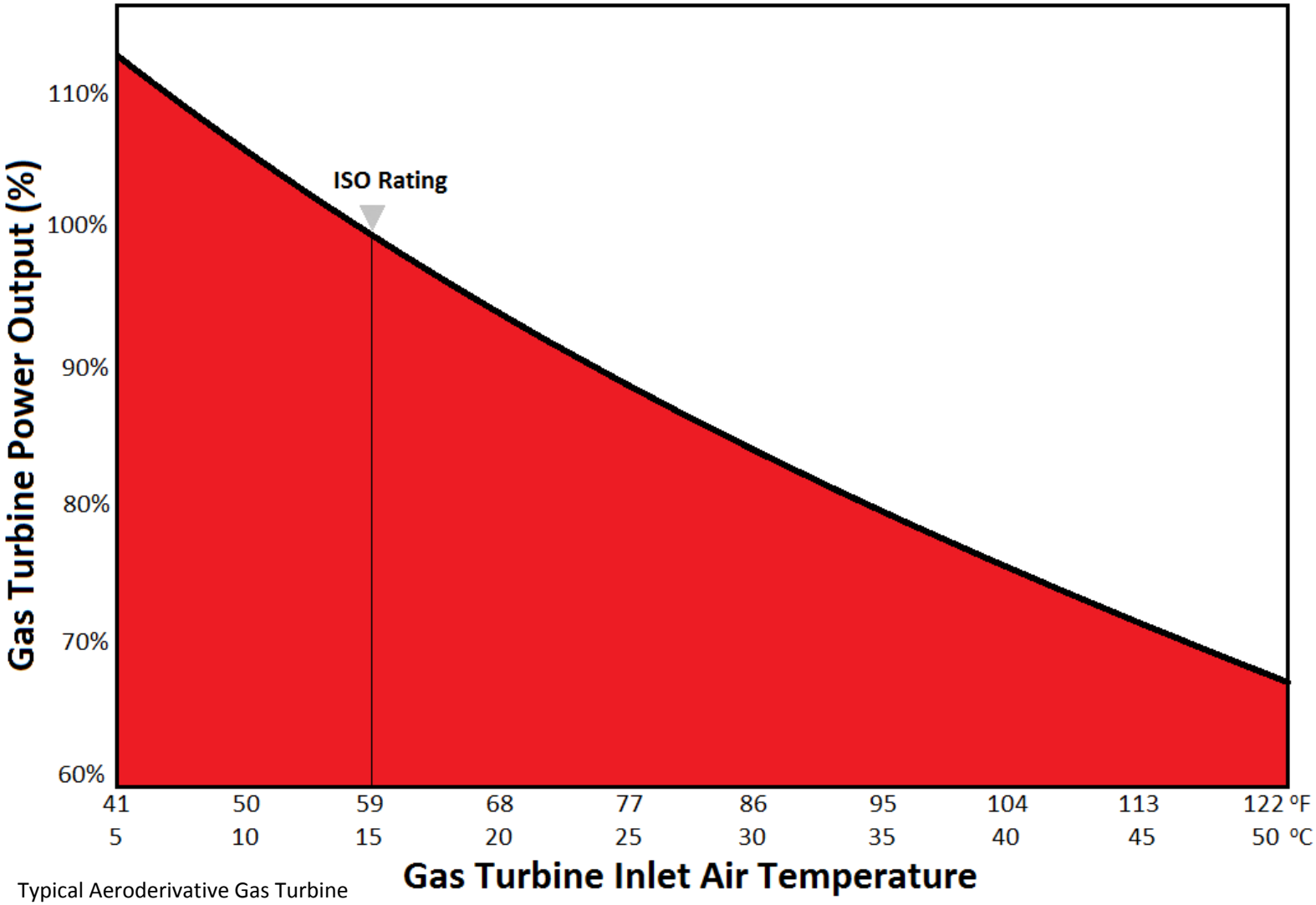
Why Hybrid Inlet Cooling?



Typical Aeroderivative Gas Turbine

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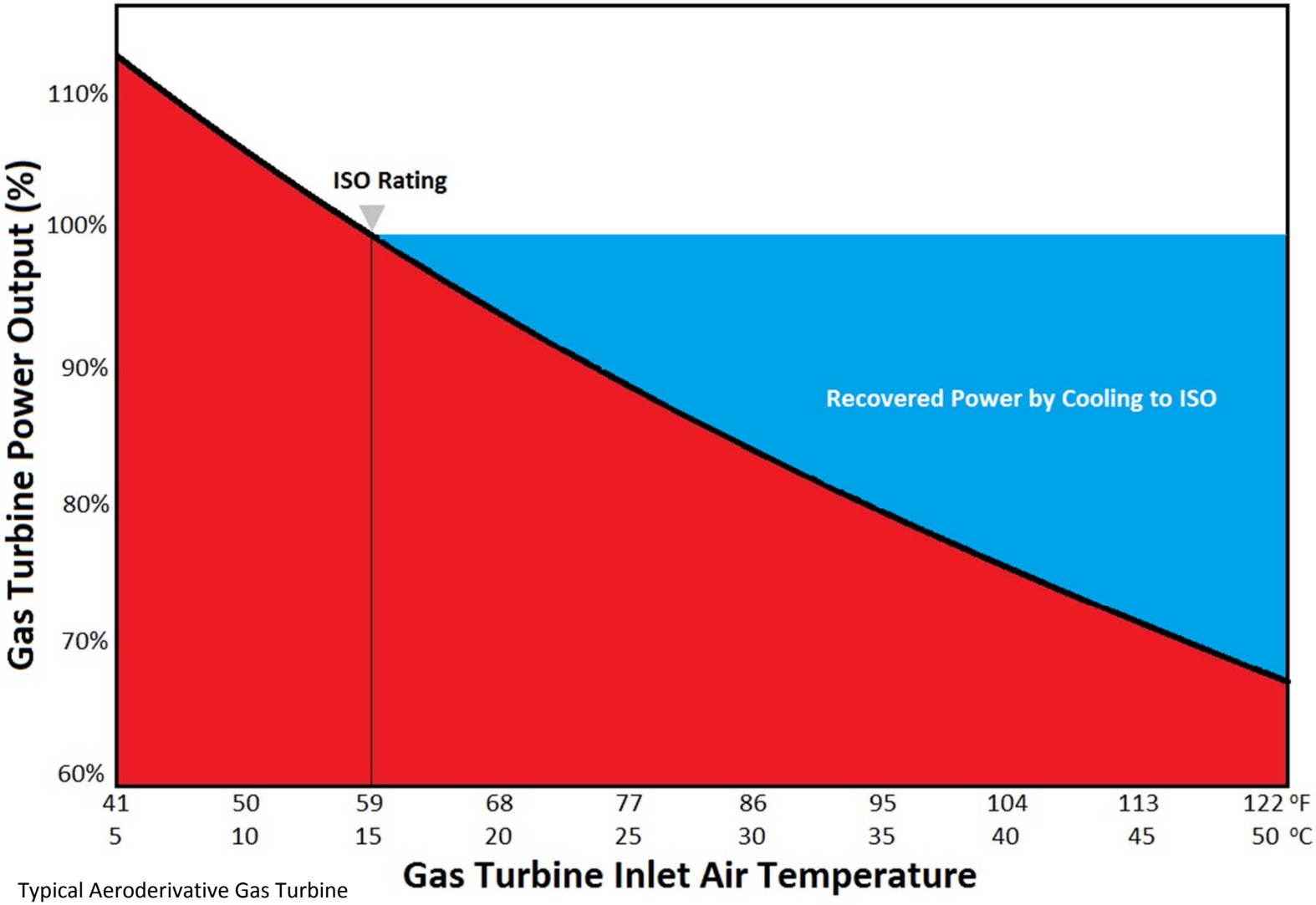
Why Hybrid Inlet Cooling?



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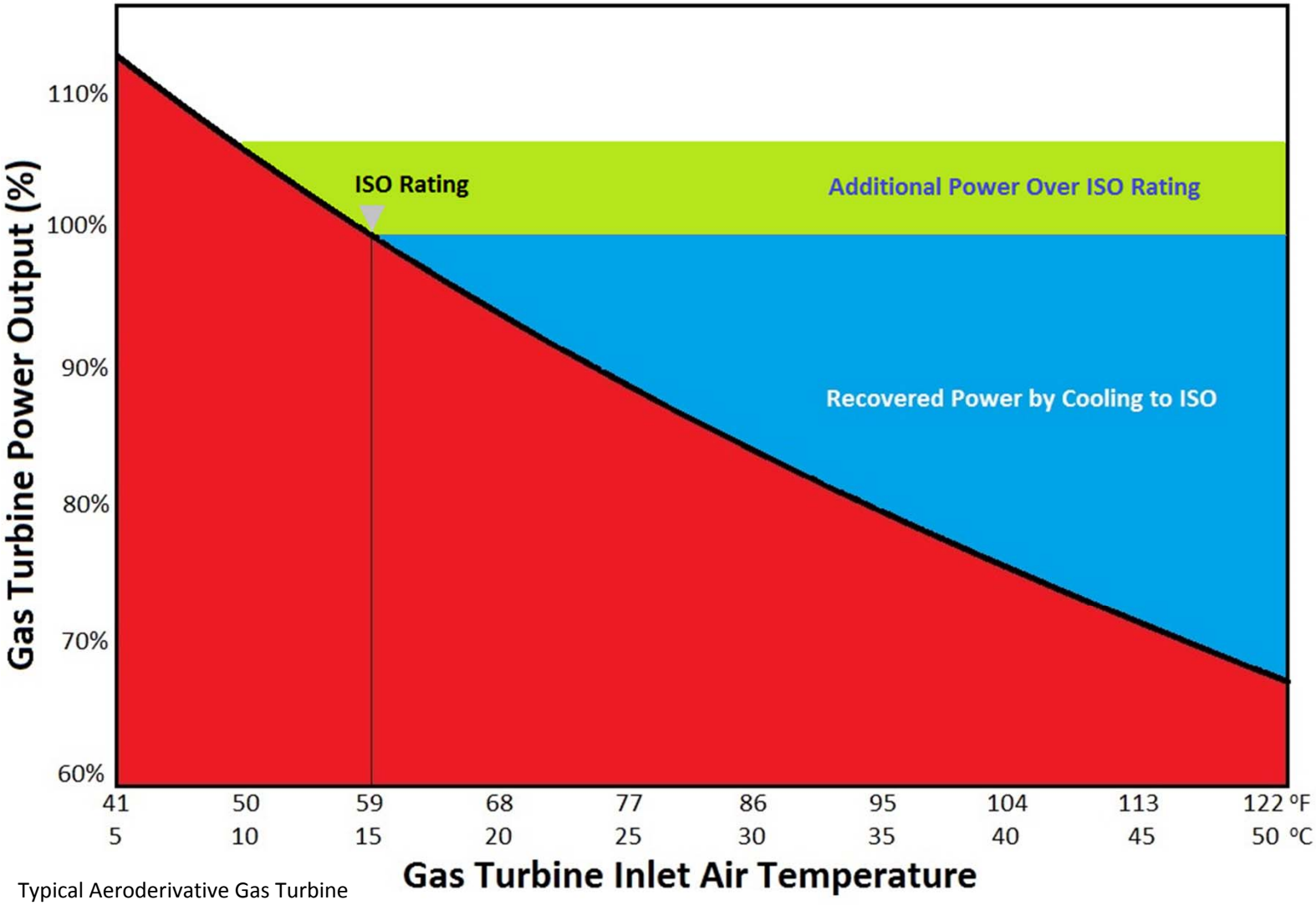
Why Hybrid Inlet Cooling?



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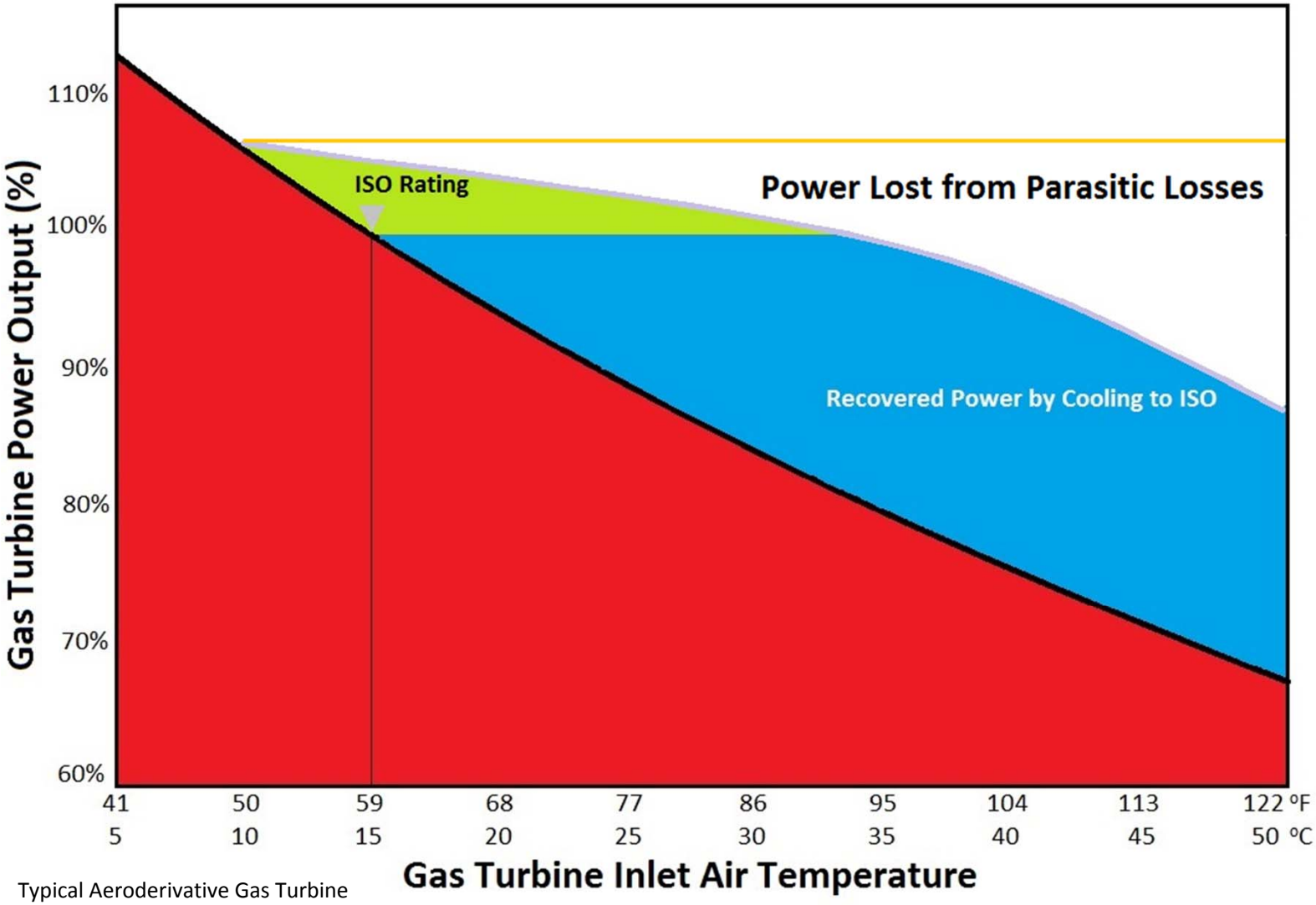
Why Hybrid Inlet Cooling?



Typical Aeroderivative Gas Turbine

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What is a Hybrid System?

- A Hybrid turbine inlet cooling system combines technology to provide an economical and highly efficient inlet cooling system.
- Supplies cooler air than standard evaporative systems
- Less parasitic power consumption than mechanical chilling
- System redundancy
- Different hybrid combinations include:
  - Hybrid Chiller
  - Hybrid Evaporative Cooling
  - Hybrid with Thermal Energy Storage

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Properties of Air

- Dry bulb: Air temperature measured
- Wet bulb: Lowest temperature possible by evaporating water into air
- Relative Humidity: Capacity of air to hold additional water vapor
- Humidity Ratio: Mass of water to mass of air
- Enthalpy: Internal energy of air
- Specific Volume: Ratio of volume to mass of air

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The Psychrometric Chart

Dry Bulb Temperature

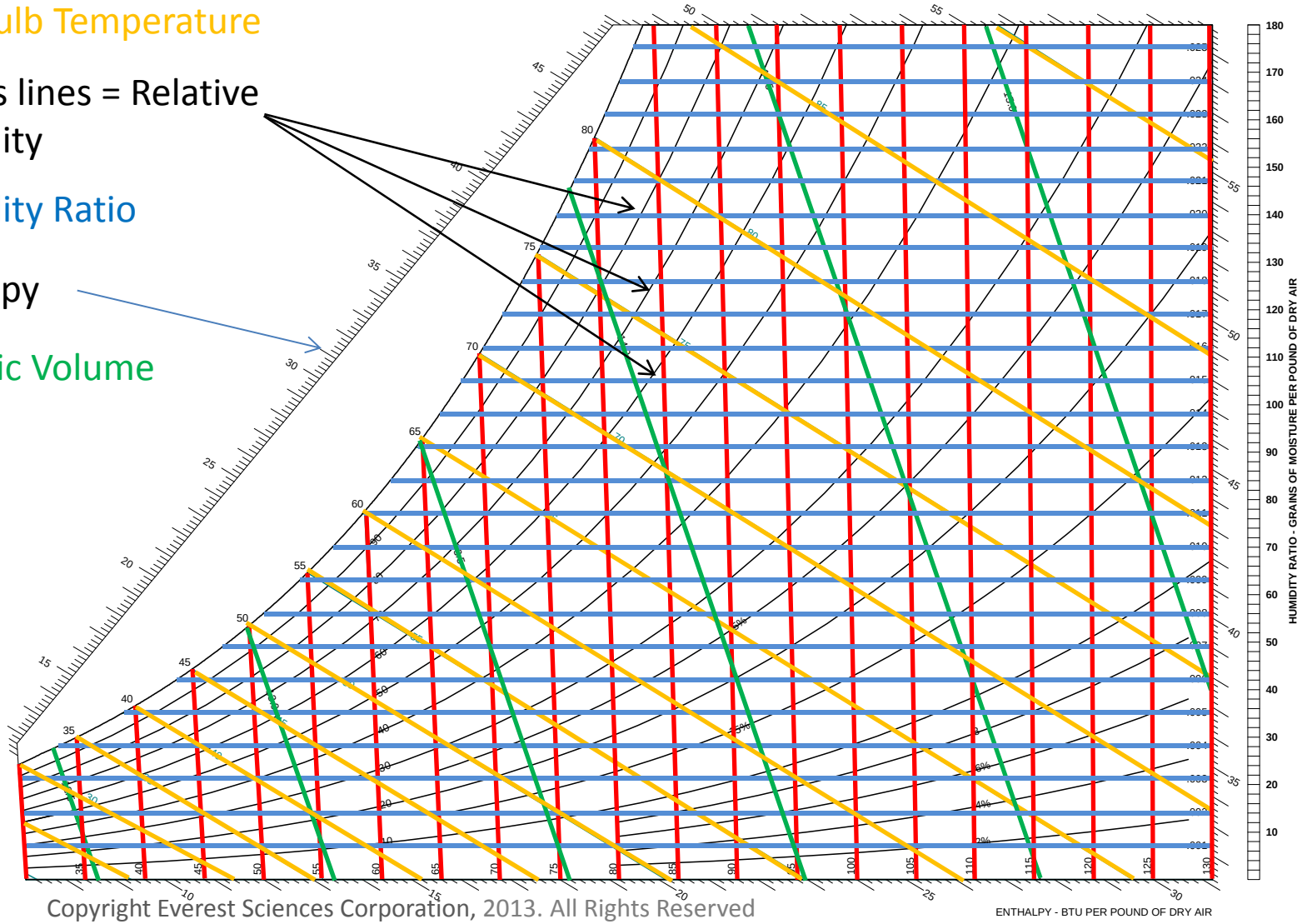
Wet Bulb Temperature

Curves lines = Relative humidity

Humidity Ratio

Enthalpy

Specific Volume



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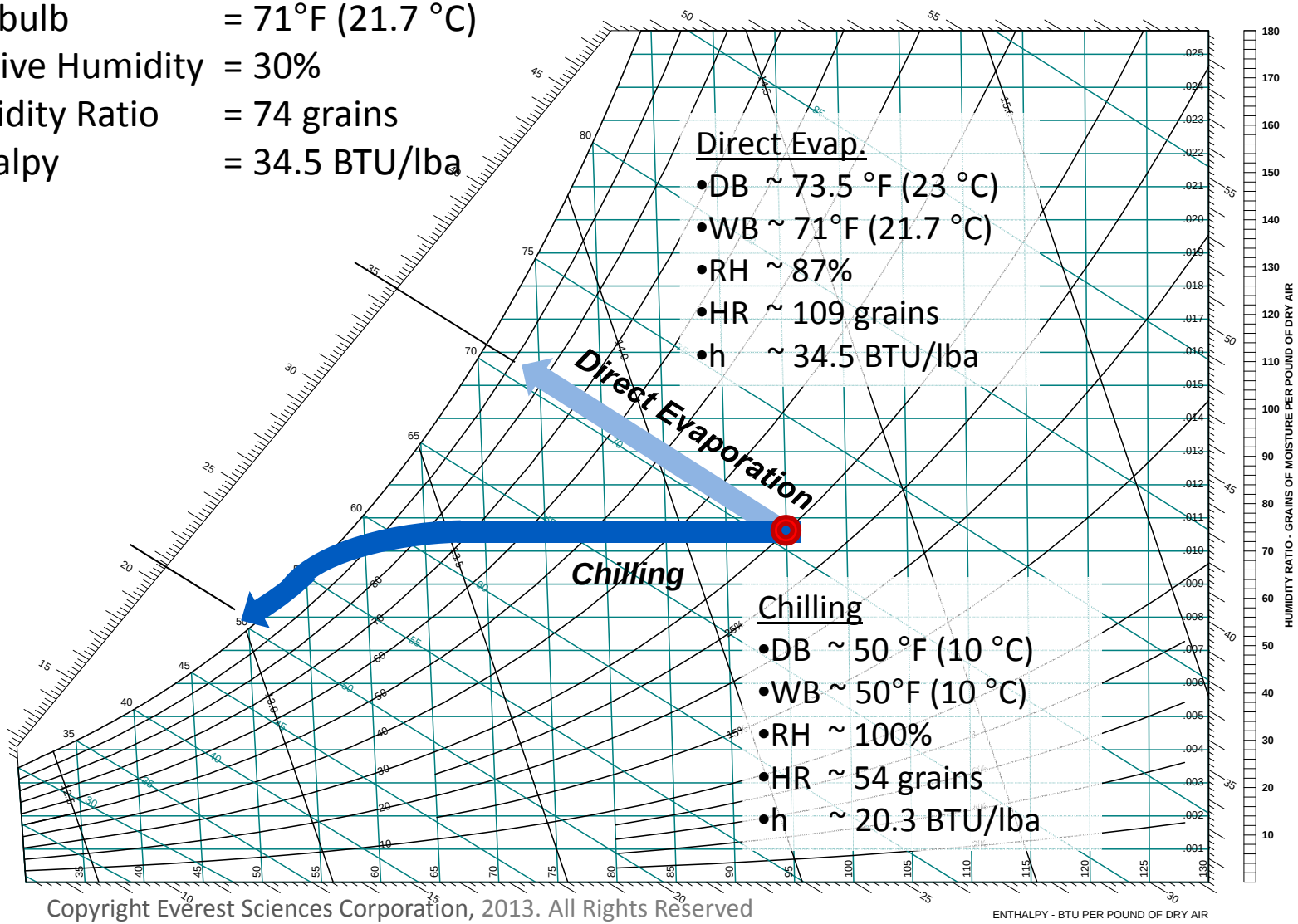
Conventional Cooling

- Ambient Conditions
  - Dry-bulb = 95 °F (35 °C)
  - Wet-bulb = 71°F (21.7 °C)
  - Relative Humidity = 30%
  - Humidity Ratio = 74 grains
  - Enthalpy = 34.5 BTU/lba



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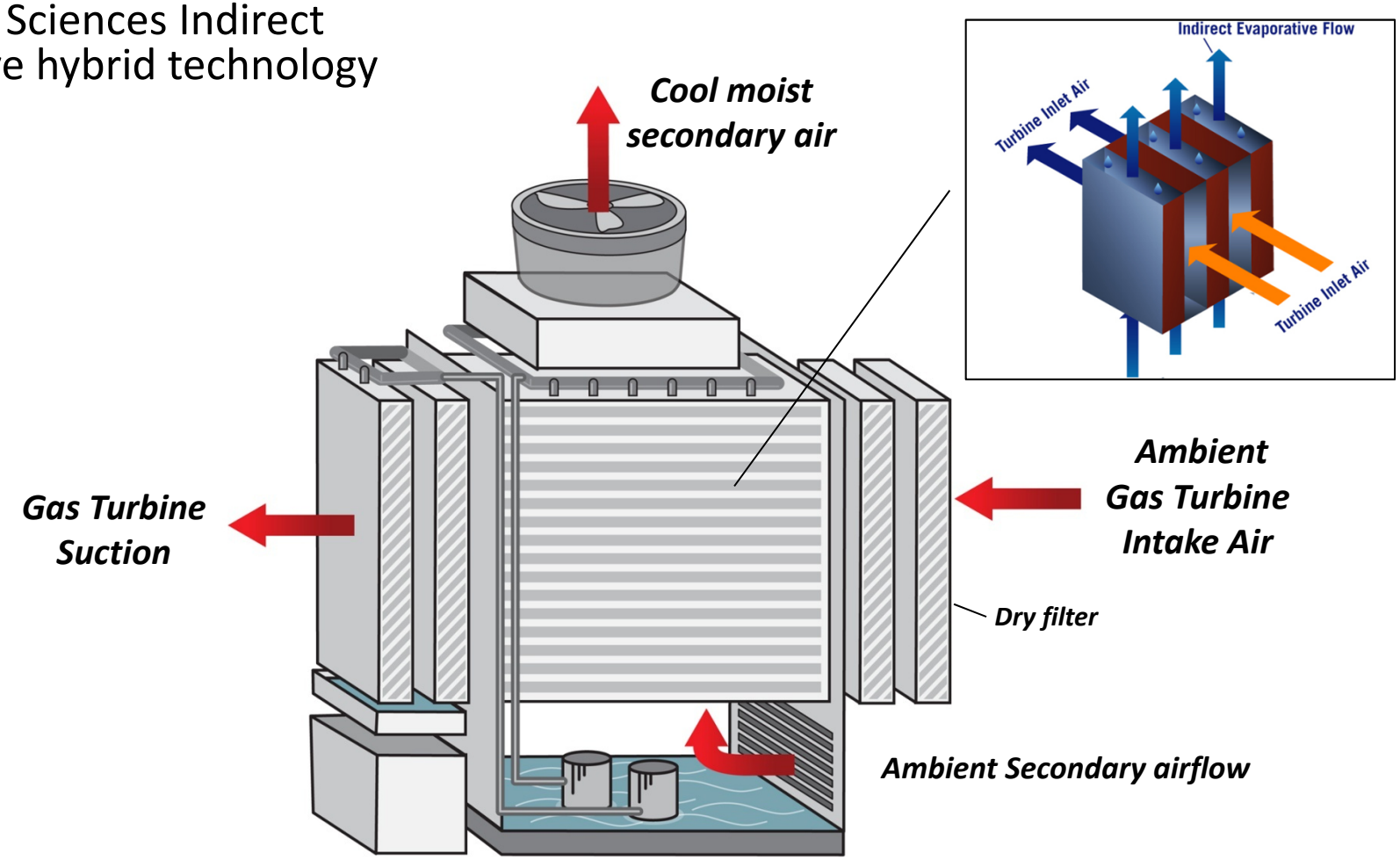
Hybrid System

Everest Sciences Indirect Evaporative hybrid technology



US and other international patents including 6,385,987 and 7,765,827

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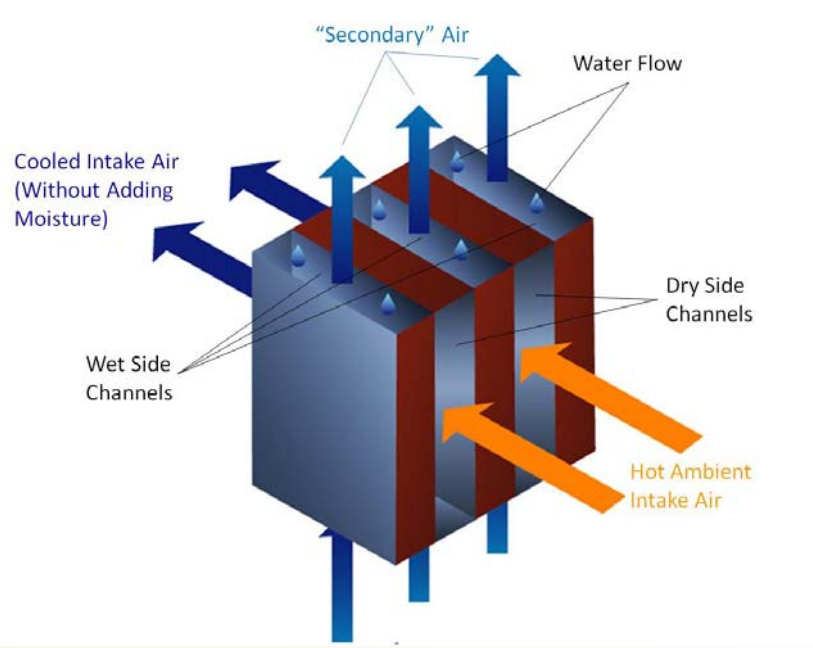
Indirect Evaporative Heat Exchanger

- Indirect Evaporative Cooling
  - Evaporative cooling in secondary air stream
  - Super Efficient Cross Flow heat exchanger cools inlet air stream
  - Cooling without introduction of moisture in primary air
  - Technology is mature and low risk



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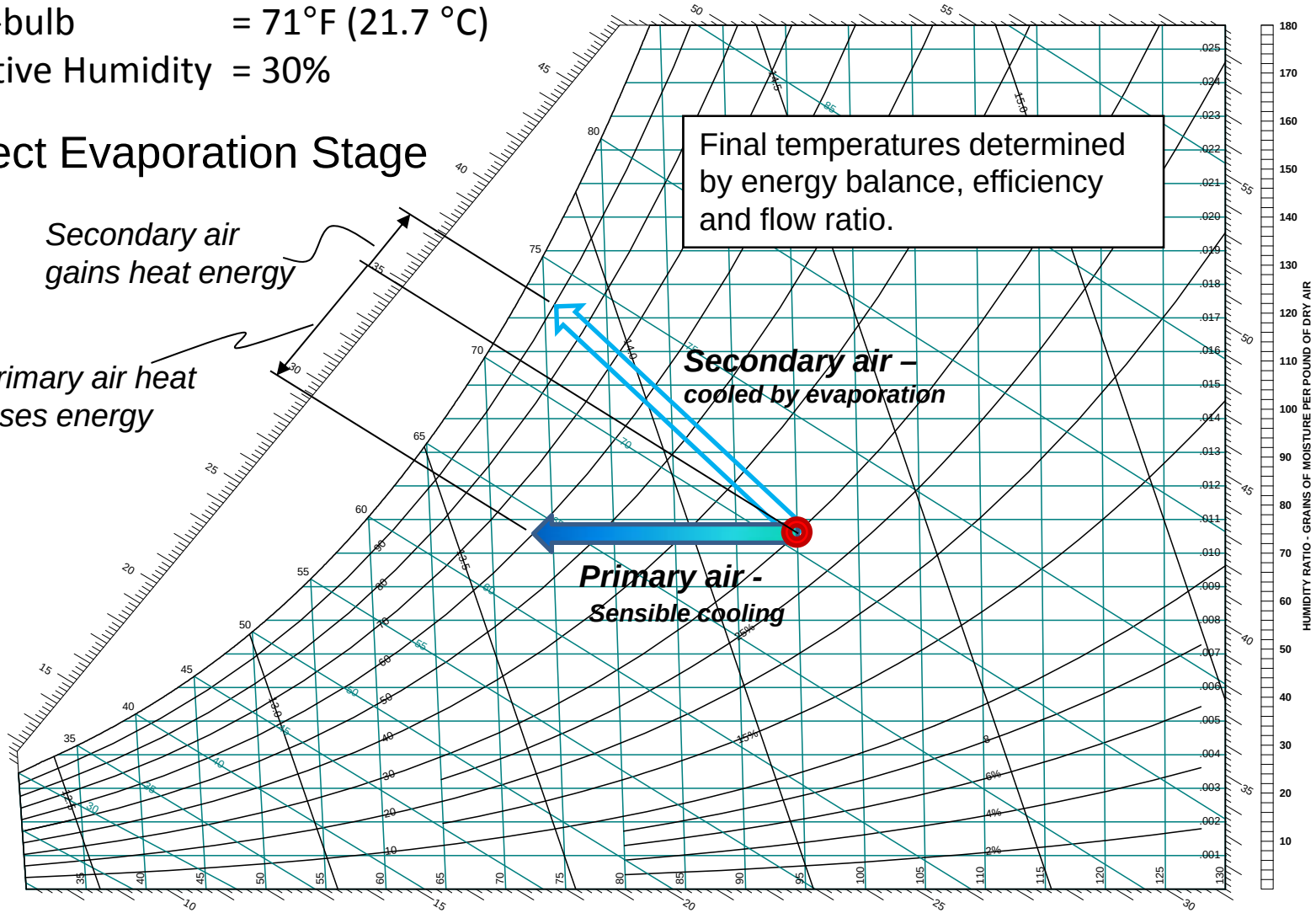
Indirect Evaporative Psychromentrics

- Ambient Conditions
  - Dry-bulb = 95 °F (35 °C)
  - Wet-bulb = 71°F (21.7 °C)
  - Relative Humidity = 30%

Indirect Evaporation Stage



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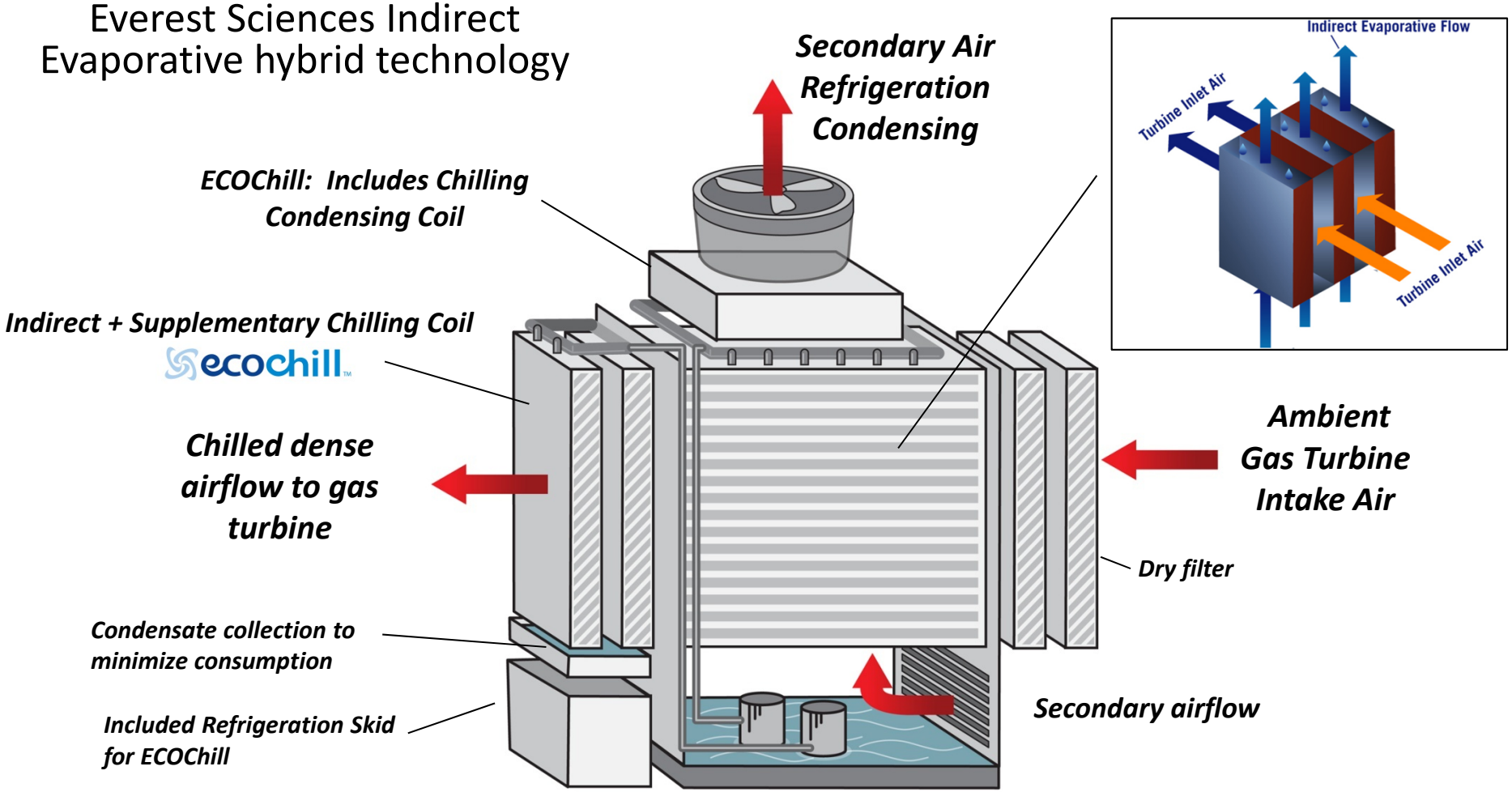
Indirect Evap. + Supplementary Chilling

Everest Sciences Indirect Evaporative hybrid technology



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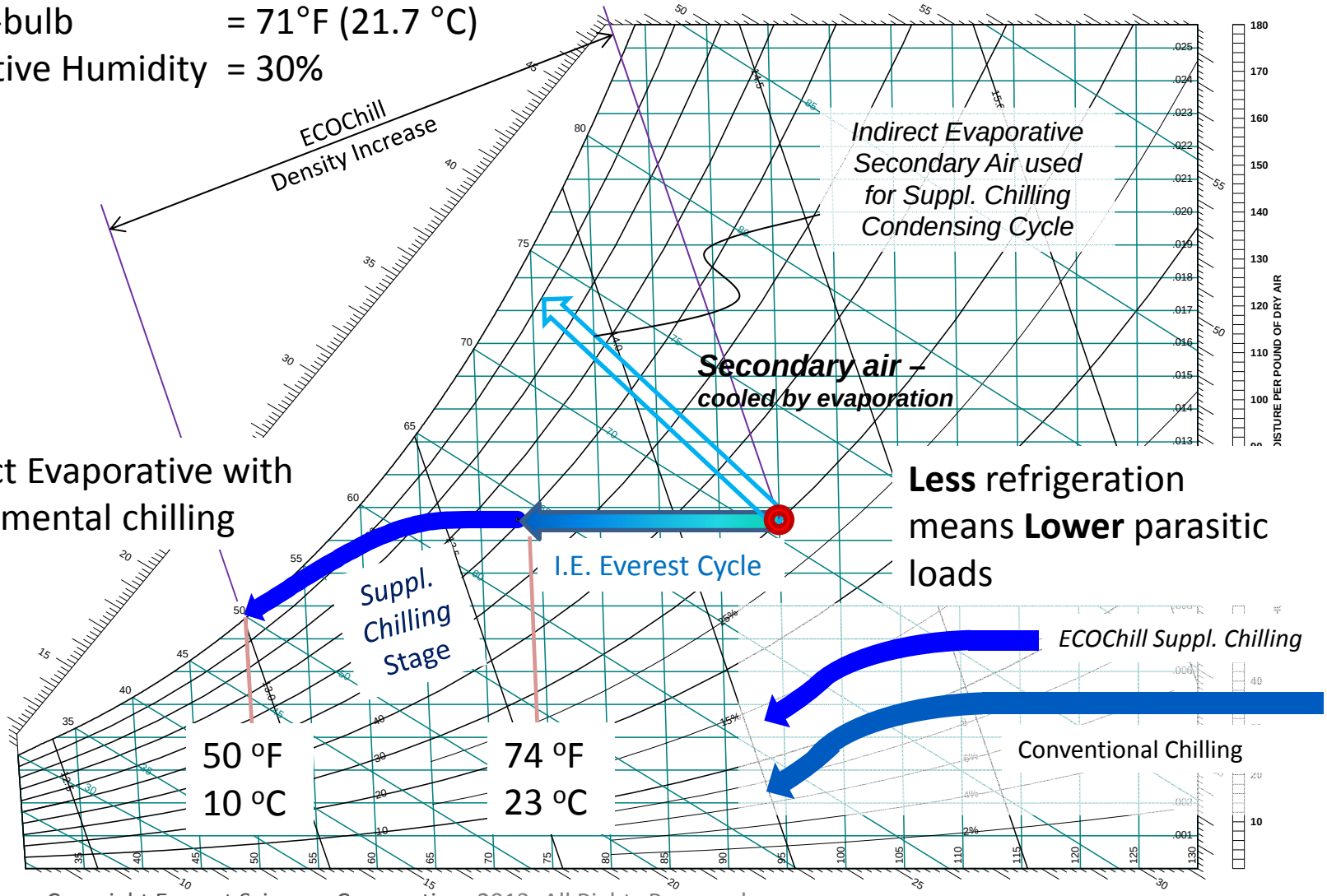
Indirect Evap. + Suppl. Chilling Example

<u>Ambient Conditions</u>

- Dry-bulb = 95 °F (35 °C)
- Wet-bulb = 71°F (21.7 °C)
- Relative Humidity = 30%



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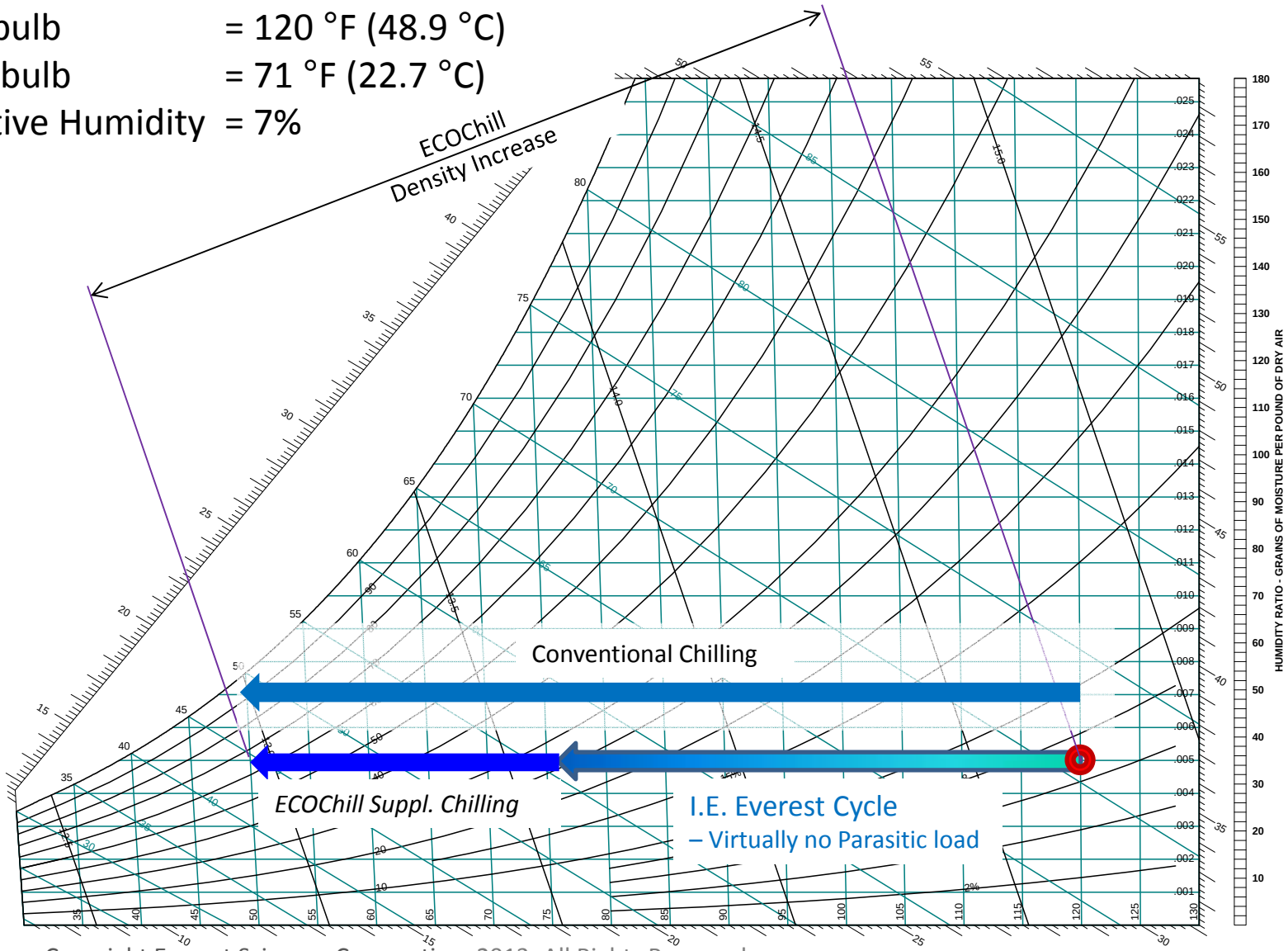
Indirect Evap. + Suppl. Chilling Hot Climate

- Ambient Conditions
  - Dry-bulb = 120 °F (48.9 °C)
  - Wet-bulb = 71 °F (22.7 °C)
  - Relative Humidity = 7%



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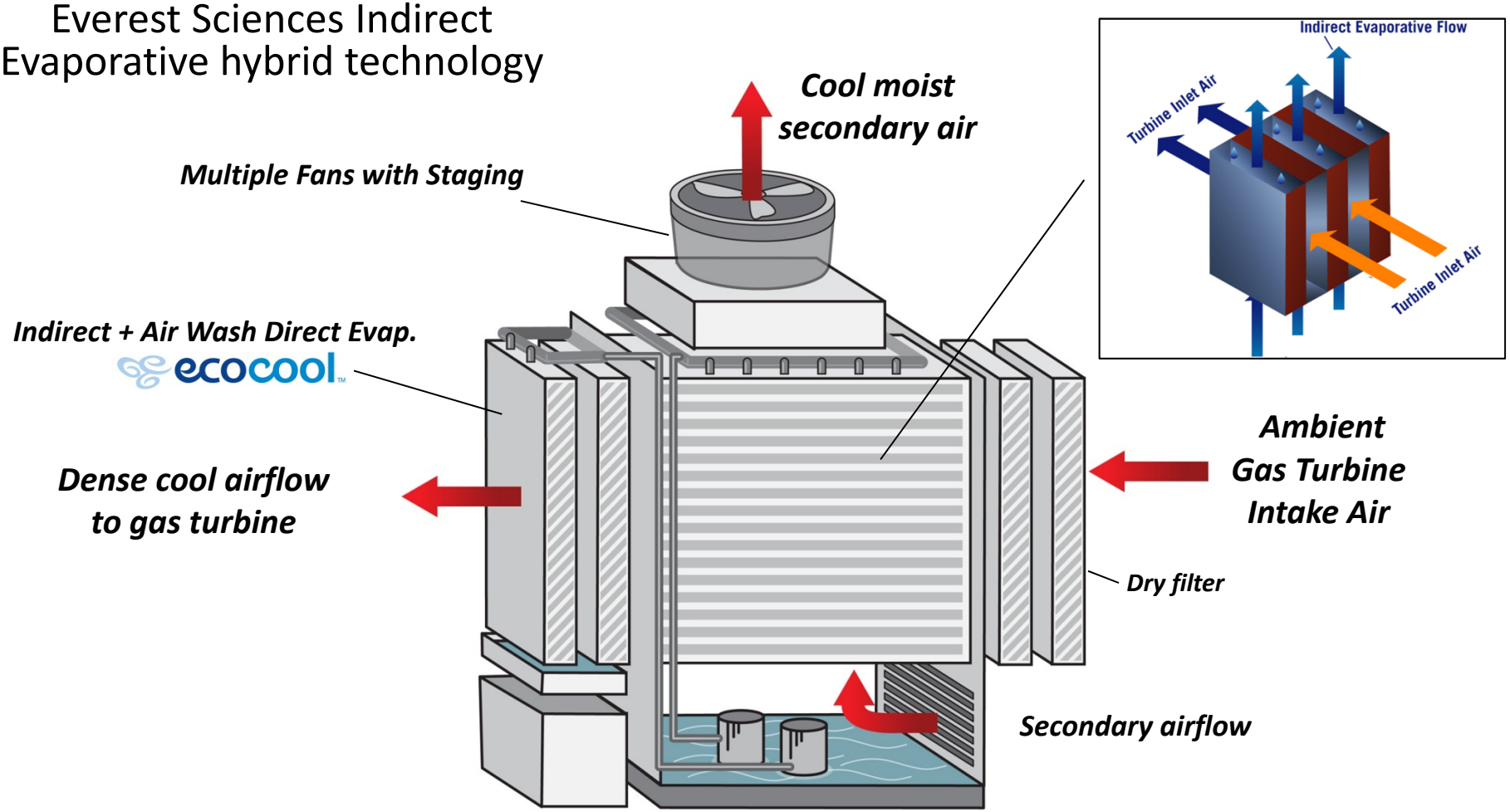
Indirect Evap. + Direct Evap.

Everest Sciences Indirect Evaporative hybrid technology



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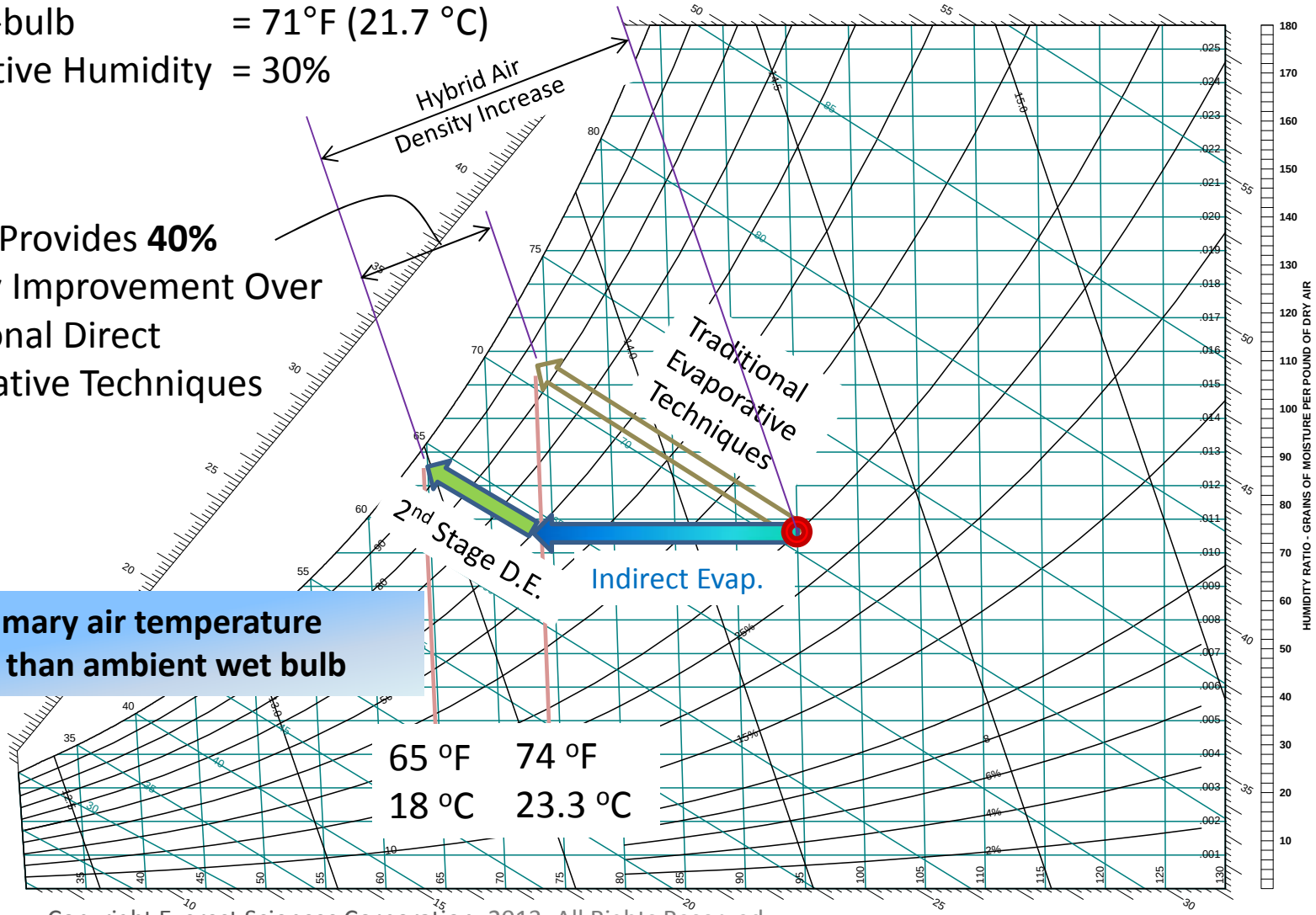
Indirect + Direct Evap. Example

- Ambient Conditions
  - Dry-bulb = 95 °F (35 °C)
  - Wet-bulb = 71°F (21.7 °C)
  - Relative Humidity = 30%

Hybrid Provides **40%** Density Improvement Over Traditional Direct Evaporative Techniques



Final primary air temperature is <u>lower</u> than ambient wet bulb

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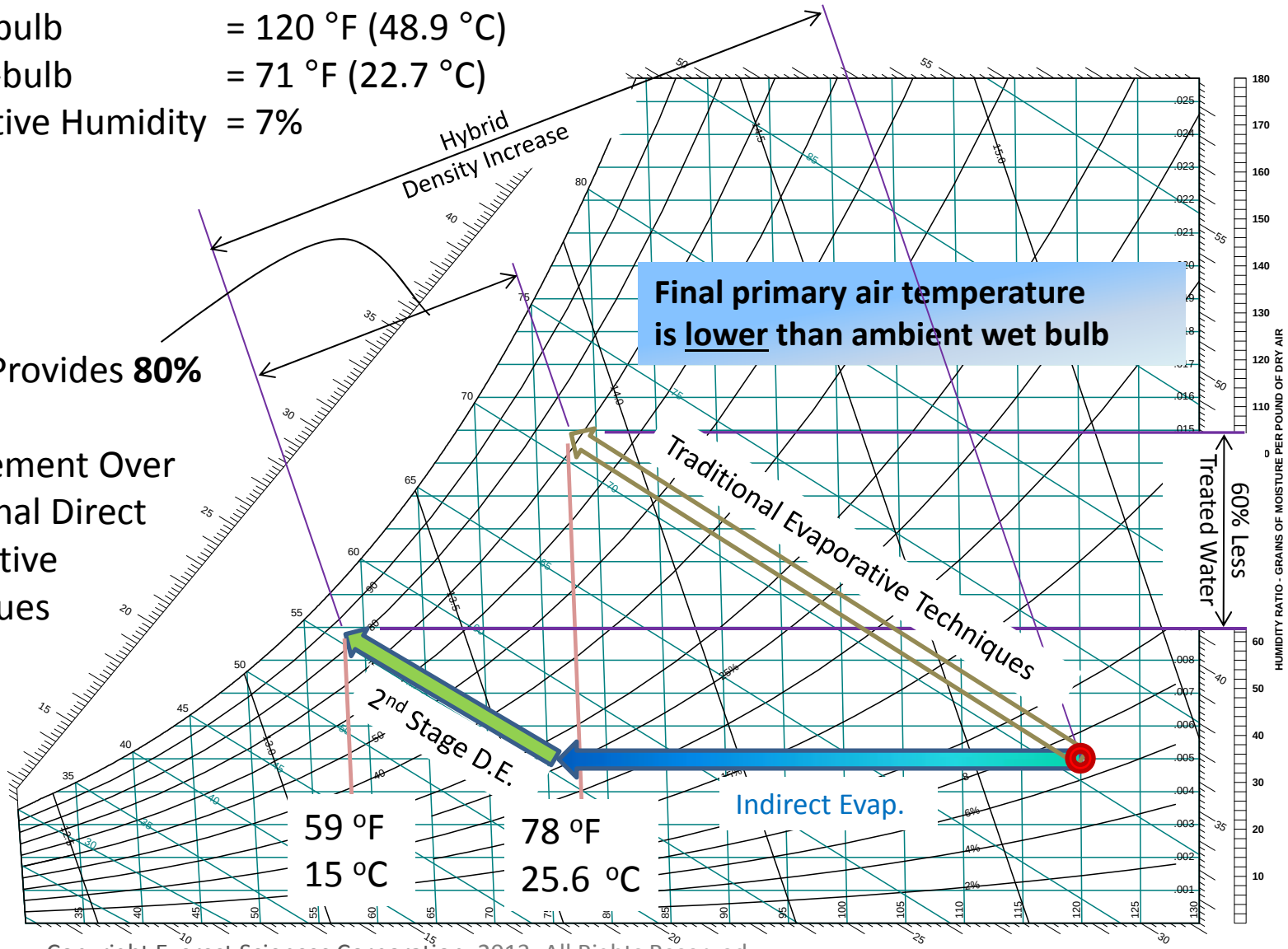
Indirect + Direct Evap. in Hot Climates

- Ambient Conditions
  - Dry-bulb = 120 °F (48.9 °C)
  - Wet-bulb = 71 °F (22.7 °C)
  - Relative Humidity = 7%

Hybrid Provides **80%** Density Improvement Over Traditional Direct Evaporative Techniques



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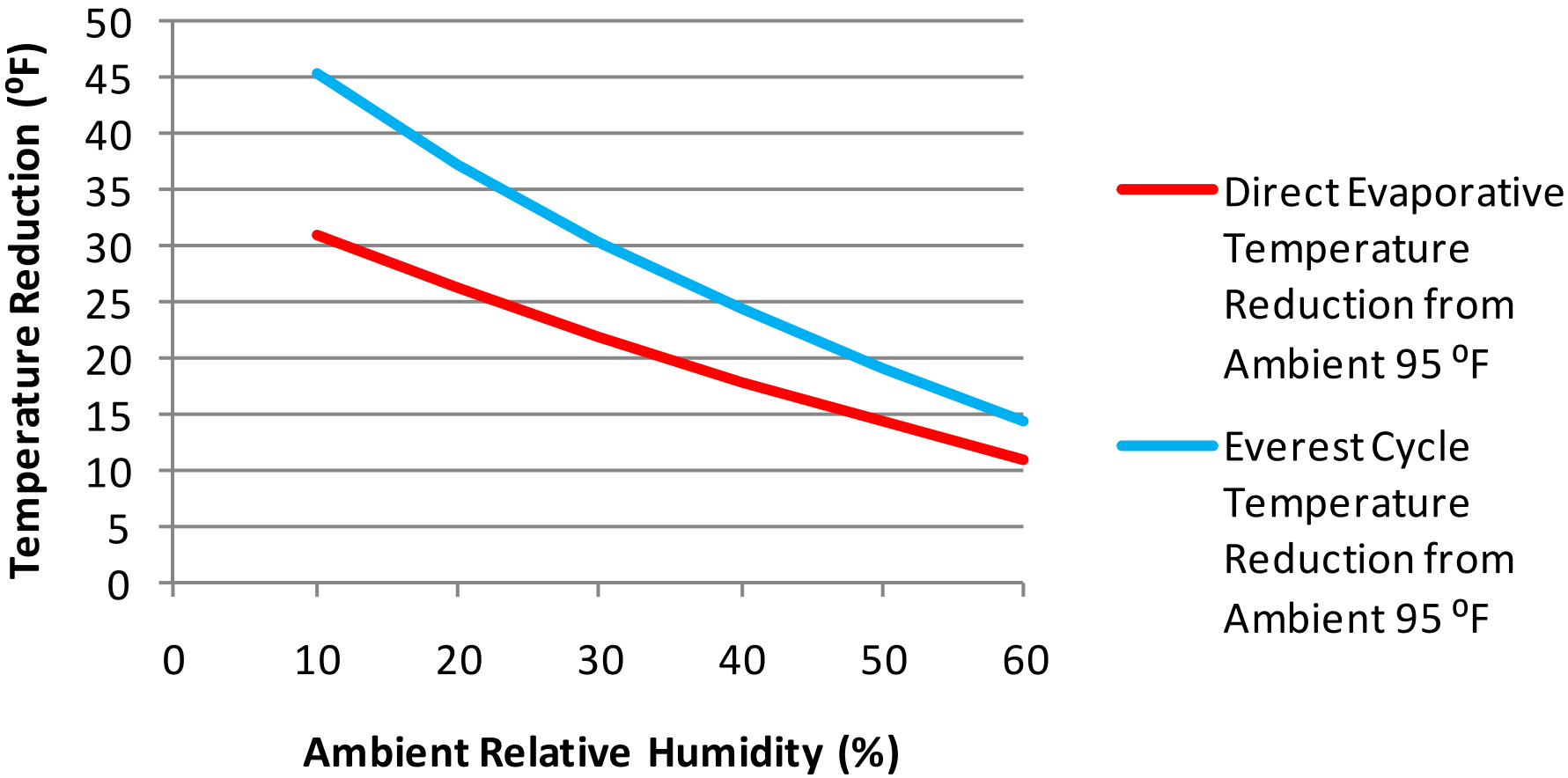
Hybrid vs. Direct Evap. Varying RH

Everest Cooling vs. Direct Evaporation



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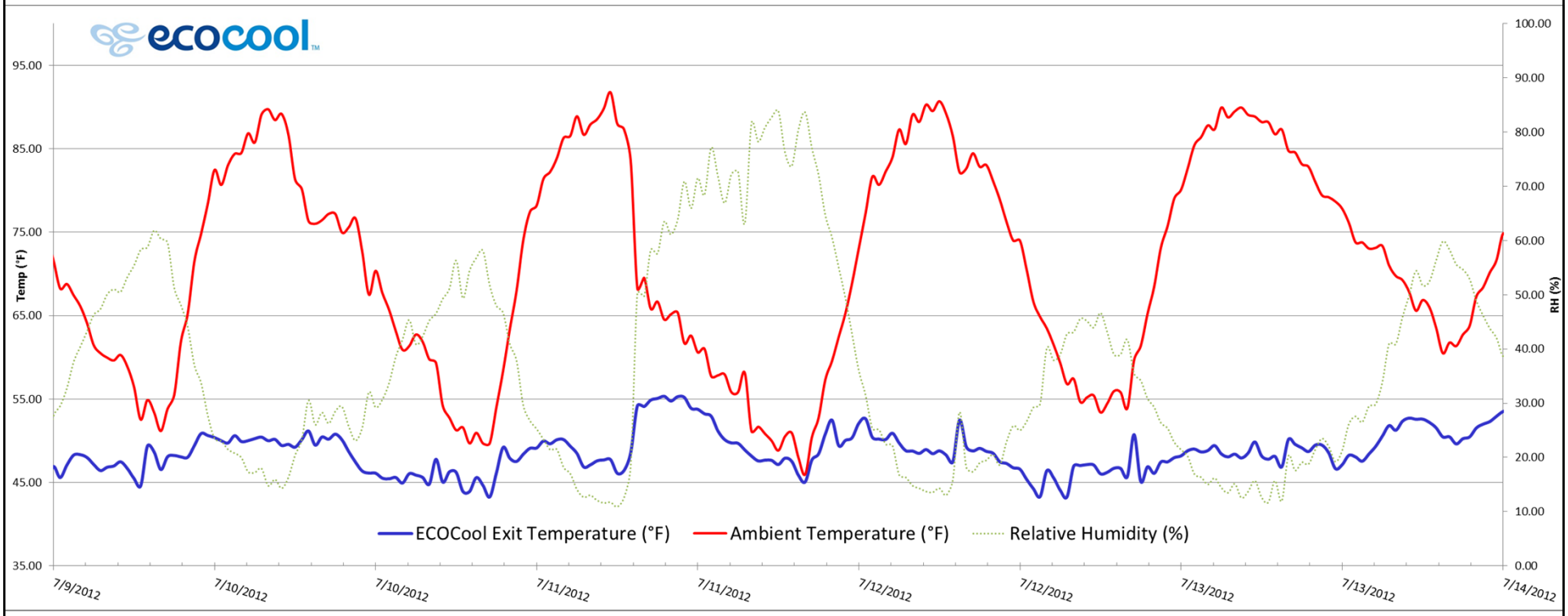
Performance Example Indirect + Direct

Actual Sample Historical Data for an Operational ECOCool



- **Plant turns off traditional direct evaporative system when ambient conditions fall below 60 °F**
- **ECOCool provides cooler air and automatically turns off direct evaporative stage while continuing to offer indirect evaporative cooling during cooler ambient hours**
- **ECOCool thus provides greater operational benefit**

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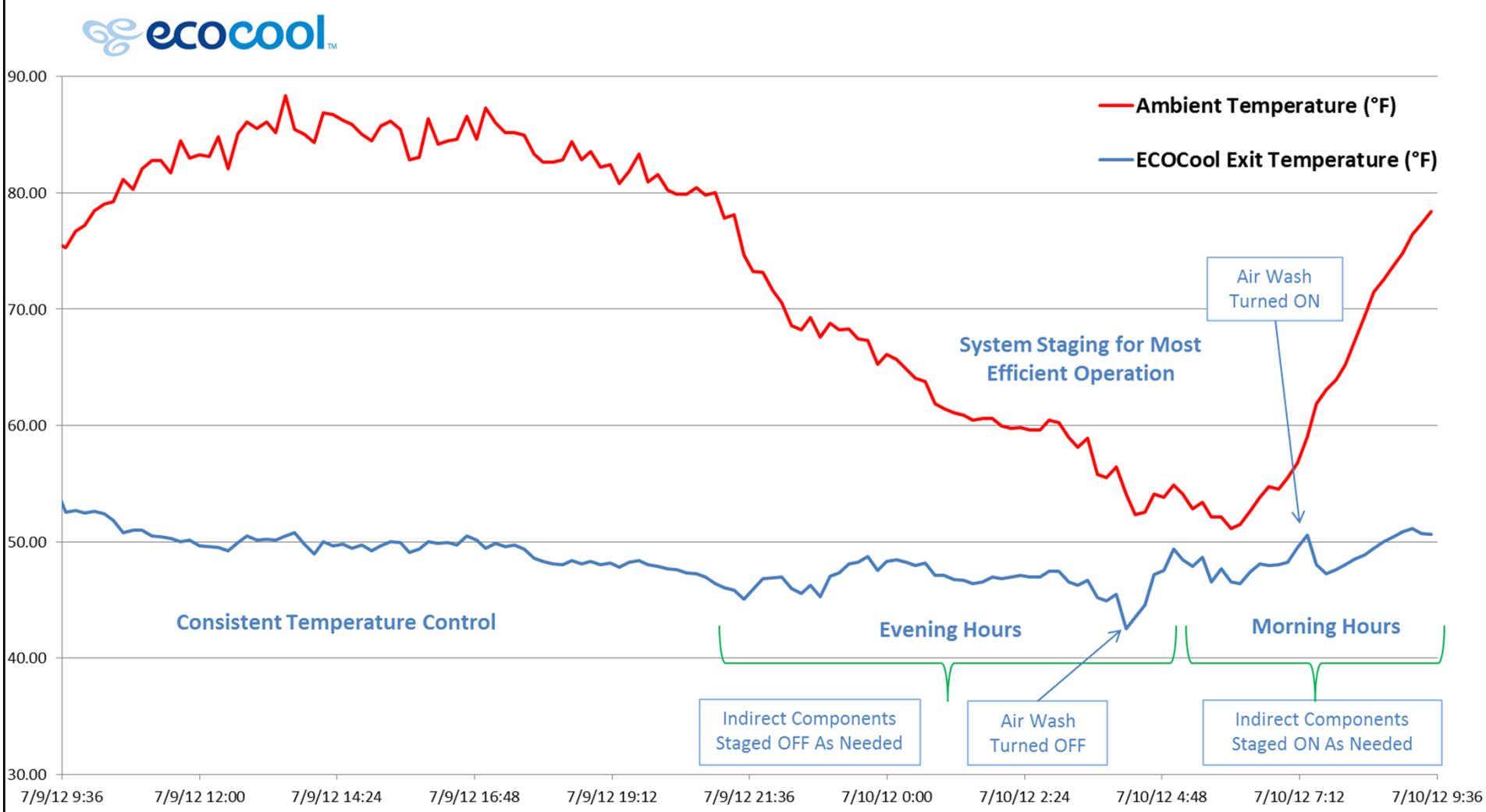
Hybrid Control

24 Hour Historical Data for an Operational ECOCool



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System Control

- Hybrid systems typically controlled by onboard computer
- Controller makes all decision on cooling staging
  - Stages fans, pumps, compressors, etc.
  - Constantly evaluating how to cool air most effectively while minimizing power consumption
  - Allows for remote operation
- Provides numerous feedback signals to plant DCS system

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Water Management

- Indirect Evaporative water does not contact turbine air
  - Manage concentrations with blow-down (automated)
  - Can include additives to increase cycles of concentration

- Water used in Direct Evaporative system should follow GT OEM requirements

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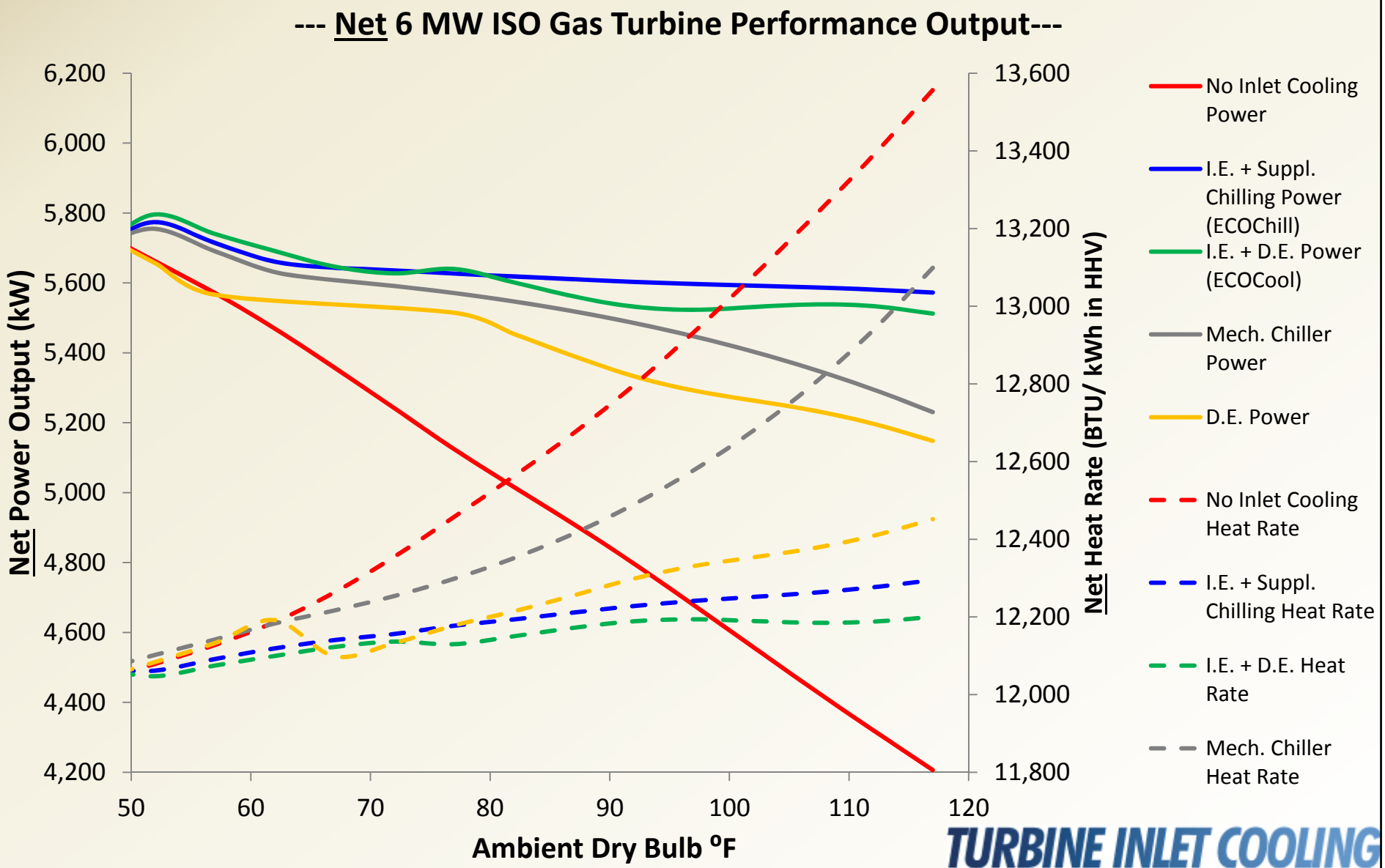
Hot Dry Climate Performance



* Power and Heat Rate based on book rated engine performance without deterioration.

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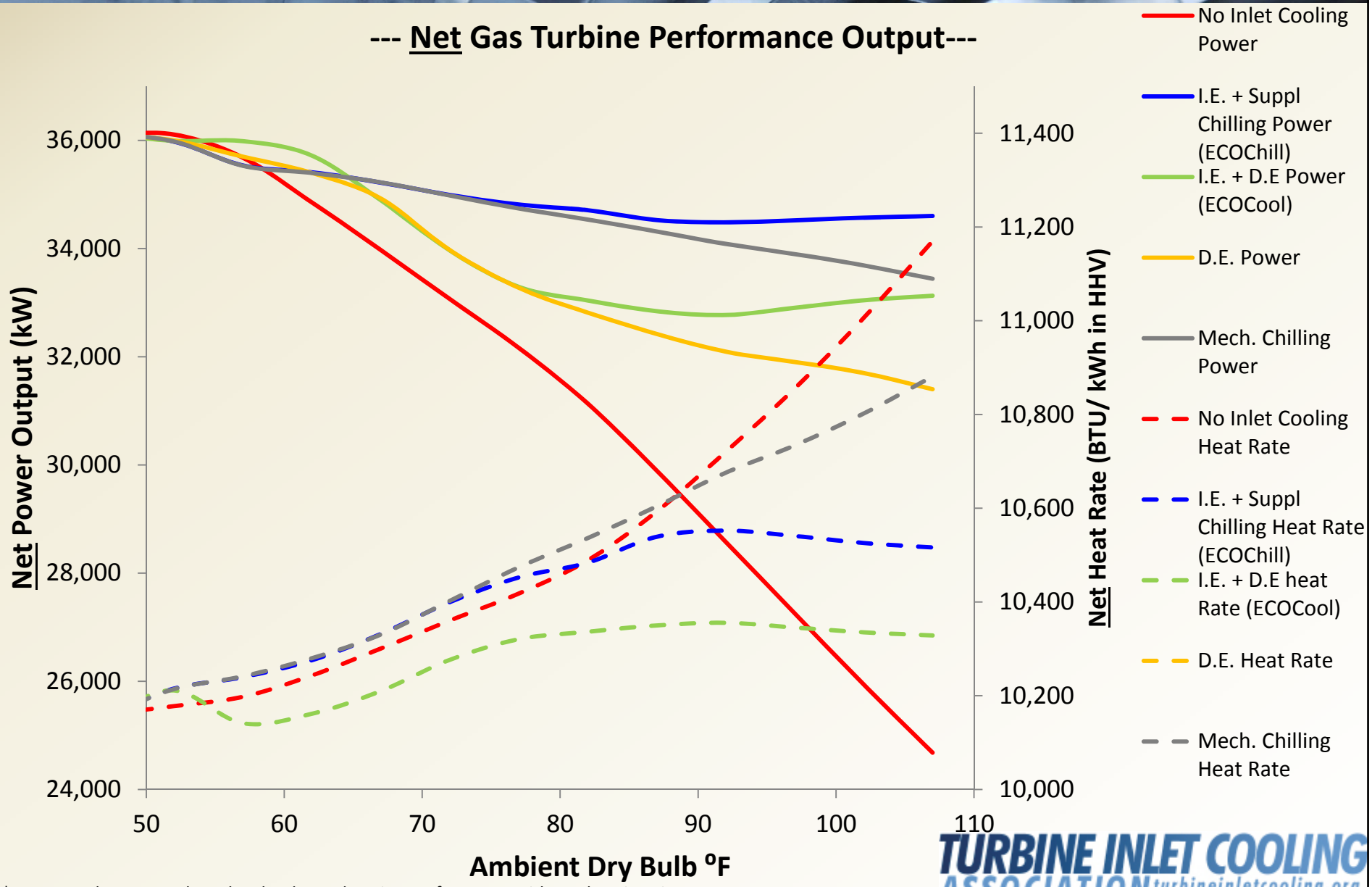
Hot Humid Climate Performance



* Power and Heat Rate based on book rated engine performance without deterioration.

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Integrated Hybrid Packaged Design

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Modular Installation

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ECOChill™ System

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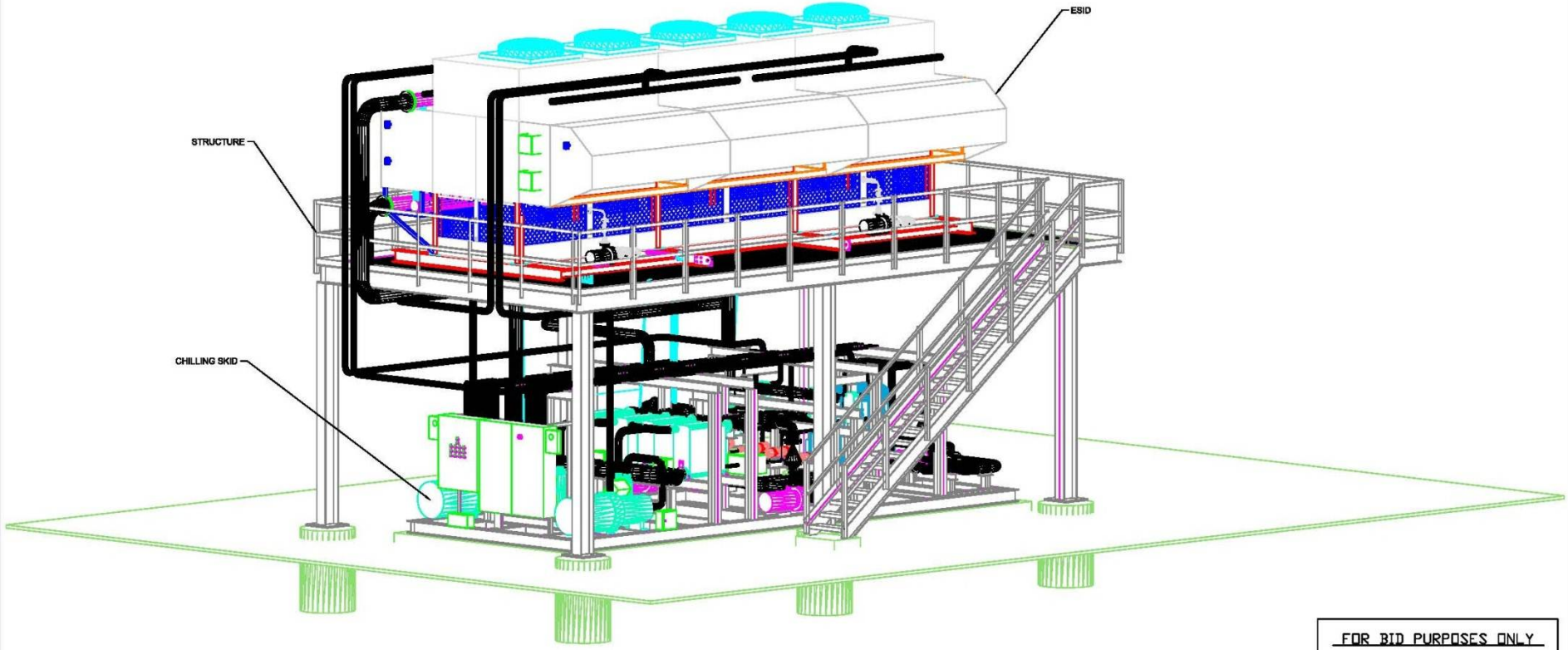
Elevated Installation



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CHECKED	SQ	06/27/12
ENG APPR		
MFG APPR		

SIZE B | DWG NO 60C-ESID-001-001 | REV A
SCALE: NTS | SHEET 1 OF 5

Elevated Installation

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Various Installations

Questions?

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