Gas Turbine Inlet Air Cooling System

The 3rd Annual Australian Gas Turbine Conference

6th – 7th December 2001
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Australia

Presented by

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PB Power Australia

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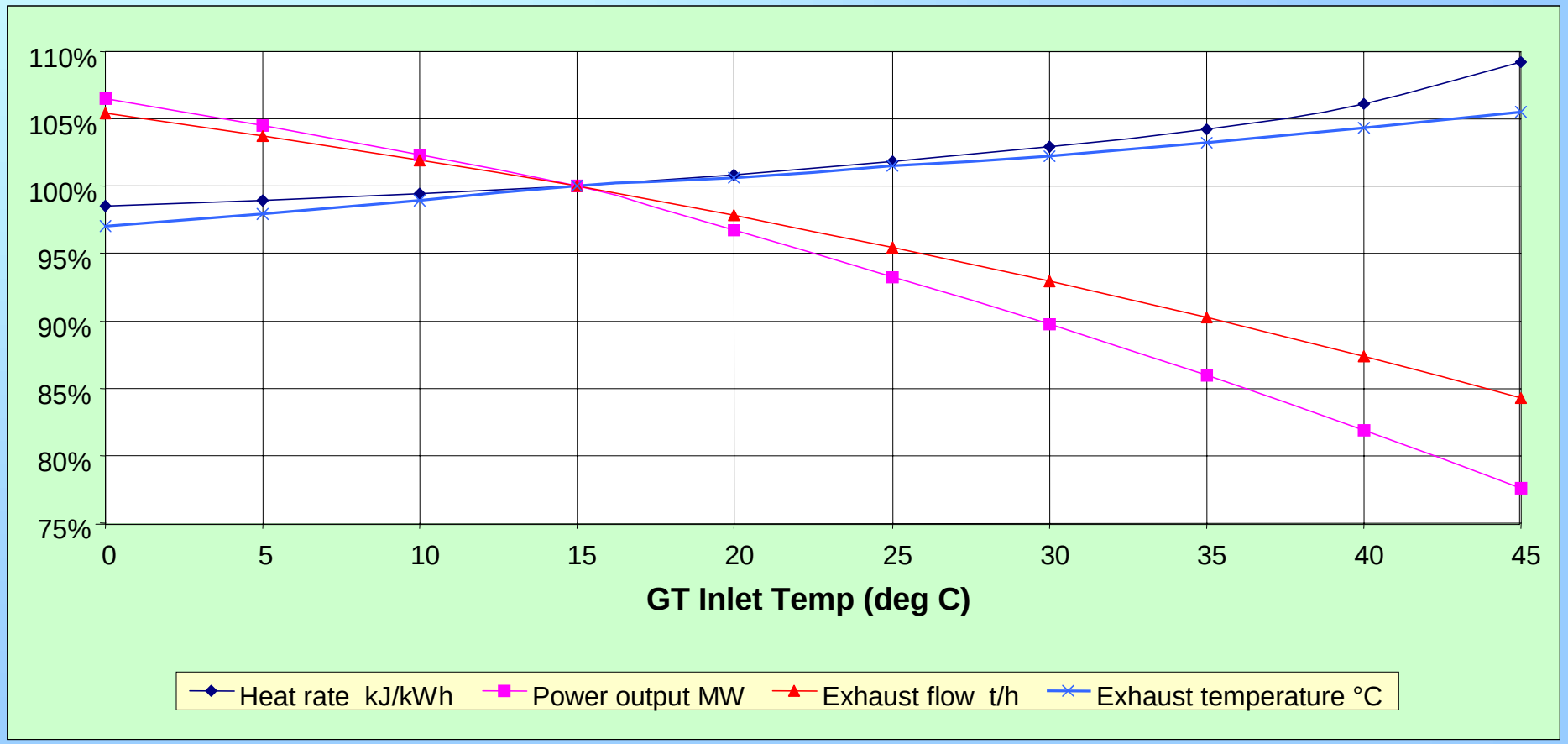
Heavy Duty GT - Effects of Ambient Temp



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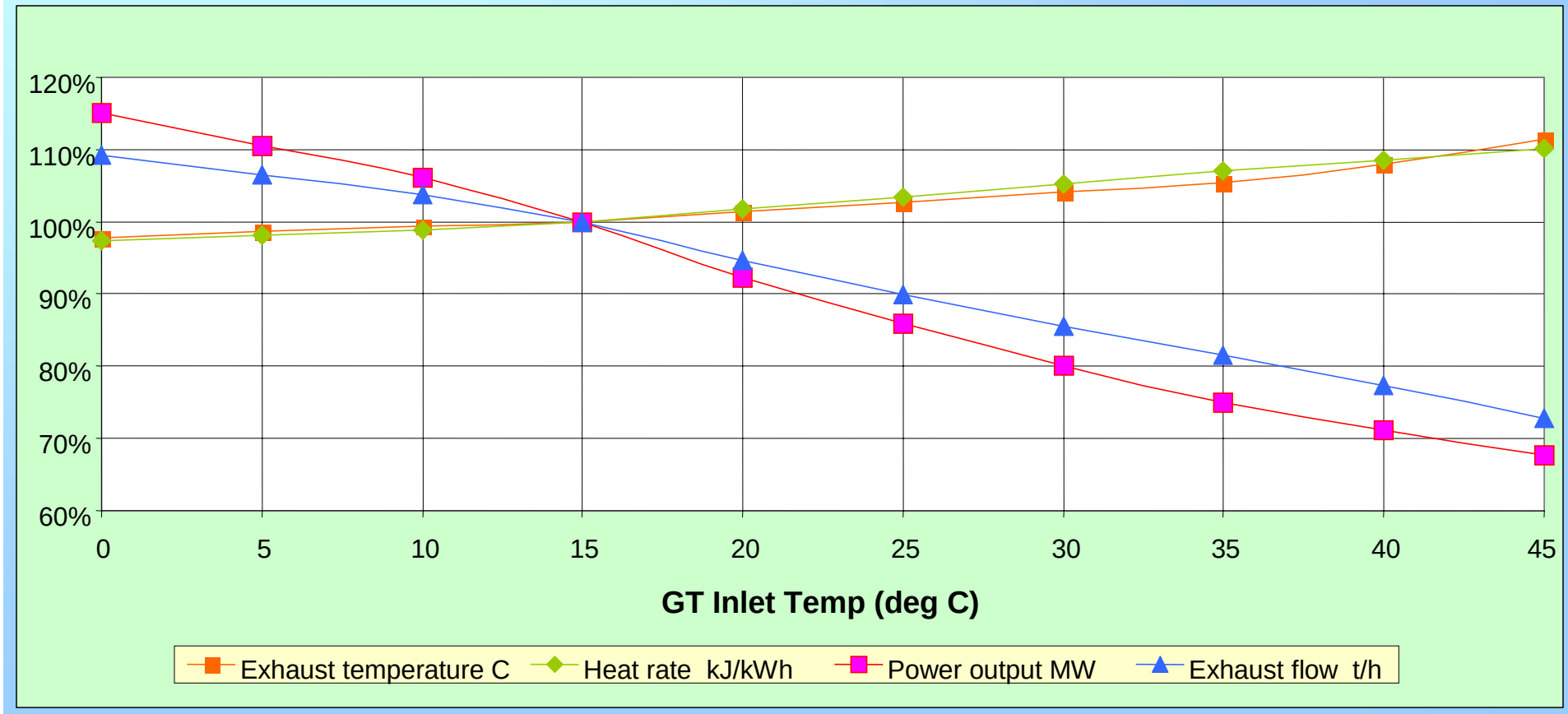
Aero-Derivative GT - Effects of Ambient Temp



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Gas Turbine Performance Design Basis

What Does ISO Condition Mean?

- Dry bulb 15°C
- Relative humidity 60%
- Wet bulb temperature 7.2°C
- Atmospheric pressure 1 bar (sea level)

Most of the gas turbine installations are not in ISO standard locations, they are in the real world

Ambient Air and Gas Turbine Performance

1. Air density is inversely related to the dry bulb temperature
2. Gas turbine output depends on mass flow and not the volume of air
3. Ambient temperature affects the following points drastically
    - Air flow
    - Output
    - Heat rate
    - Exhaust temperature

Gas Turbine Inlet Air Cooling

Available Technologies

1. Evaporative cooler
2. Fogging system
3. Mechanical refrigeration system (direct type)
4. Mechanical refrigeration system (indirect type)
5. Mechanical refrigeration with ice storage
6. Mechanical refrigeration system with chilled water storage
7. Single stage Lithium Bromide Absorption chiller
8. Two stage Lithium Bromide Absorption chiller

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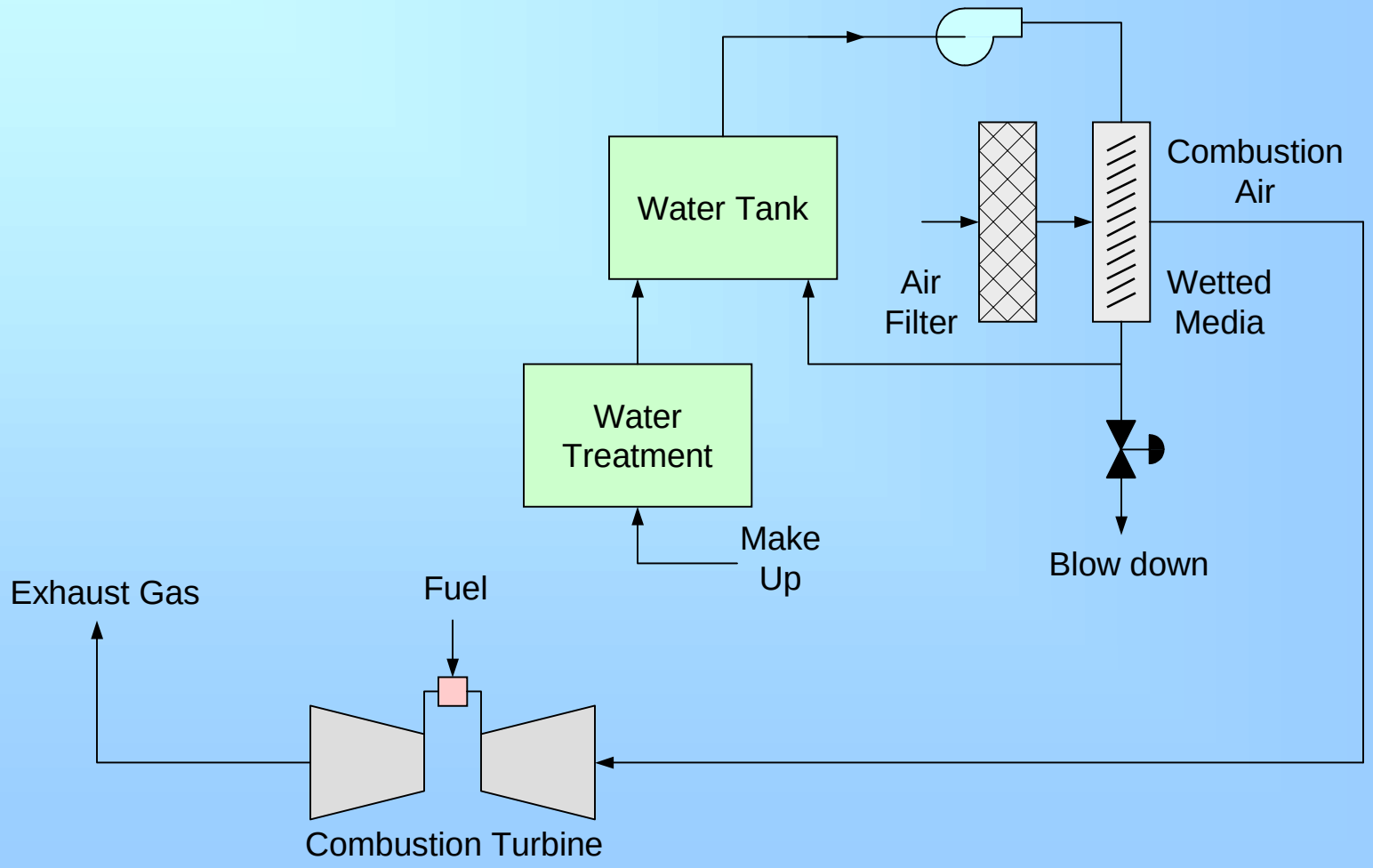
Schematic of Evaporative Air Cooling shown with Optional Water Treatment



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Evaporative Cooler

Applications: Areas where RH and wet bulb temperature is rather low

Advantage

- Lowest capital cost
- Lowest O&M cost
- Can operate on raw water
- Quick delivery and installation time
- Operates as an air washer and cleans the inlet air

Disadvantage

- Limitation on capacity improvement
- Highly influenced by the site wet bulb

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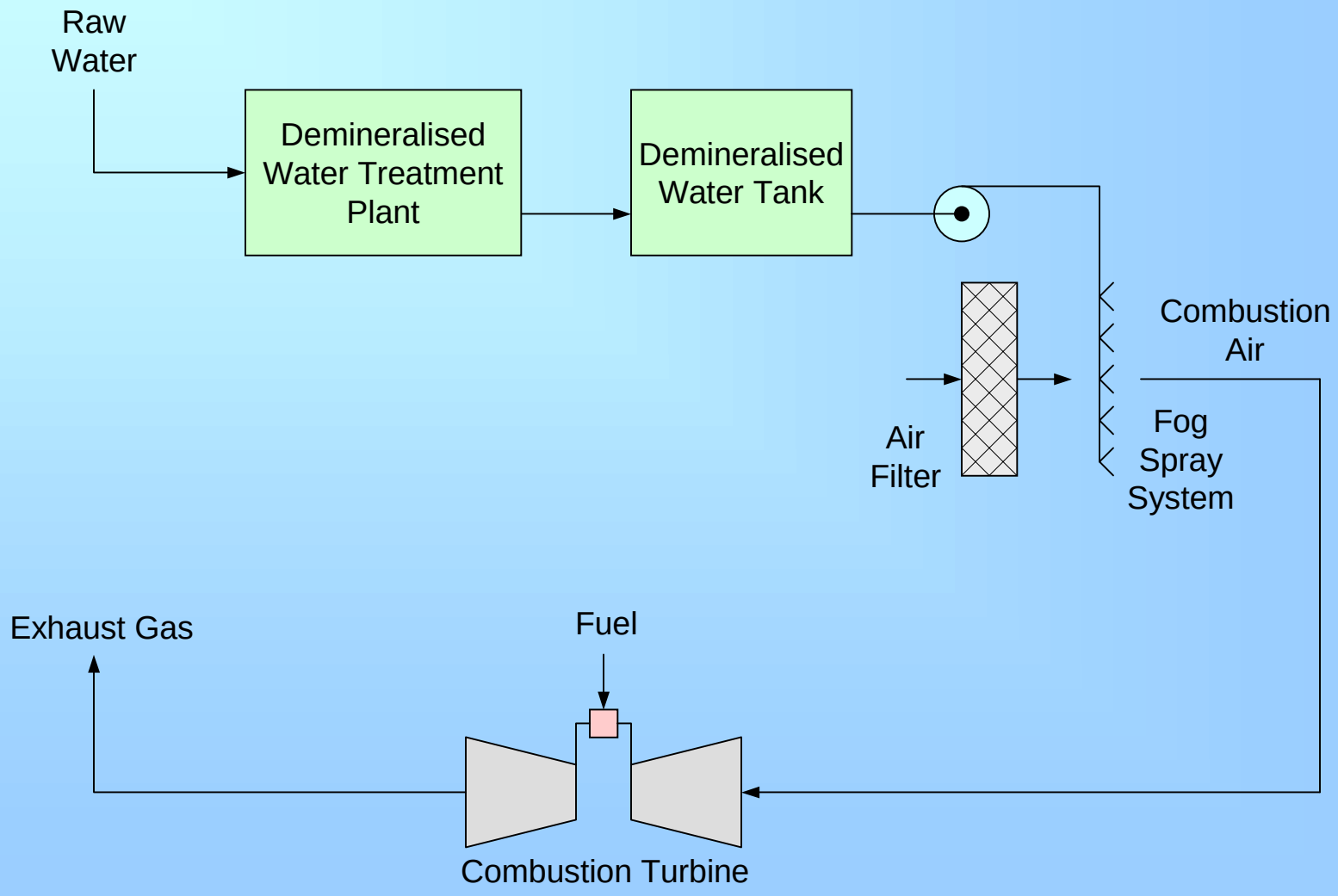
Schematic of Fog Inlet Air Cooling System Utilizing Demineralised Water



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Fog Systems

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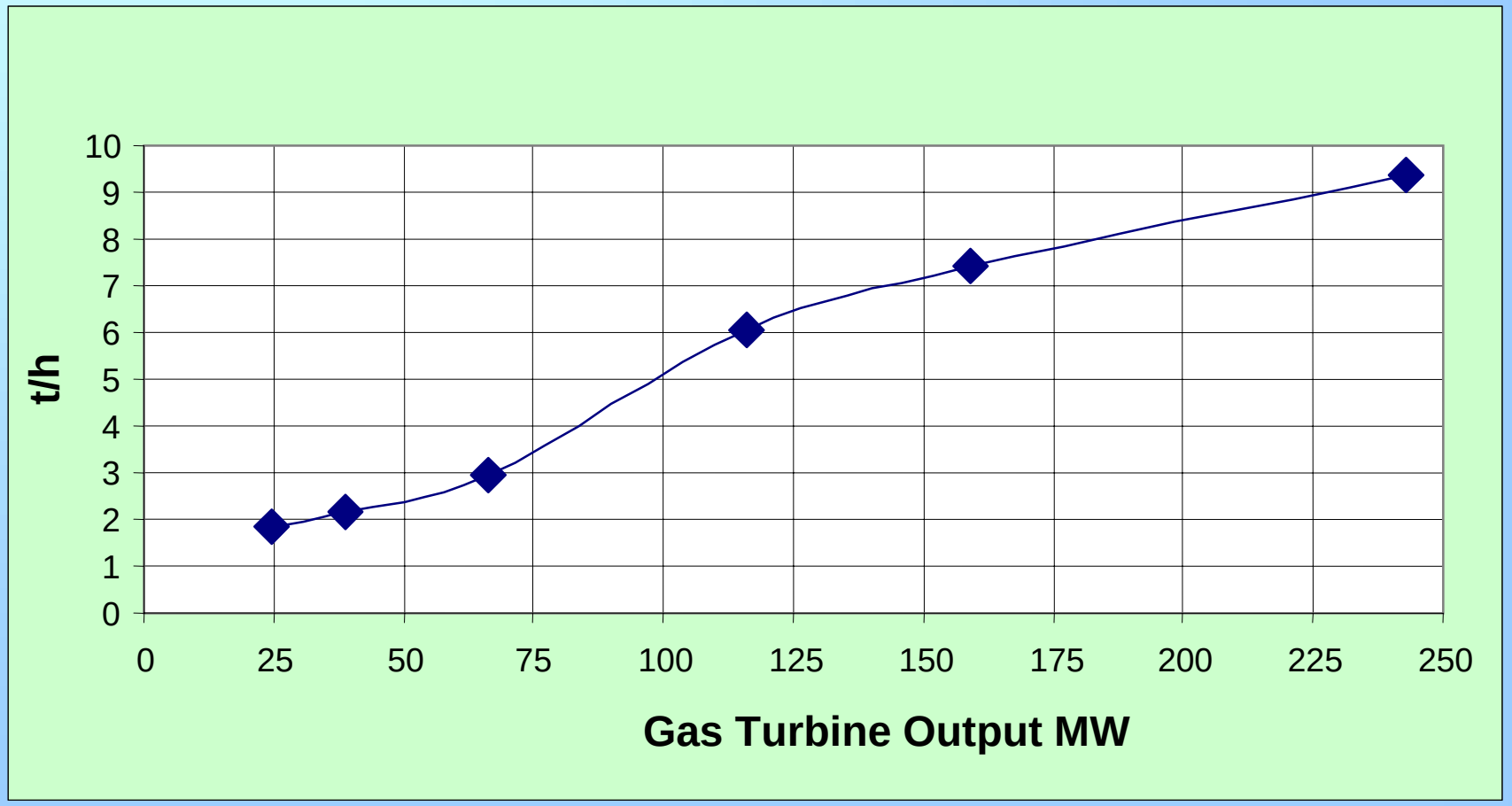
Demineralised Water Quality For Fog System Inlet Air Cooling

Total dissolved solids	5 PPM maximum
pH	6-8
Na + K	0.1 PPM maximum
Silica (SiO_2)	0.1 PPM maximum
Chlorides	0.5 PPM maximum
Sulphate	0.5 PPM maximum

Fogging System Demin. Water Consumption
Inlet air 36°C DB, 25°C WB
Chilled air temp 25.5°C DB 25°C WB, 96%RH



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Fogging System

Applications: Areas where RH and wet bulb temperature is rather low

Advantage

- Low capital cost
- Low O&M cost
- Can increase gas turbine performance better than evaporative cooling
- Quick delivery and installation time

Disadvantage

- Limitation on capacity improvement
- Highly influenced by the site wet bulb

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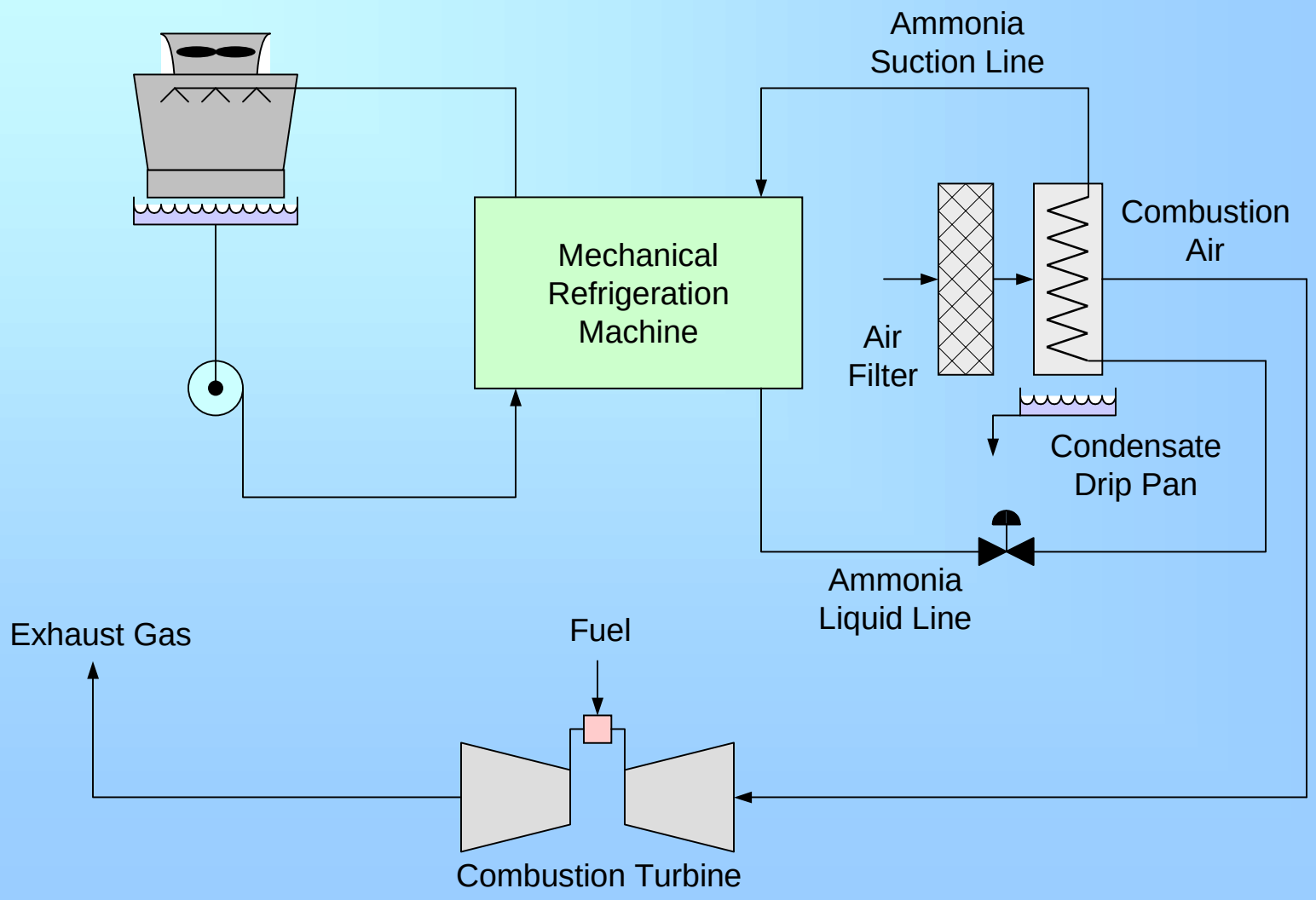
Schematic of a Direct System Using an Ammonia Refrigeration Machine



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Mechanical Refrigeration System (Direct Type)

Applications: Areas where relative humidity is rather high

Advantage

- Can increase gas turbine performance better than evaporative cooling, and fog system

Disadvantage

- High initial capital cost
- High O&M cost
- Longer delivery and installation time
- Expertise is needed to operate and maintain the plant

Gas Turbine Inlet Air Cooling

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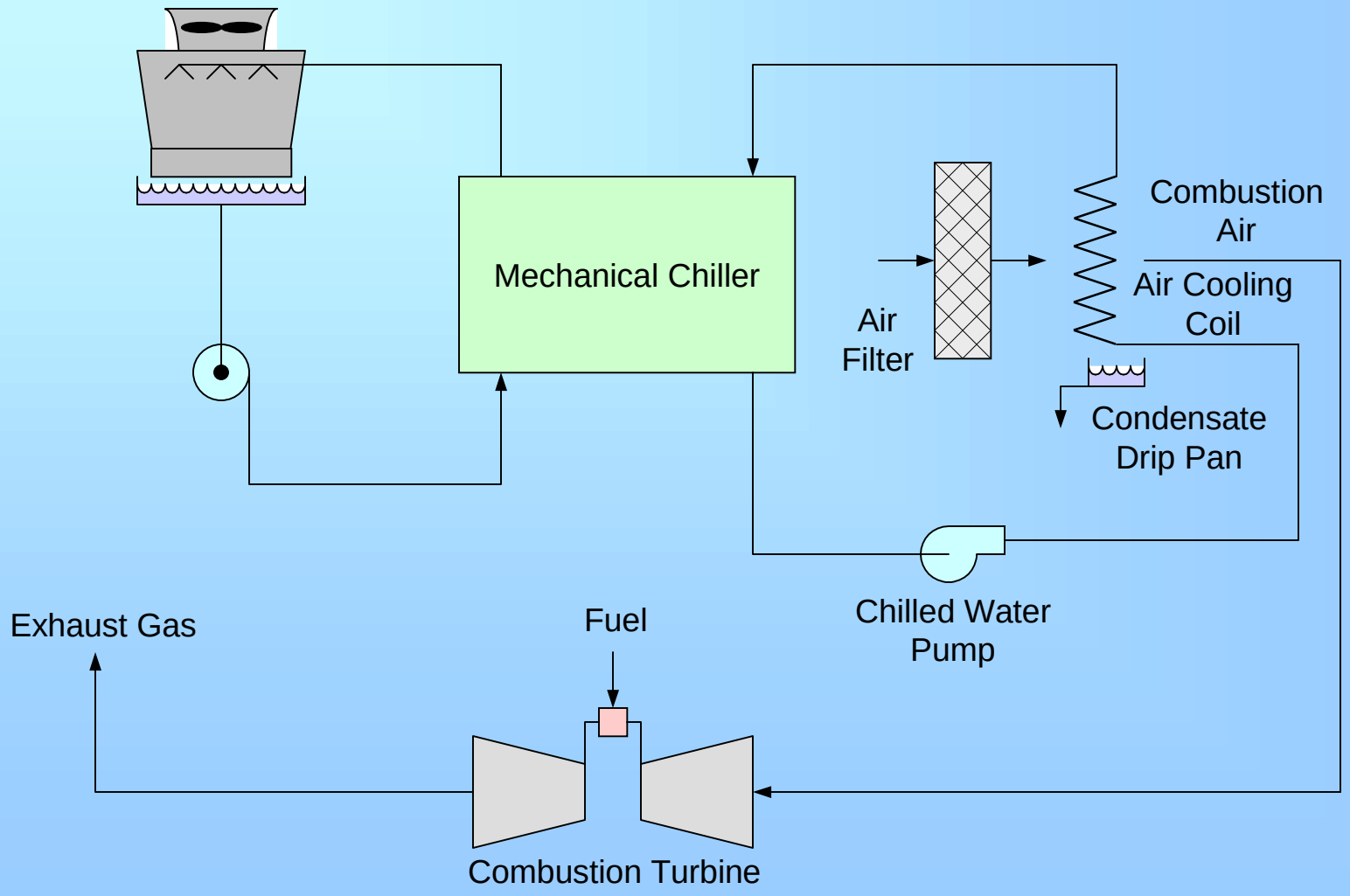
Schematic of an Indirect System Using a Mechanical Chiller



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Mechanical Refrigeration System (Indirect Type)

Applications: Areas where relative humidity is rather high

Advantage

- Can increase gas turbine performance better than evaporative cooling, and fog system
- Not very sensitive to ambient air wet bulb temperature

Disadvantage

- High initial capital cost
- High O&M cost
- Long delivery and installation time
- Expertise is needed to operate and maintain the plant
- Requires extra chilled water cooling circuit
- Higher parasitic load than direct type
- Higher energy input compared to direct type chiller

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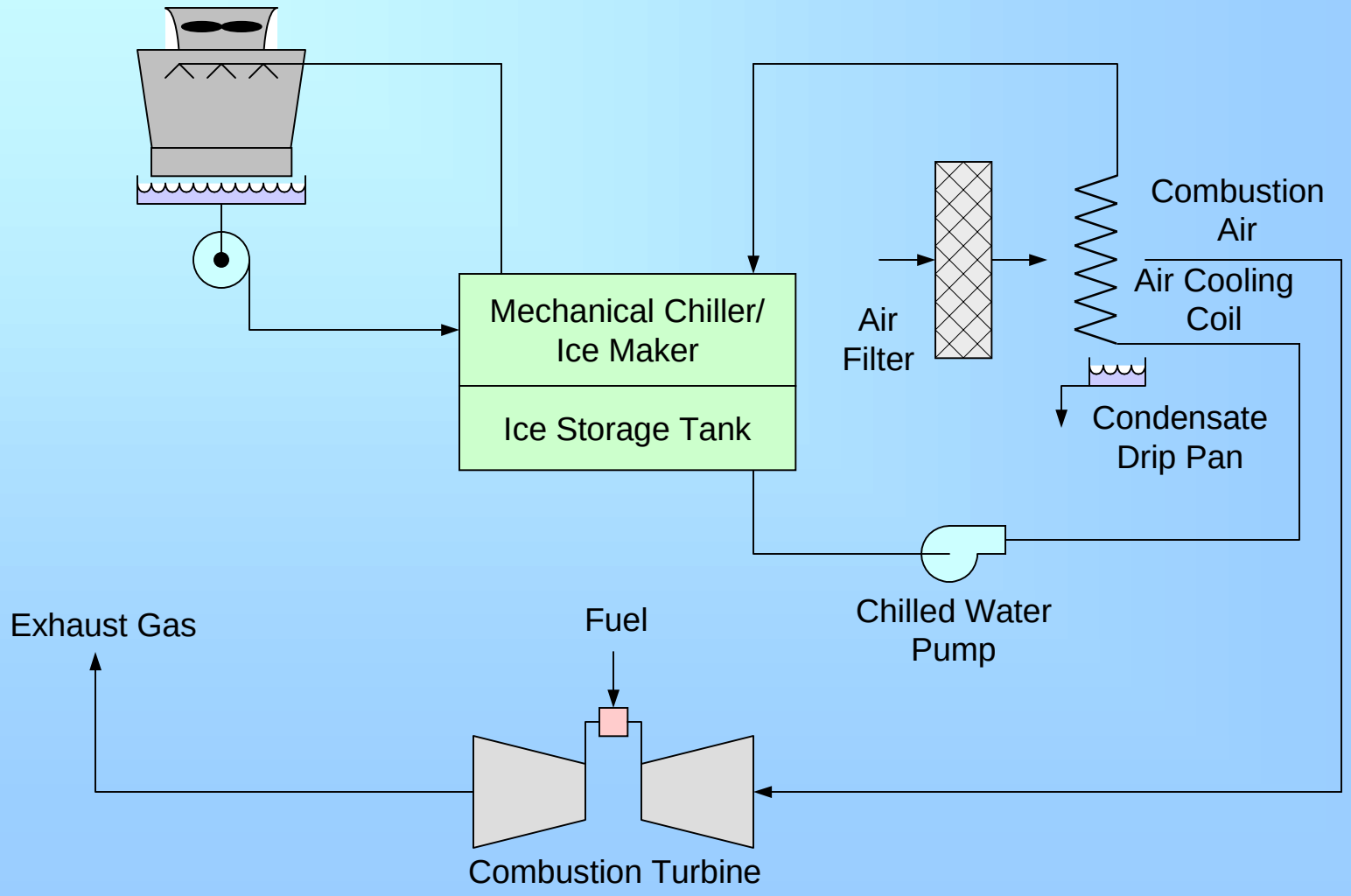
Inlet Air Cooling With Ice Storage, Chilled Water Storage System Schematic



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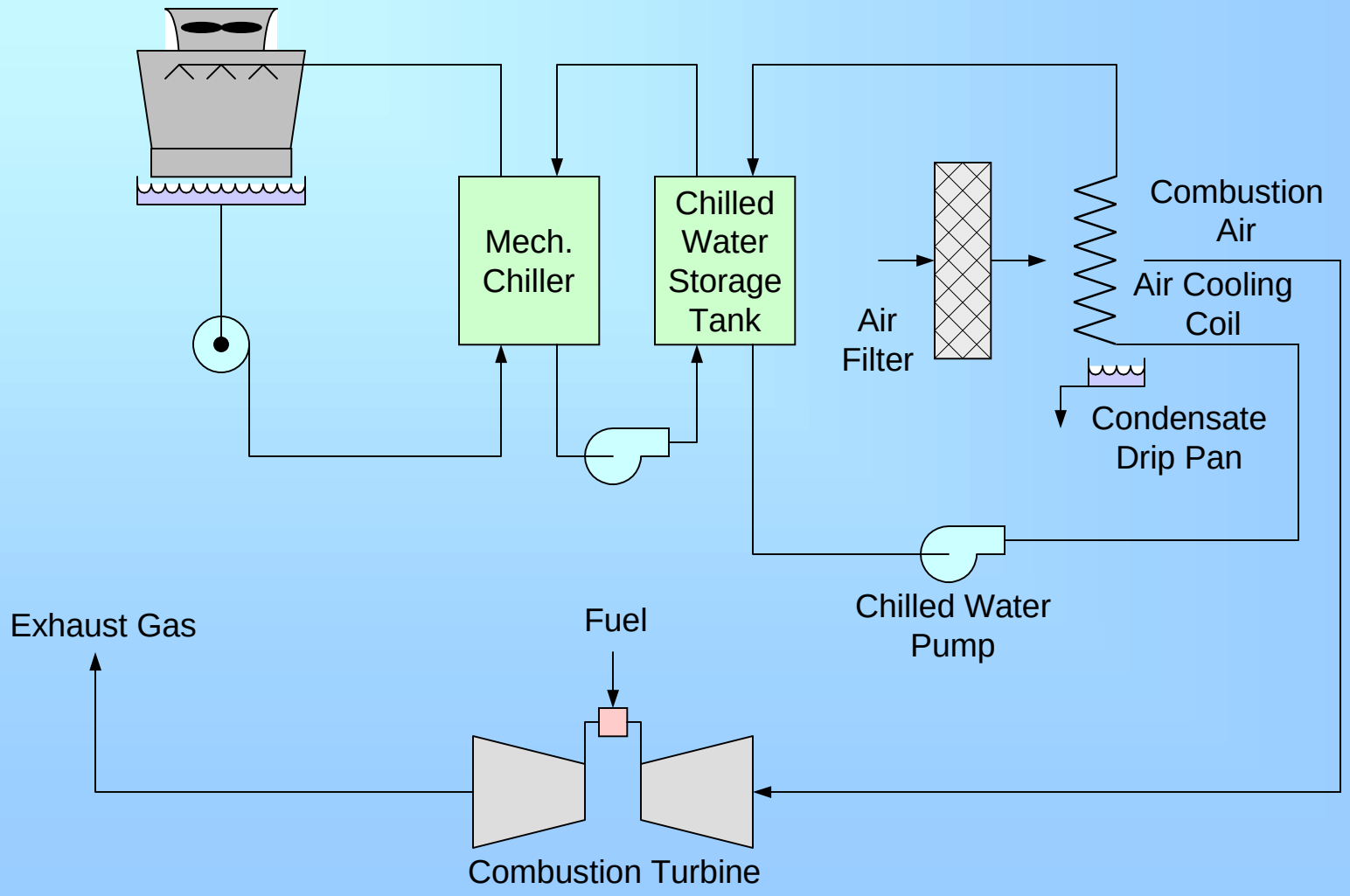
Inlet Air Cooling With Chilled Water Storage System Schematic



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Mechanical Refrigeration System With Ice Storage

Applications: Areas where RH is rather high,plus a wide variation in electricity tariff between peak and non peak hours

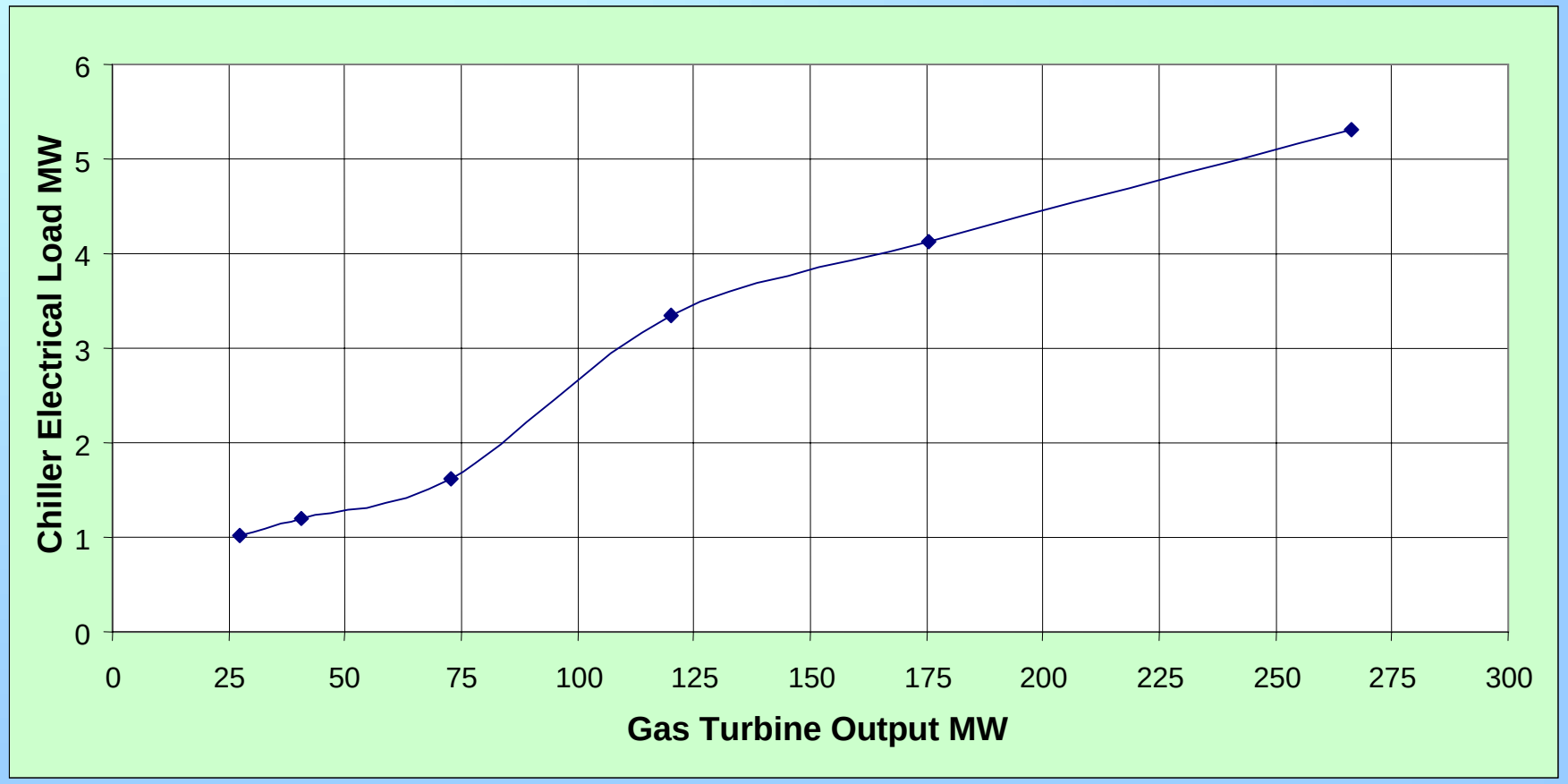
Advantage

- Can increase gas turbine performance better than evaporative cooling, and fog system
- Not very sensitive to ambient air wet bulb temperature
- Can utilise low night time tariff to produce and store ice for peak hours operation

Disadvantage

- High initial capital cost
- High O&M cost
- Longer delivery and installation time
- Higher expertise is needed to operate and maintain the plant

Chiller Electrical Load MW
36°C DB, 25°C WB, 10°C Chilled Air Temp



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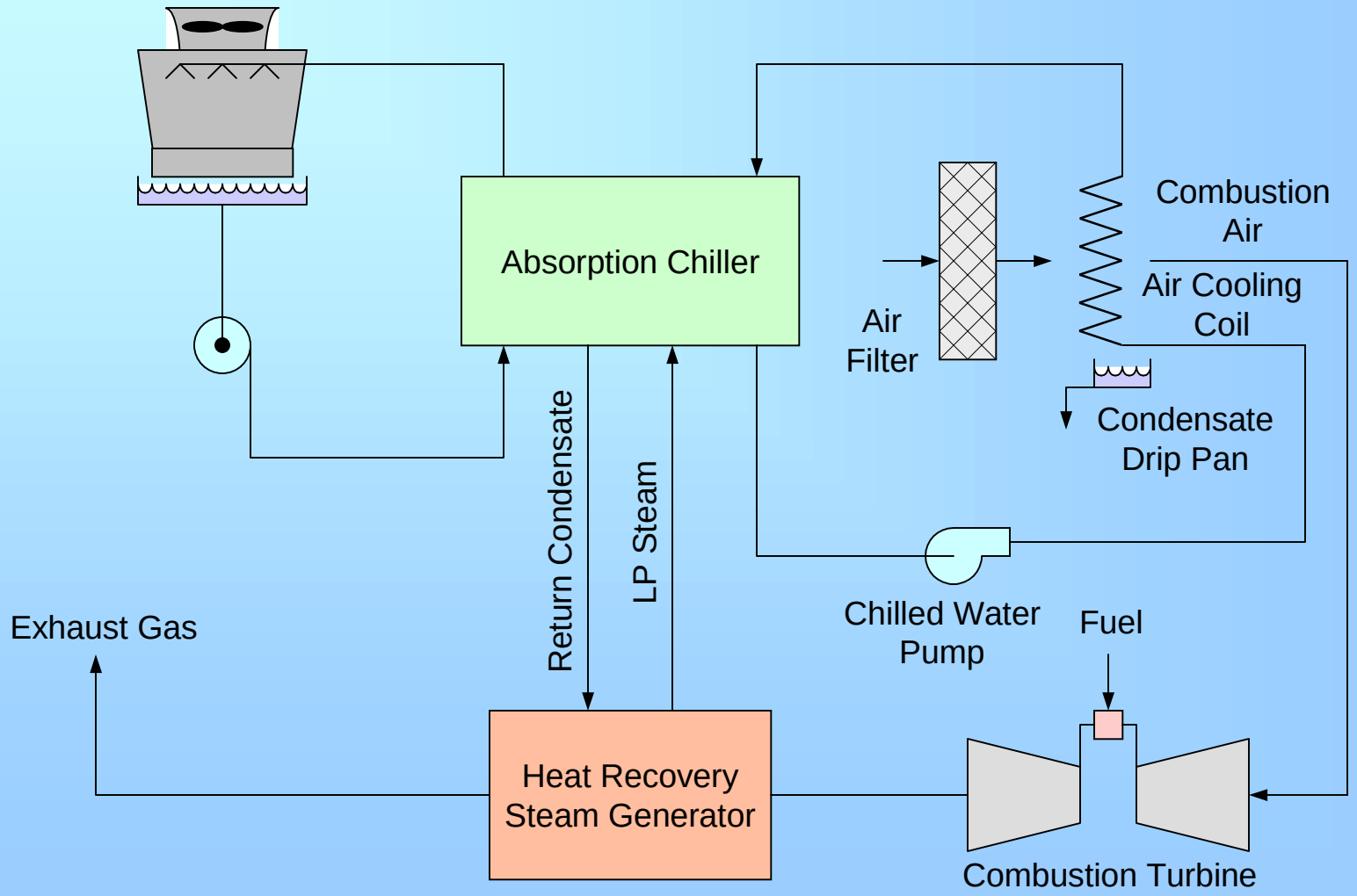
Absorption Chiller Inlet Air Cooling System Schematic



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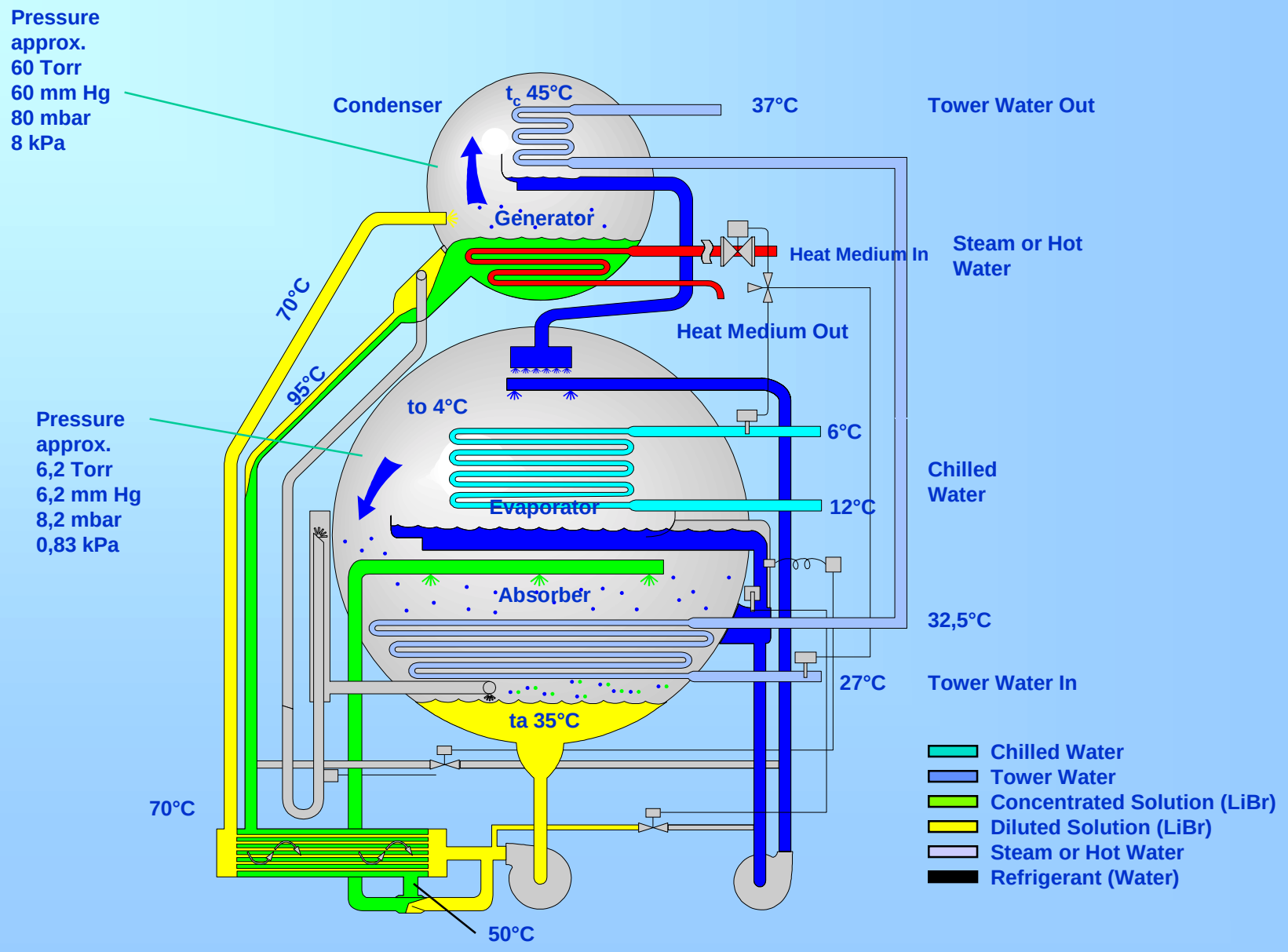
Flow Diagram



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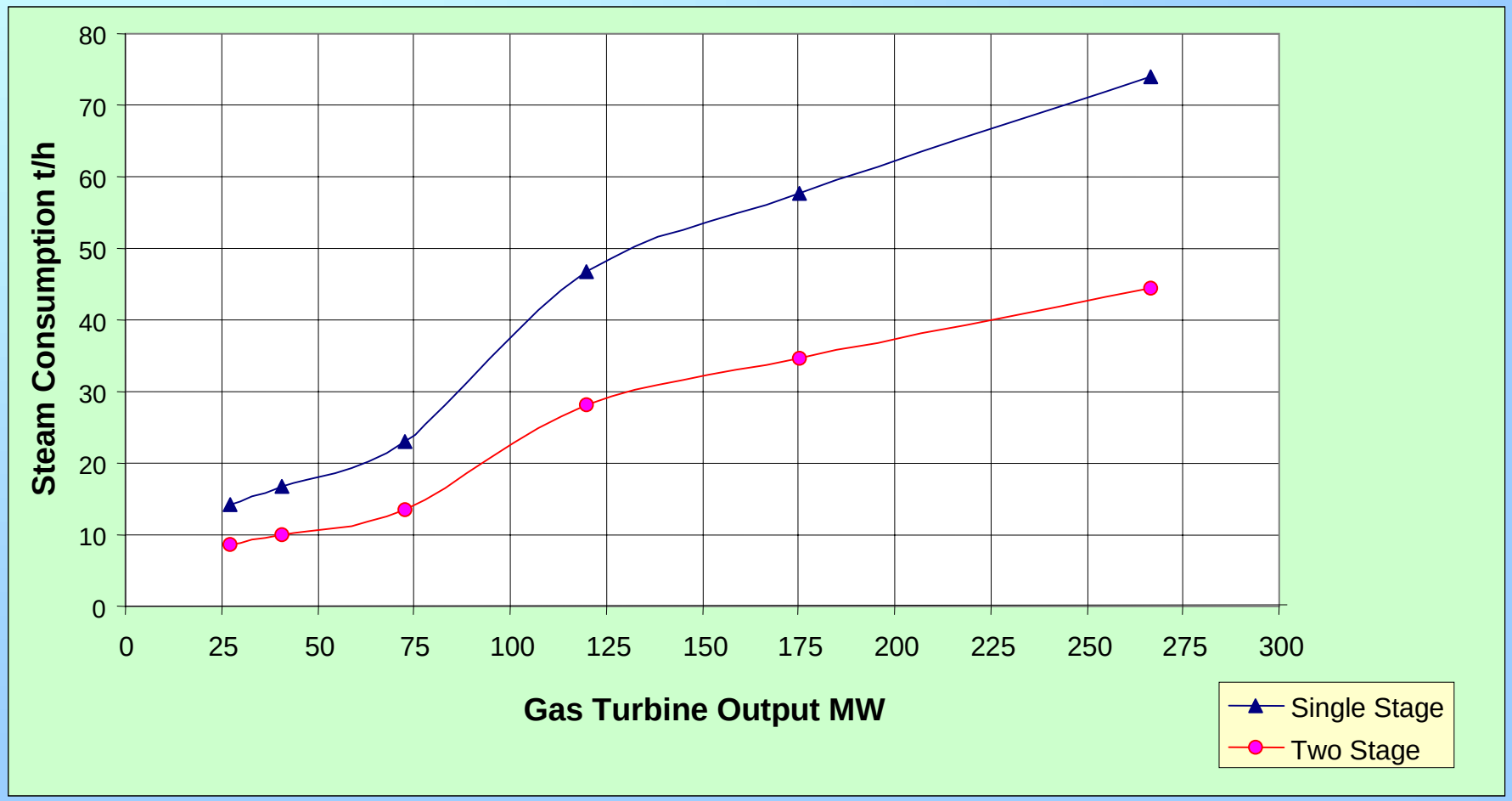
Picture courtesy of York International

Absorption Chiller Steam Consumption 36°C DB, 25°C WB, 10°C Chilled Air Temp



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Single Stage Lithium Bromide Absorption Chiller

Applications: Areas where relative humidity is rather high, and the plant is going to operate in a combined cycle or cogeneration mode and has access to low pressure steam

Advantage

- Can increase gas turbine performance better than evaporative cooling, and fog system
- Not very sensitive to ambient air wet bulb temperature
- Low electrical parasitic load

Disadvantage

- High initial capital cost
- High O&M cost
- Longer delivery and installation time
- High expertise is needed to operate and maintain the plant
- In case of a steam operated chiller, cannot be applied in an open cycle gas turbine plant

Two Stage Lithium Bromide Absorption Chiller

Applications: Areas where relative humidity is rather high, and the plant is going to operate in a combined cycle or cogeneration mode and has access to low pressure steam

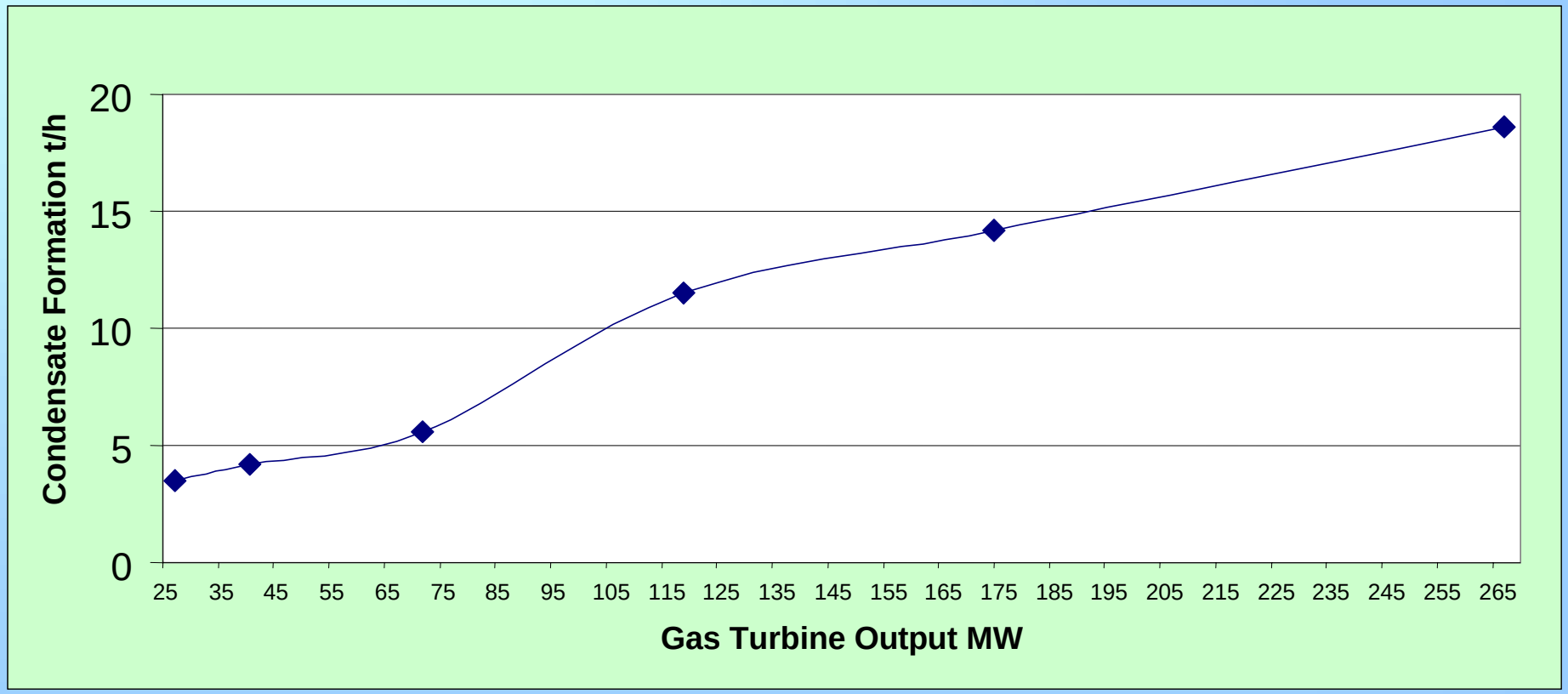
Advantage

- Can increase gas turbine performance better than evaporative cooling, and fog system
- Not very sensitive to ambient air wet bulb temperature
- Low electrical parasitic load
- Requires less steam per unit of refrigeration than single stage chiller

Disadvantage

- High initial capital cost
- High O&M cost
- Longer delivery and installation time
- High expertise is needed to operate and maintain the plant
- In case of a steam operated chiller, cannot be applied in an open cycle gas turbine plant

Condensate Formation on the Chilled Water Coil t/h Based on 36°C DB, 25°C WB, 10°C Chilled Inlet Air Temperature



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Performance Evaluation Of Different Inlet Air Cooling Systems

Base Condition

- 35°C Dry bulb
- 25°C Dry bulb
- 44.7% Relative humidity

Real world condition

Increase in power output

		Percent Change
Gas turbine output before inlet air cooling	108.23 MW (net)	0%
Gas turbine output with mechanical refrigeration system and inlet air temperature of 10°C	124.8 MW (net including chiller electrical load)	15.3%
Gas turbine with evaporative cooler running at 85% RH	114.8 MW (net)	6%
Gas turbine with fog system running at 100% RH	116.65 MW (net)	7.69%

Capital Cost Comparisons of Inlet Cooling Systems

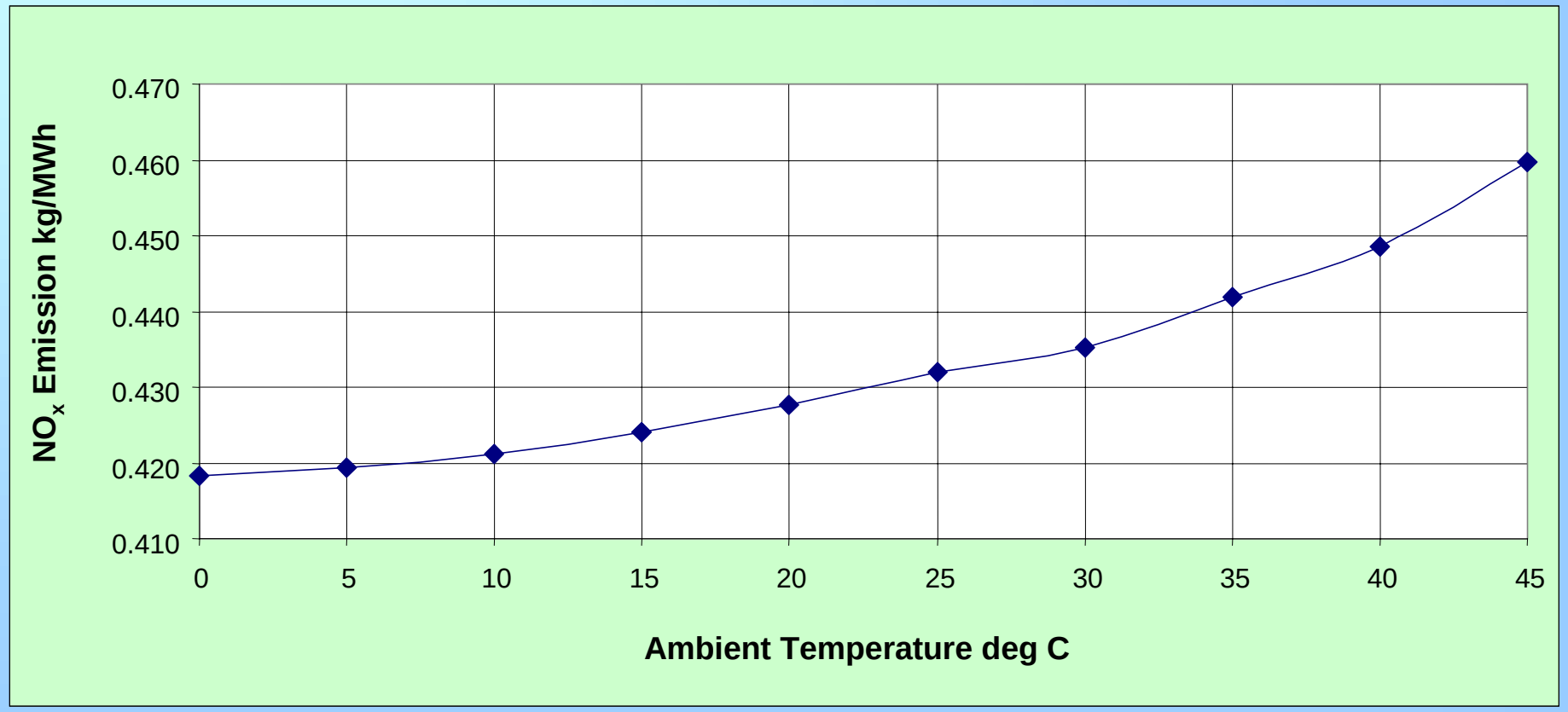
Options	Relative Costs
Evaporative cooler	1
Fog system (excluding water treatment plant)	2
Single stage LiBr absorption chiller	8
Two stage LiBr absorption chiller	10
Ammonia mechanical refrigeration system	9.5

Major Contributors To The O&M Costs

Options	O&M Costs
Evaporative cooler	■ Make up water ■ Water treatment (if applicable)
Fog system (excluding water treatment plant)	■ Make up water ■ Demineralised water treatment ■ Injection pump power consumption
Single stage LiBr absorption chiller	■ Steam ■ Cooling tower chemical treatment ■ Chiller maintenance ■ Electric power consumption
Two stage LiBr absorption chiller	■ Steam ■ Cooling tower chemical treatment and make up water ■ Chiller maintenance ■ Electric power consumption
Ammonia mechanical refrigeration system	■ Electric power consumption ■ Cooling tower chemical treatment and make up water ■ Chiller maintenance

Heavy Duty Gas Turbine NO_x Emission kg/MWh

GT with Dry Low NOx burner



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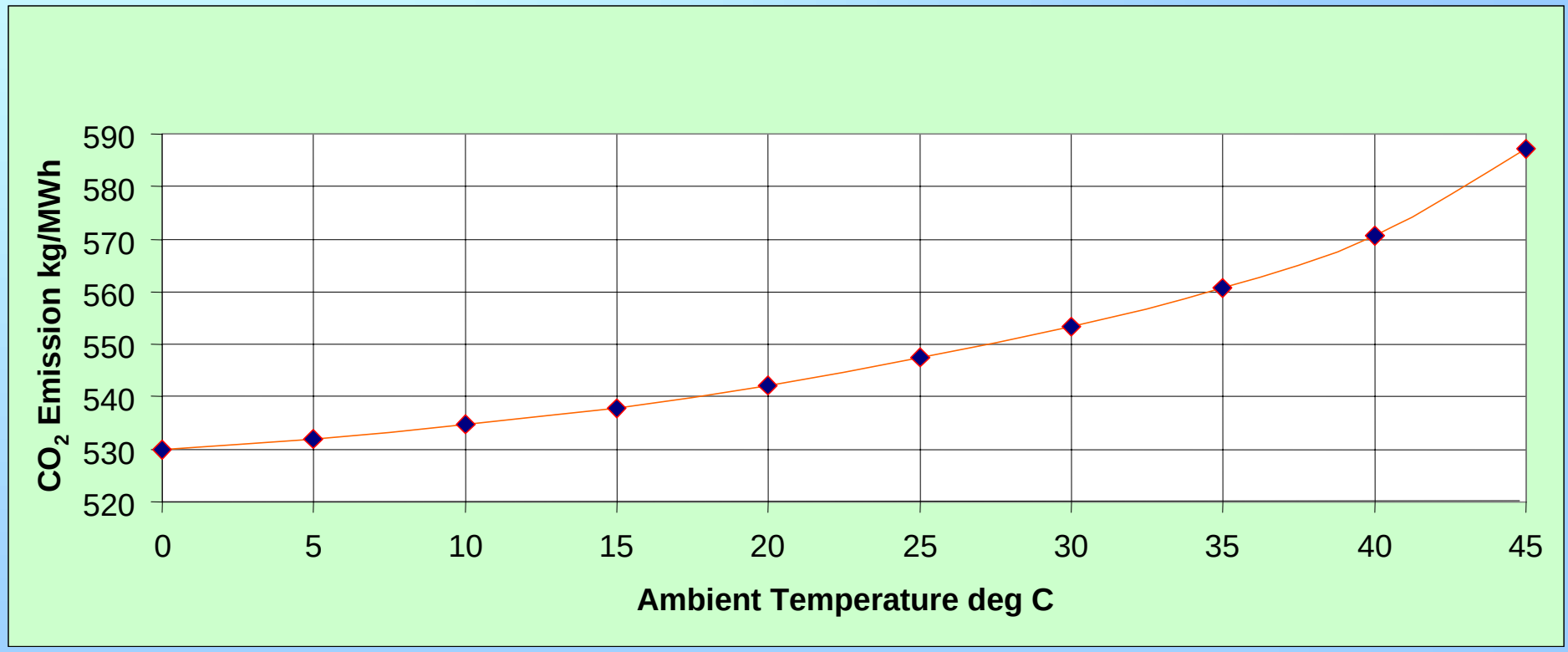
Heavy Duty Gas Turbine CO_2 Emission kg/MWh



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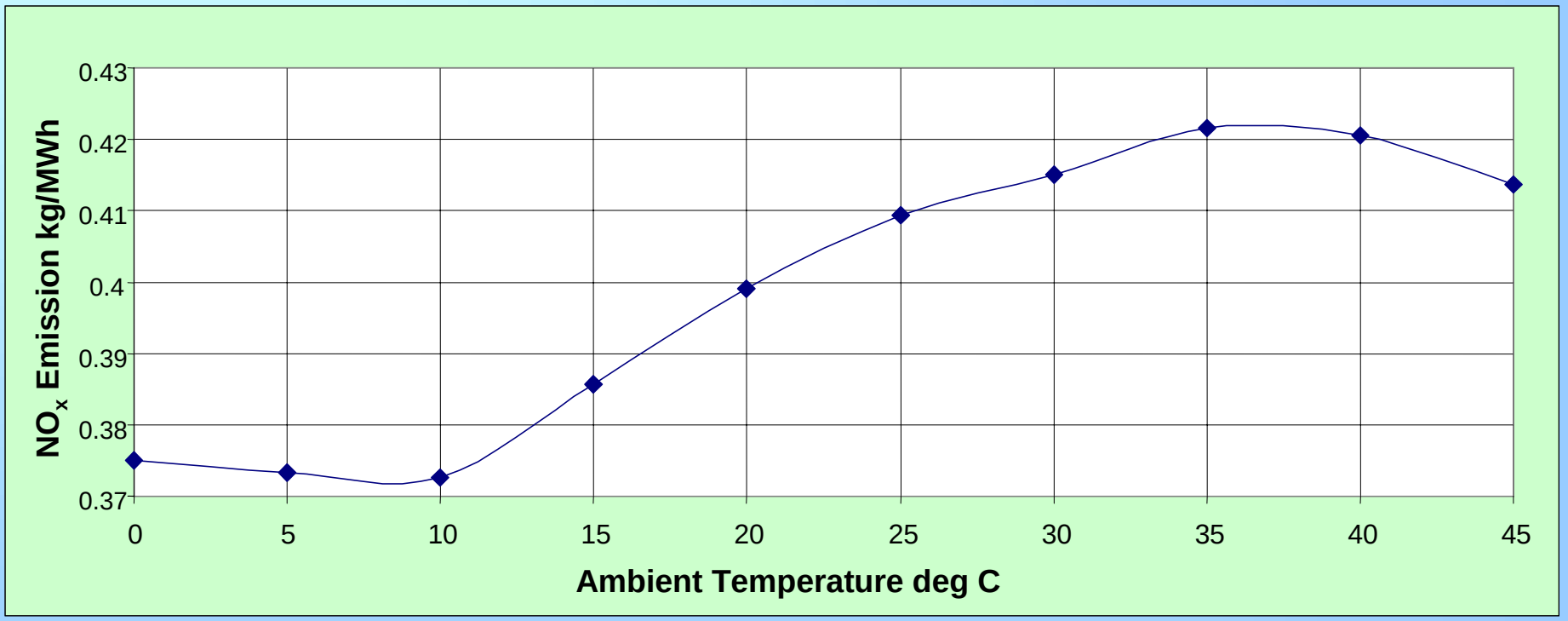
Aero-Derivative Gas Turbine NO_x Emission kg/MWh

GT with Dry Low NOx burner



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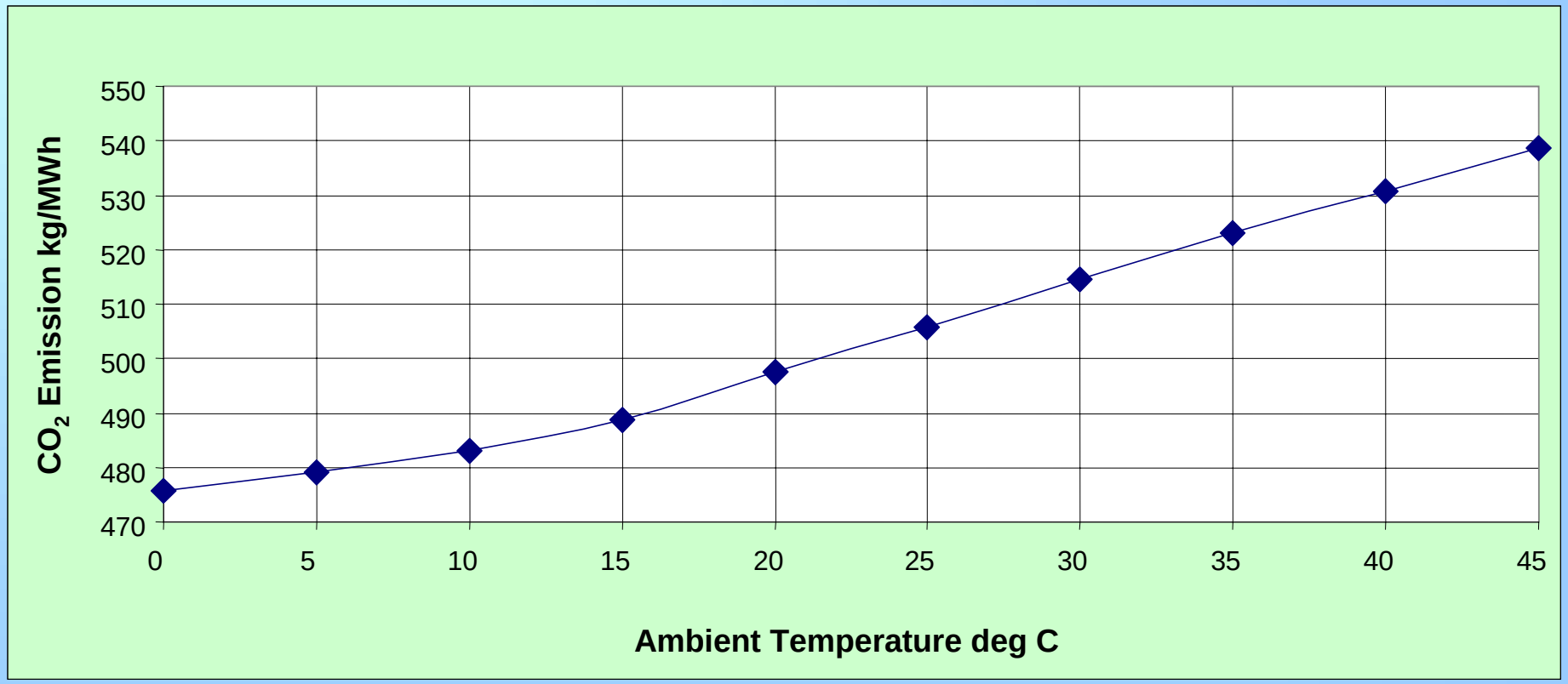
Aero-Derivative Gas Turbine CO_2 Emission kg/MWh



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In Selecting Inlet Air Cooling As A Retrofit To An Existing Plant

Points to watch:

- Check the generator capacity in order not to overload the generator
- Quality of raw water for the evaporative cooler
- When using an existing demineralised water treatment plant, be careful about the capacity and quality of available demineralised water
- With an existing heat recovery steam generator, inlet air cooling will change the behaviour of the existing HRSG, leading to a drop in steam production at high pressure and increase in intermediate and low pressure steam