Turbine Air Systems

An Introduction To Turbine Inlet Chilling

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Sponsored by: Turbine Inlet Cooling Association (TICA)

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economic. clean. energy.

AGENDA

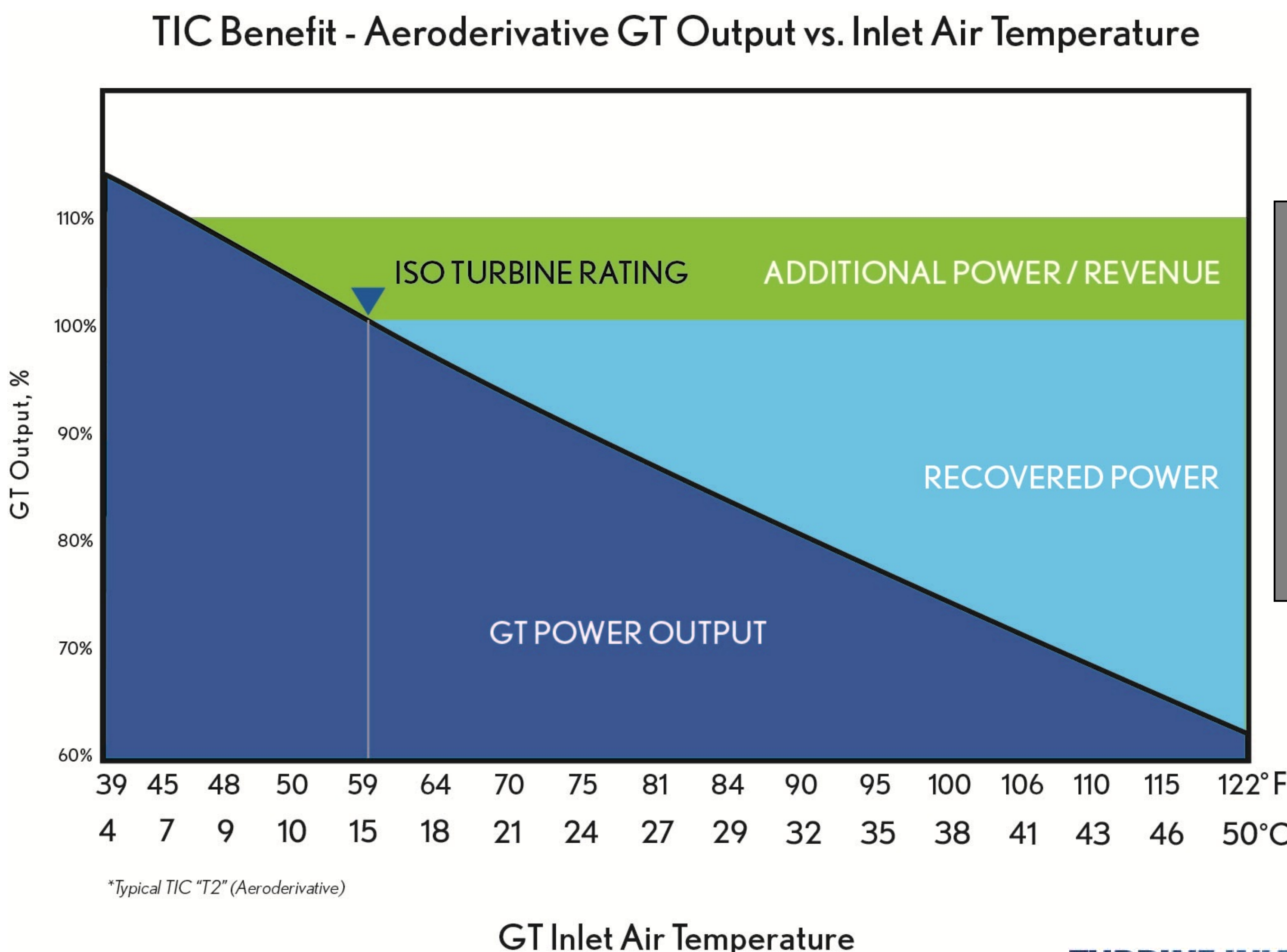
- Turbine Inlet Chilling 101
  - Chilling Attributes / When It Makes Sense / System Overview / Design Considerations
- Turbine Inlet Chilling Technology Types
  - Mechanical Chillers / Absorption
- Turbine Inlet Chilling Retrofits
  - Power Plant and Air-Filter Retrofit Considerations
- Turbine Inlet Chilling With Thermal Energy Storage
  - Thermal Energy Storage Overview
- Questions and Answers Session

CORE COMPETENCIES

TAS MANUFACTURING CAPABILITIES

- ISO 9001:2008 Registered
- 240,000 square feet fabrication /assembly area
- 47,000 Square feet of office space
- Crane Capability – Single 80-Ton Pick
- ASME Section 9 Compliant Welding Program
- Third party NDE (x-ray, mag particle ,etc)
- In-house pneumatic system pressure / leak testing

WHY TURBINE INLET CHILLING?



"The fundamentals of a gas turbine are such that on a hot day the gas turbine loses output and operates less efficiently."

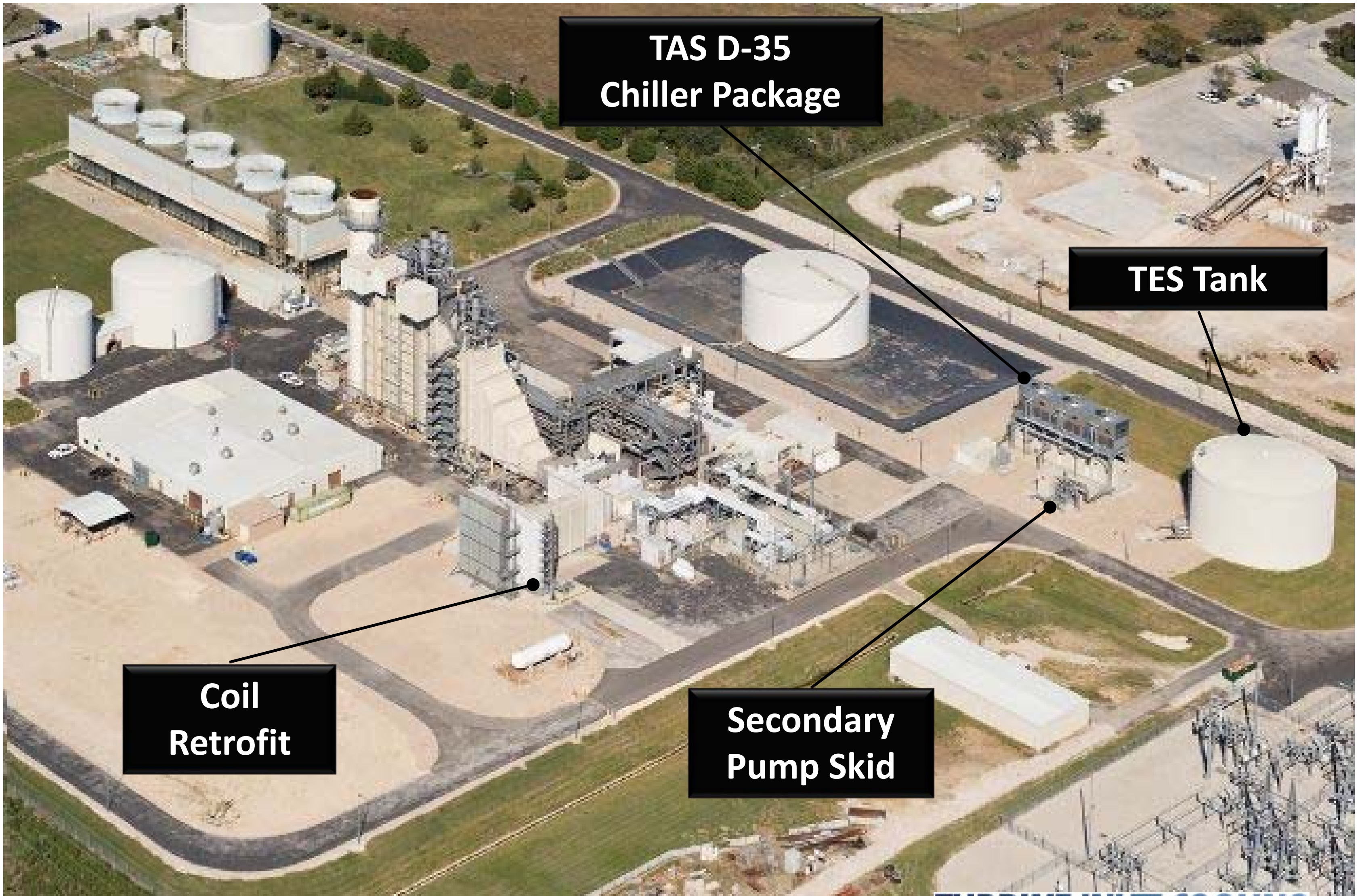
TIC TECHNOLOGY ATTRIBUTES

- Produces "hidden" MWs with existing assets at costs less than new built generation
- Adds significant flexibility to operations
- Maintains ideal gas turbine air temperature
- Allows for arbitraging night time power pricing for day time peak pricing with thermal storage capability
- Eliminates weather risk
- Provides emissions predictability
- Provides opportunity to offset degradation
- Achieves all of the above with lower non-fuel O&M costs

WHEN TIC MAKES SENSE

- Market demand in the form of:
  - High peak power demand or growing peak power load profile
  - Non-energy sales revenue in addition to energy sales (capacity payments – PJM market in US)
- Climate suitable to TIC(hot and humid environment)
- Muni / Coop / Gov't Utility looking to take advantage of incremental power improvement with existing assets
- Need incremental power in a relatively quick timeframe compared to new build generation (permits, construction, etc.)
- Short on a Power Purchase Agreement (PPA) obligation and needs incremental power from the installed asset

CHILLING COMPONENT OVERVIEW



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DESIGN CONSIDERATIONS

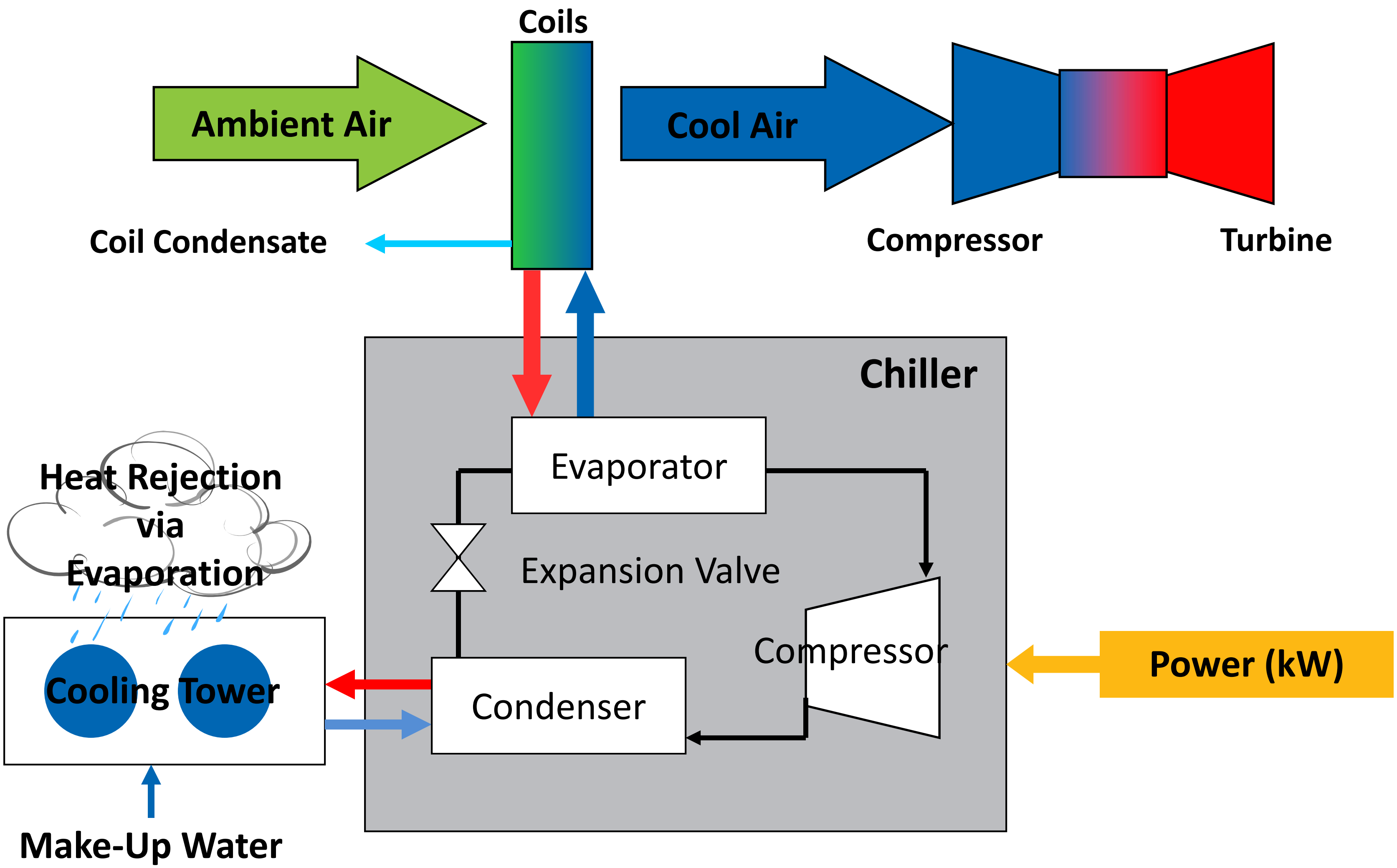
Power Plant Considerations

- Desired Plant Output
  - Satisfy Capacity Contract
  - Satisfy Competitive Specification
  - Site Utility Limitation
  - Optimal Heat Rate
- Thermal Energy Storage Shift (Charge vs. Discharge)
- Ambient Design
  - Dry Bulb / Wet Bulb
  - Target Inlet Temperature
  - Mass Flow
- Space Availability
- Energy Source
  - Steam or Electrical Supply

Chiller Considerations

- Inlet Coil Design
  - Face Velocity
  - Pressure Drop
  - Freeze Protection
- Chiller Package Design
  - Refrigerant Type
  - Heat Rejection Technology (Water / Air / Absorption)
  - Pump Redundancy
  - Cooling Tower Mat'ls / Sound
- Electrical
  - Feeds
  - Standards (NEC / IEC)
  - Protection (Arc Flash)
  - Controls

WATER-COOLED MECHANICAL



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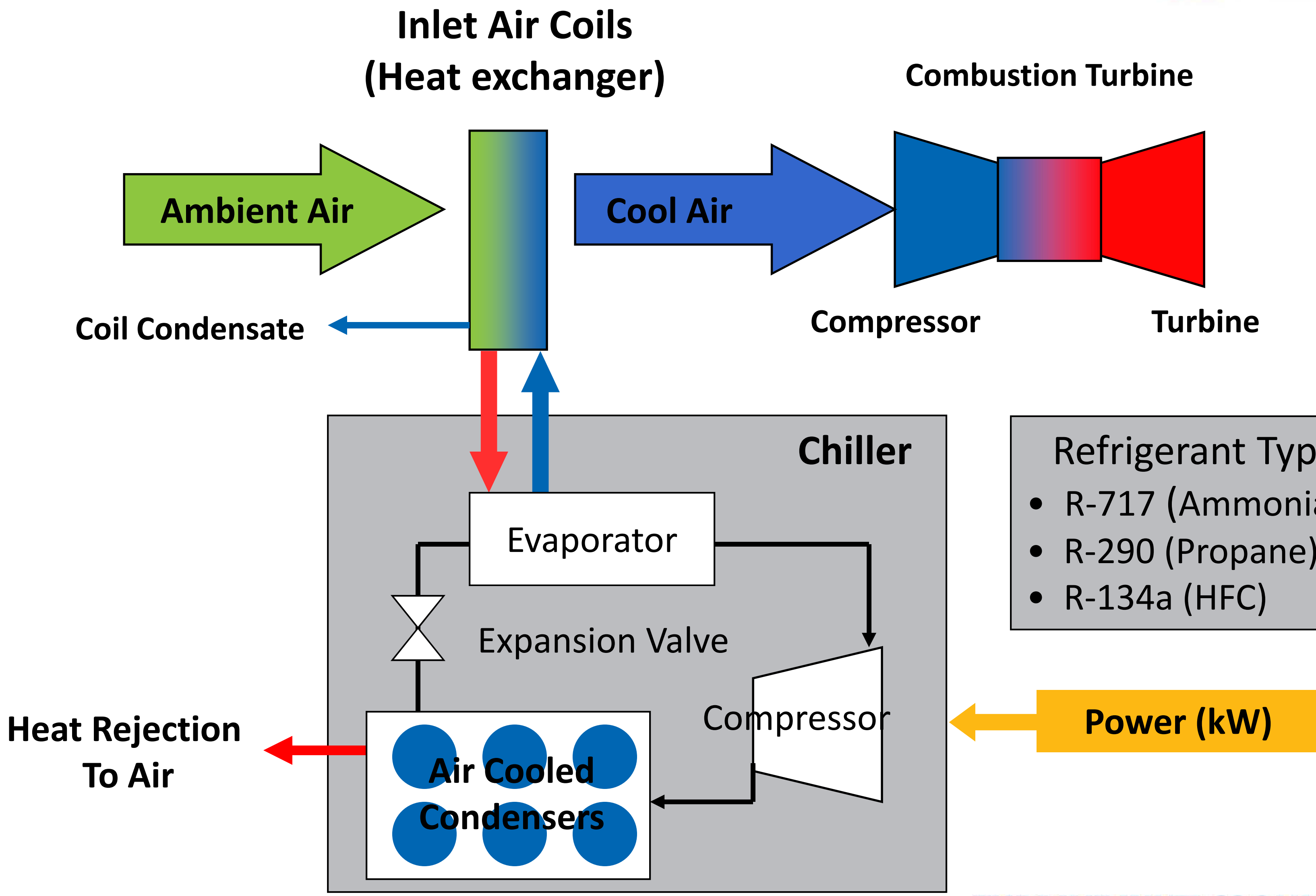
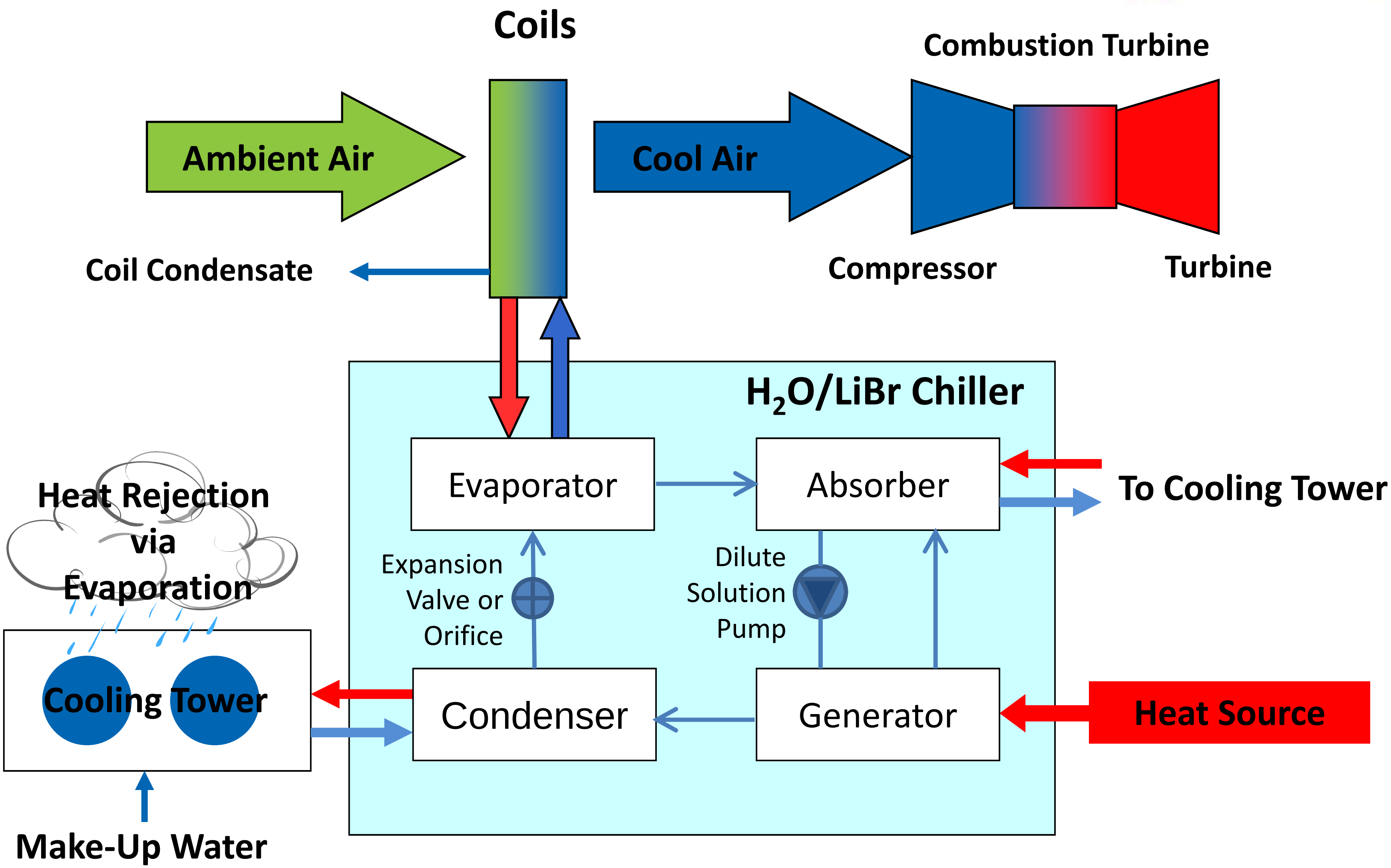
AIR-COOLED MECHANICAL



Refrigerant Types
- R-717 (Ammonia)
- R-290 (Propane)
- R-134a (HFC)

ABSORPTION


Coils
Combustion Turbine
Ambient Air
Cool Air
Coil Condensate
Compressor
Turbine
H_2O/LiBr Chiller
Evaporator
Absorber
To Cooling Tower
Heat Rejection via Evaporation
Expansion Valve or Orifice
Dilute Solution Pump
Cooling Tower
Condenser
Generator
Heat Source
Make-Up Water

ABSORPTION CONSIDERATIONS

Advantages

- Significantly lower electrical load
- Good use of waste heat if available such as:
  - Hot water
  - LP steam
  - Direct engine exhaust
- Well paired with a Thermal Energy Storage (TES) system, that allows the absorption chiller to operate at constant load

Disadvantages

- Higher capital cost
- Low thermal efficiency
  - Higher water consumption
  - Not good in an air-cooled application
- Larger equipment footprint
  - Requires around 1/3 more cooling tower capacity compared to mechanical chiller
- Potentially reduced life expectancy compared to mechanical chiller
  - Highly dependent on quality of maintenance
- Can be prone to vacuum leaks
- Possibility of solution crystallization
- Does not cycle effectively

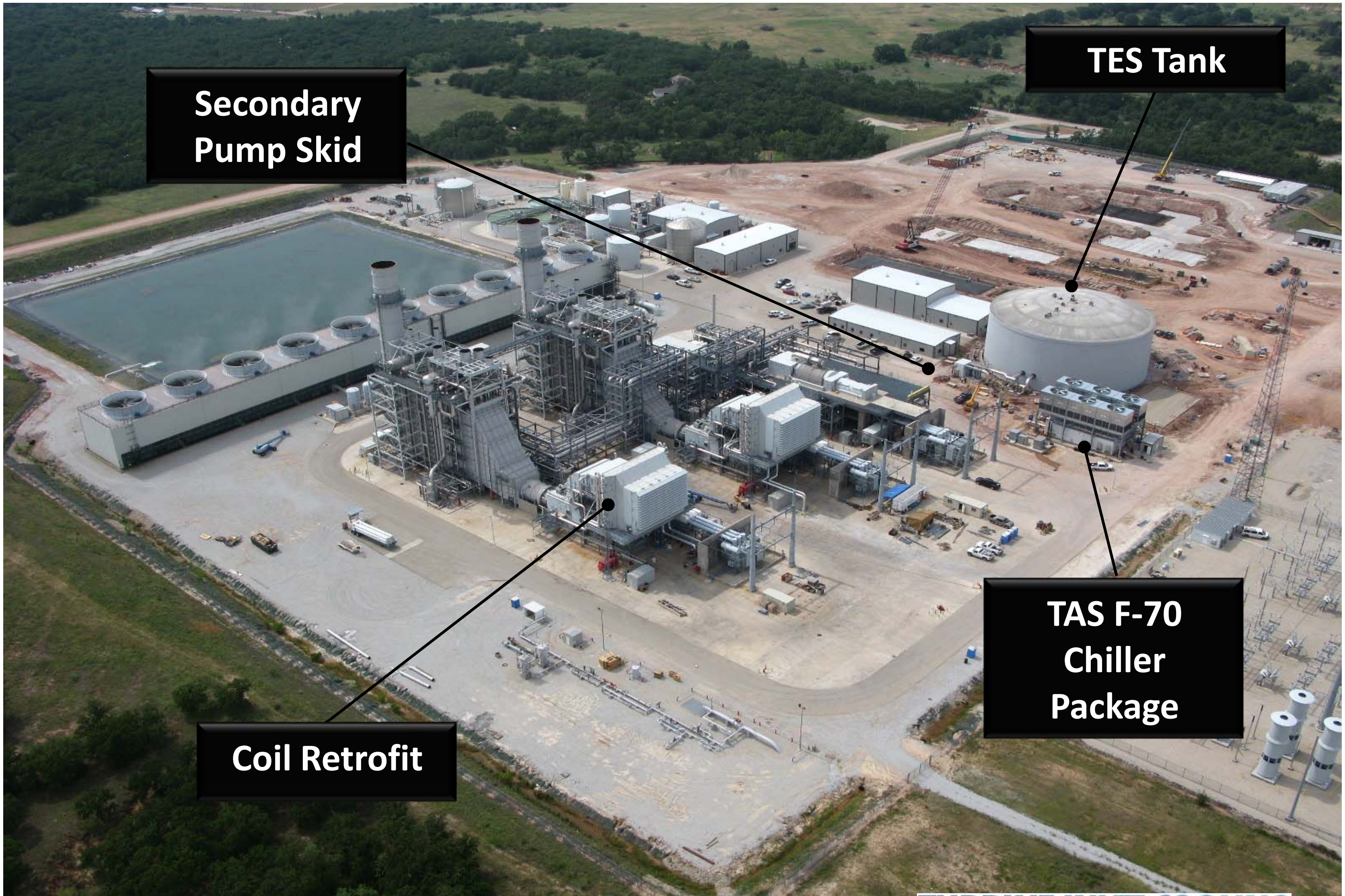
SHIFT IN TECHNOLOGY ACCEPTANCE

- Historically Turbine Inlet Chilling (TIC) applications have been limited to aeroderivative peaking power plants only
- In the past 5-years there have been significant awards in chilling advanced combined cycle power plants globally

- Application advantages:
  - Ancillary services
  - Capacity payments
  - SuperPeak™
  - Grid flexibility with increased renewable penetration
  - Storage as spinning reserve
  - Compliments night time wind generation

USA located 3 x 1 MHI 501G Power Plant

TURBINE INLET CHILLING RETROFIT



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RETROFIT PROJECT EXAMPLE

- Customer: Confidential
- Site location: Texas
- Project Timing: 2008-2009
- Outage Duration: ~15-30 Days
- Construction Man-Hours: ~50,000
- Construction Duration: ~9 Months
- Project Timing: 2008-2009
- Turbine OEM: GE Frame 7FA
- Power Plant Type: 2 x 1 Combined Cycle

AIR FILTER RETROFITS

Erection of Filter Platform Extension

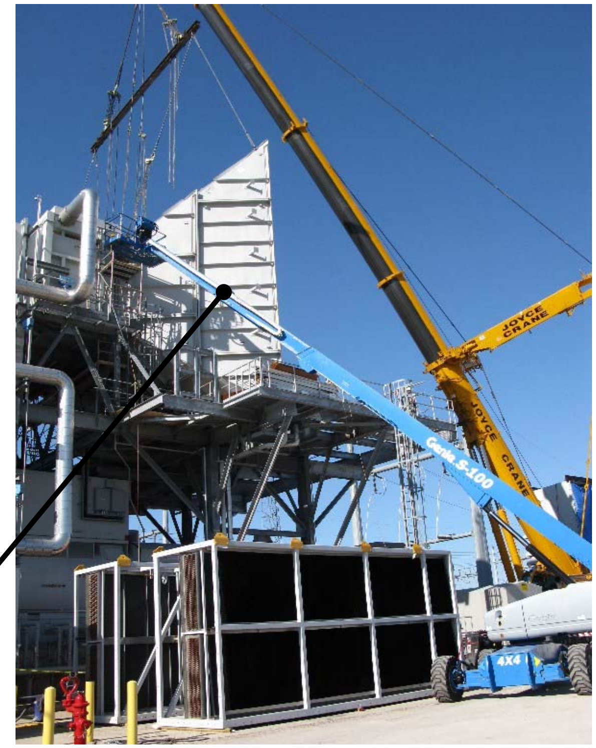
Existing Filter Removal

AIR FILTER RETROFITS

Right Hand Coil Module

Four Coil Modules Installed

New Transition



AIR FILTER RETROFITS

Filter Module Installed

Coil Module Access Platforms

Coil Assembly Header

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RETROFIT PHOTO

FILTER HOUSE RETROFIT FEATURES

- Coil Module Sizing
- Filter House Transition
- Coil Location
- Filter House Obstructions (Forward / Aft)
- Filter House Structure / Modifications
- Filter House Ducting (Concentric / Eccentric)
- Outage Considerations (Timing / Interference)
- Chilled Water Pipe Routing
- Condensate Return

CONCENTRIC VS. ECCENTRIC

BEFORE

- Eccentric Inlet Duct
- Extended Inlet Duct for Fogging

AFTER

- Concentric Inlet Duct
- New Spacer Elevates Inlet Duct
- Existing Filter House Utilized

RETROFIT OUTAGE CONSIDERATIONS

- Parallel Construction Activities
- TIC Retrofit Should Not be Additive to Turbine Outage Durations
- At Site Construction Duration ~6 Months
- Duration From Execution to Outage ~50 Weeks
- Critical Path Retrofit Components are Air Filter Retrofit Kits / Coil Assemblies (30-35 Weeks)
- Work Can be Done In Parallel with Hot Gas Path / Major Outage Work
- Schedule Coordination a Must
- Consider Winter Outage for Performing Work

TYP. RETROFIT OUTAGE DURATIONS

Site	Duration Days Planned	Duration Days Actual
Georgia - Unit #1	21	12
Georgia - Unit #2	21	14
PJM - Unit #1	13	15
PJM - Unit #2	13	15
PJM - Unit #3	25	32
PJM - Unit #4	25	32
Texas #1	18	15
Texas #2	26	23
Texas #3	29	20
Average	**21**	**20**

- Planning durations should be 3-4 weeks
- Contractor equipment / site familiarity and capability very important
- Outage duration typically dictated by gas turbine / steam turbine maintenance
- Site coordination during proposal phase required

FILTER HOUSE COIL PIPING DESIGN

Left Hand Coil Header Piping

Reverse Return Header Piping

Right Hand Coil Header Piping

www.turbineinletcooling.org

http://www.turbineinletcooling.org/coolingcalculator.html

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Thank You!

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