

Block: 3 – Natural Gas & Renewables
Forum Title: F18 - Monetizing Under-utilized Gas Resources (GTL, LNG)



Poster Title: Integration of CCGT Plant and LNG Terminal

Author: Augusto Bulte
Proposal Manager - LNG & Power Projects

Author Biography

Augusto Bulte has a MSc degree in Marine Engineering and a PhD in Chemical Engineering. He has 12 years' experience in power and LNG projects and has been proposal manager of Foster Wheeler Iberia's commercial department since 2003. He has previously held the positions of mechanical engineer and project engineer at Foster Wheeler. Augusto has experience in gas turbines for CCPP with Alstom Power, and gas engines for cogeneration services with Jenbacher.

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Abstract

A recent Foster Wheeler study indicated that process integration of cold energy recovery from an LNG terminal has the potential to provide a highly reliable and operable combined cycle gas turbine facility with enhanced economics.

This presentation covers integration opportunities targeting thermal processes, particularly, the utilization of cold process fluids from LNG regasification to increase the electrical energy production of a CCGT plant.

As the chiller system will be in operation 7,000 hours per year, the economic analysis shows a gain of around US\$40 million per year in the case study, indicating a simple pay back of the installation in one year.

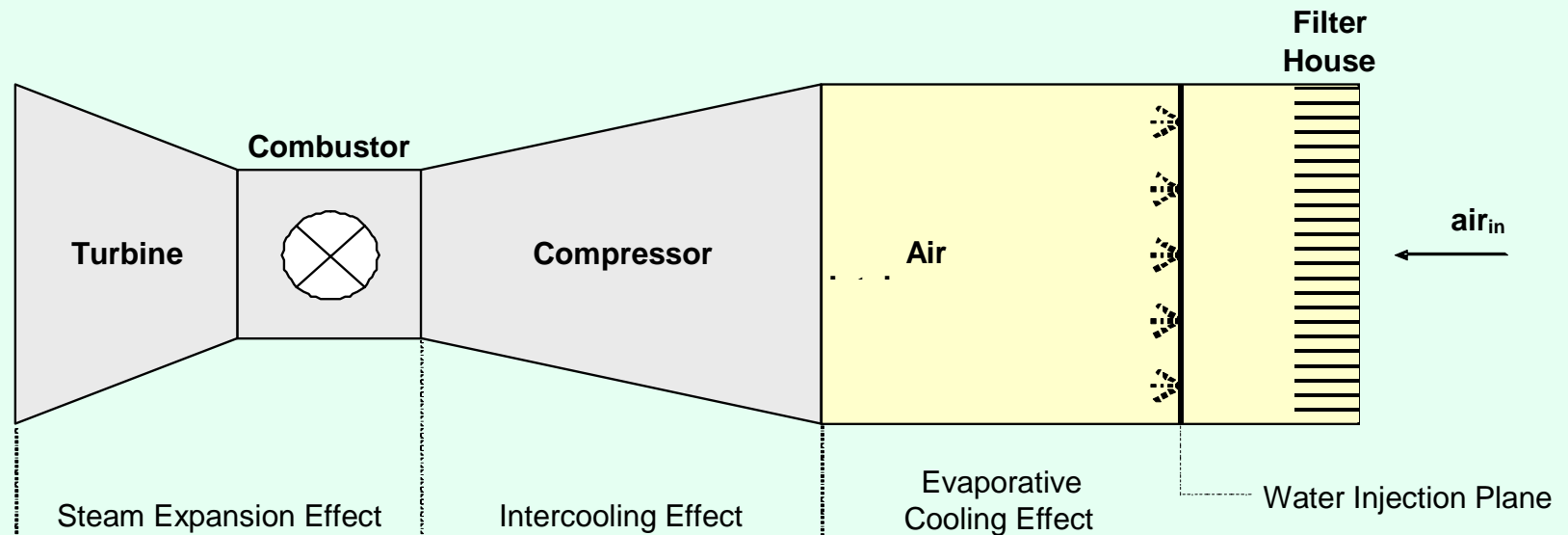


Introduction

- A recent Foster Wheeler study indicated that process integration of cold energy recovery from an LNG terminal has the potential to provide a highly reliable and operable combined cycle gas turbine facility with enhanced economics
- This presentation covers integration opportunities targeting thermal processes, particularly, the utilization of cold process fluids from LNG regasification to increase the electrical energy production of a CCGT plant



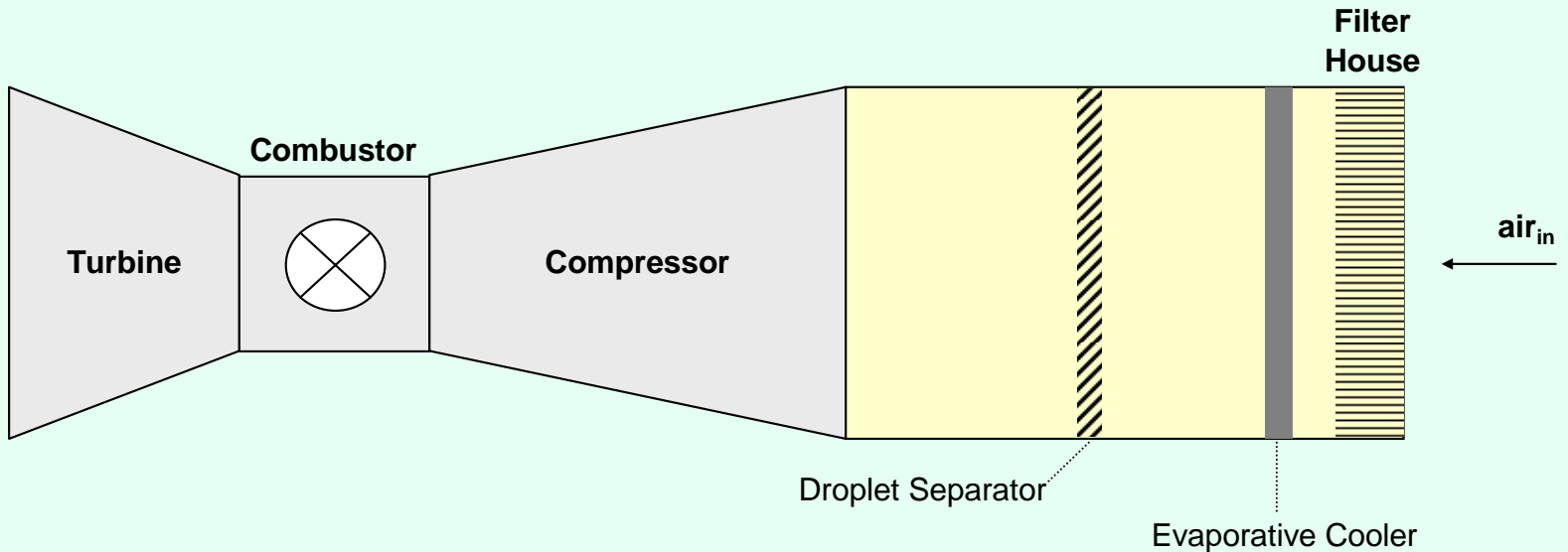
Gas Turbine Power Augmentation



- Gas turbines are air-based engines, with operating efficiencies directly sensitive to ambient conditions
- An evaporative cooler, fogging systems or chillers/coolers, can provide an increase in system power
- All these system modifications have inherently low installation and operational costs and provide a high return on investment especially for locations with relatively high ambient temperatures

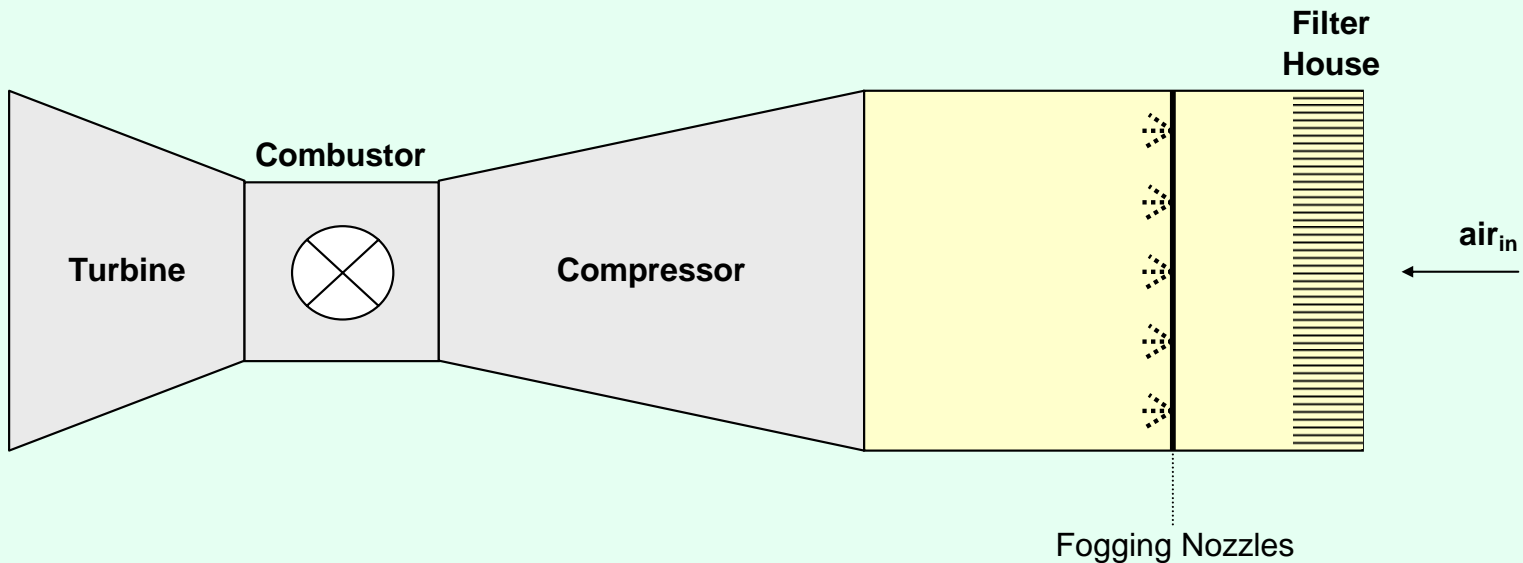


Gas Turbine Power Augmentation Evaporative Cooler



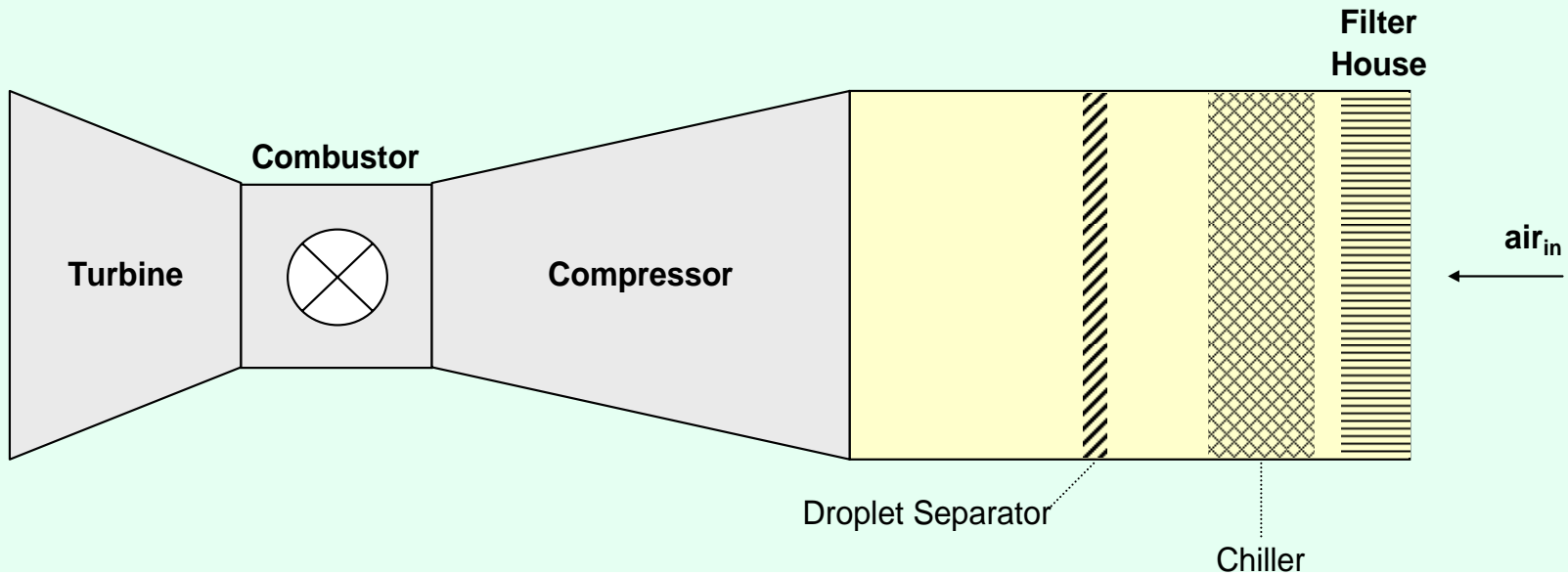
- The major components of an evaporative cooler are
 - The evaporative cooler media (cellulose or fibreglass)
 - A water distribution manifold
 - A water sump tank with low pressure recycle pump
 - A droplet separator
- Water evaporates before entering the compressor and air is cooled down before inlet
- The cooler media and the droplet separator produce a pressure drop between 1.5 and 3 mbar, and require an axial extension of the filter house

Gas Turbine Power Augmentation Fogging System



- Fogging systems increase gas turbine power similar to an evaporative cooler
- The major components of a fogging unit are
 - The nozzle rack with nozzles
 - The high pressure pump skid including a control unit and a valve skid
 - A water drain system for the air intake and the intake manifold

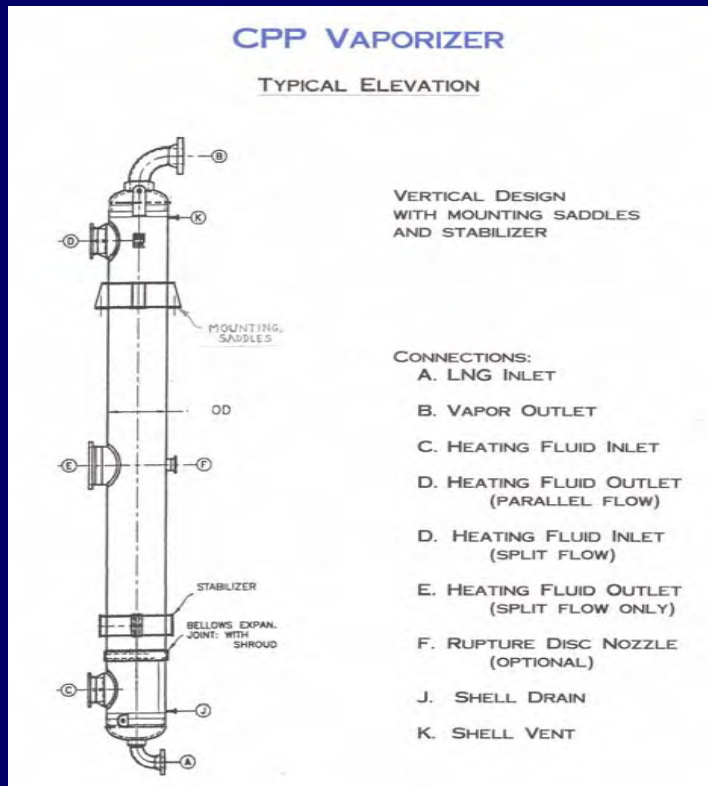
Gas Turbine Power Augmentation Chiller



- An air intake chiller system consists of a heat exchanger, which is located in the air intake downstream of the filter
- The chillers are usually installed in the gas turbine air intake, downstream of the air filter, together with a droplet separator to take out water droplets from condensation of humid air due to the temperature drop. The heat exchanger and the droplet separator produce a pressure drop of about 5 mbar, and require an axial extension of the filter-house



LNG Terminal Integration

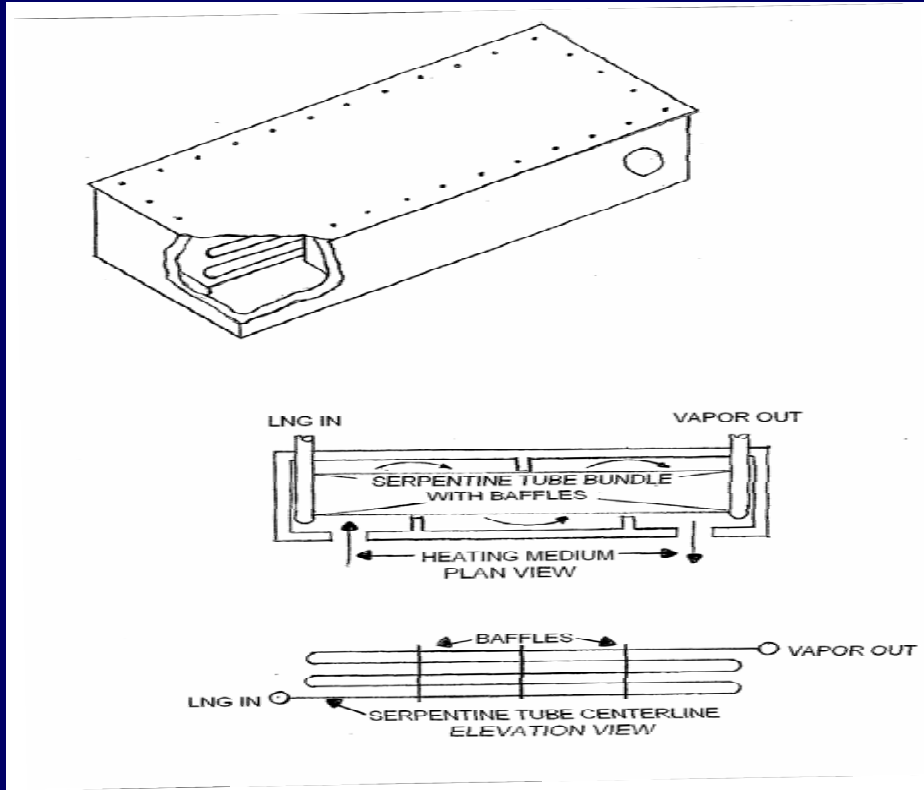


- S&T vaporizers have been considered to integrate the LNG Plant with the CCGT plant
- In the estimate study, the Chicago Power & Process Vaporizer and the Reli Vaporizer (next slide) were considered

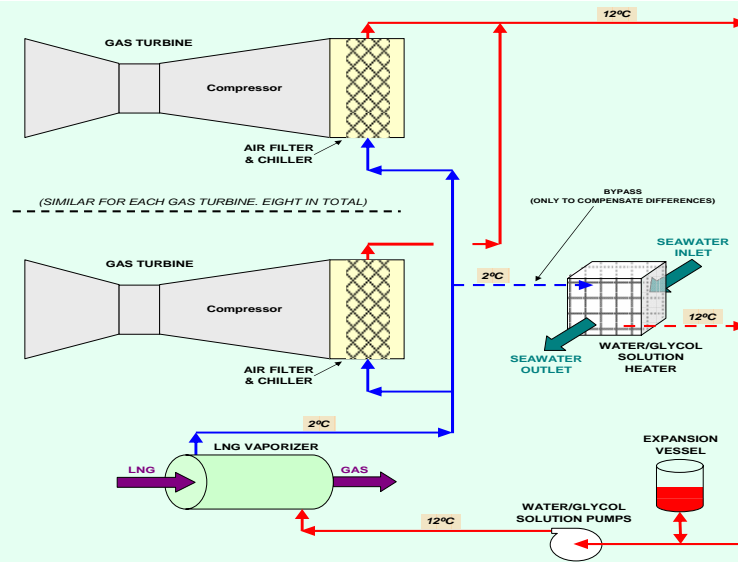


LNG Terminal Integration

Reli Vaporizer



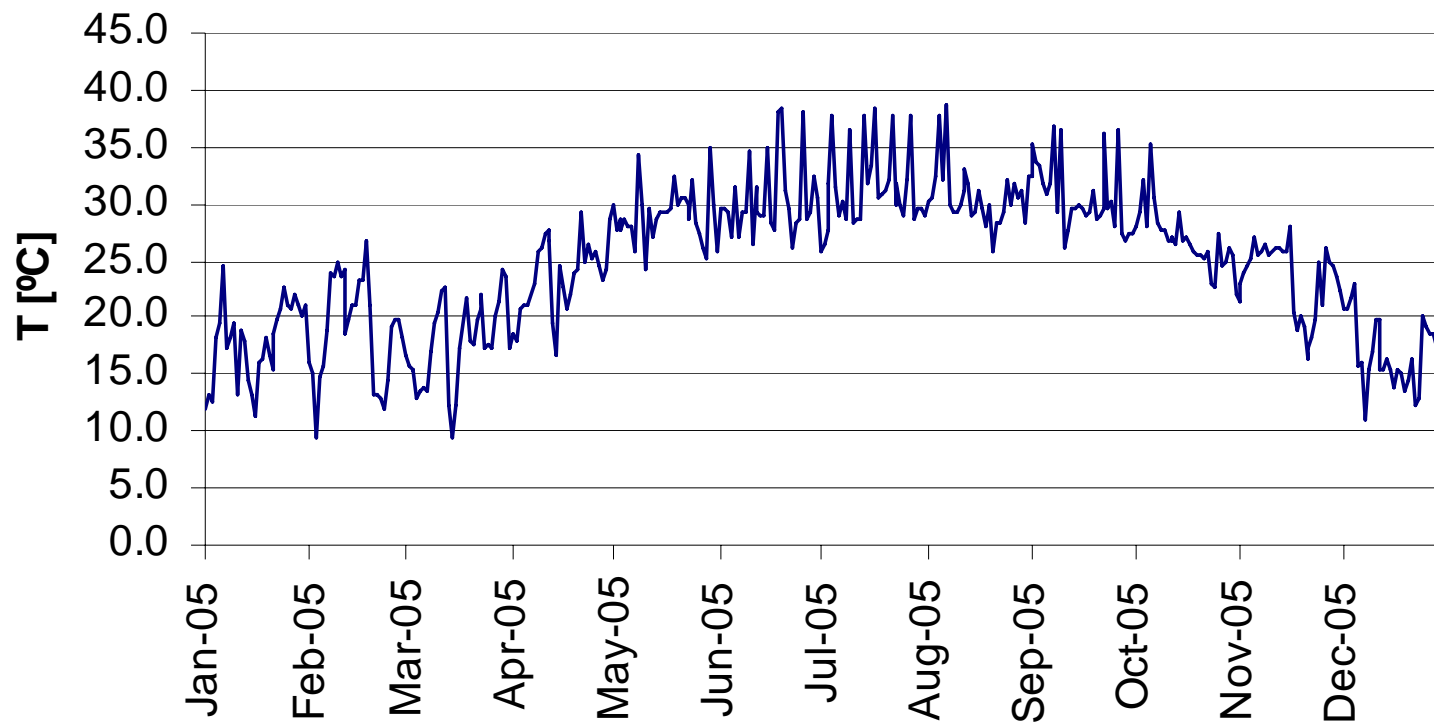
LNG Terminal Integration



- The proposed integration scheme is based upon generation of heat for the LNG process from a water/glycol solution in special vaporizers (shell & tube type). Consequently, a chilled water/glycol solution stream can be circulated to the power plant
- LNG terminal disturbances must be minimized. Regasification heat is used mostly in the CCGT plant, but if ambient conditions will not permit, two options are available:
 - Use of conventional seawater vaporizers instead of the shell & tube type
 - Use of shell & tube type vaporizer, and use of plate heat exchangers to heat the water/glycol

Daily Mean Dry Temperature

Yearly Temperature Profile



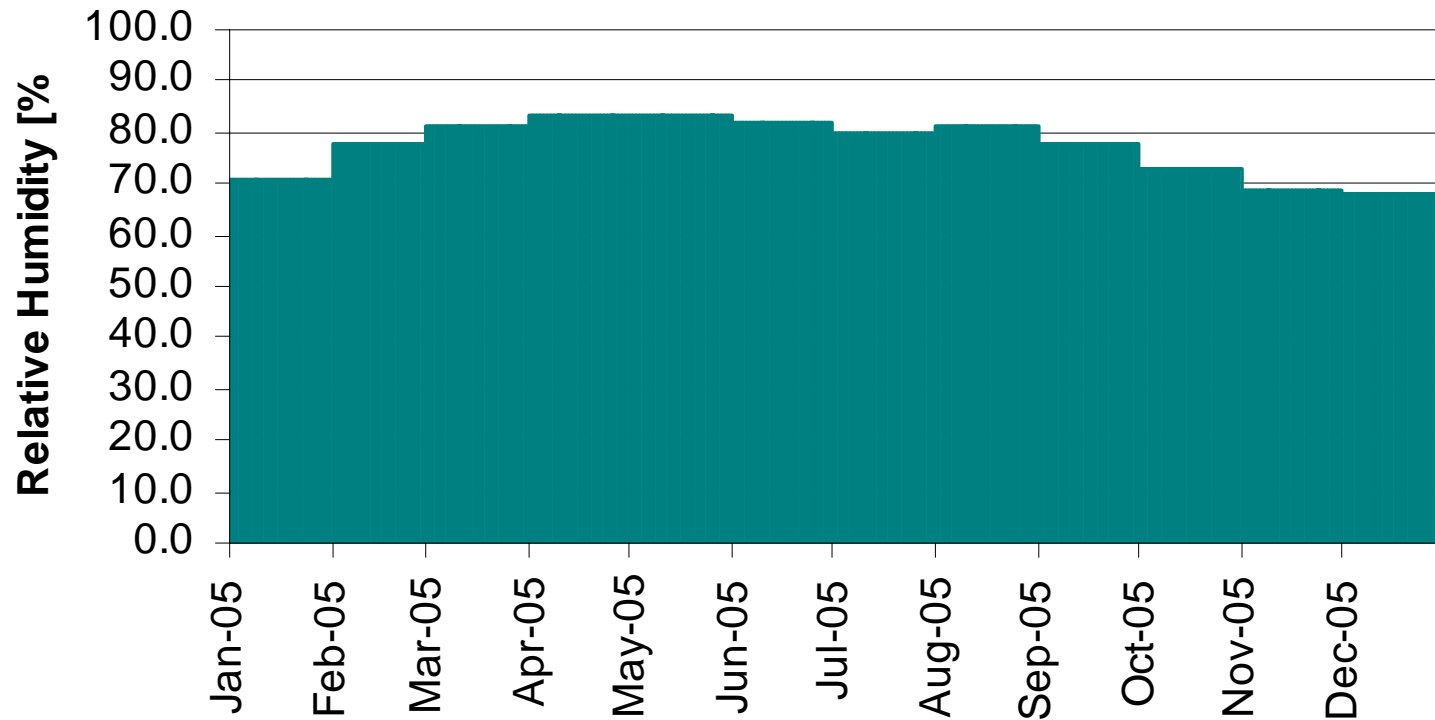
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Historical Relative Humidity

Yearly Relative Humidity Profile



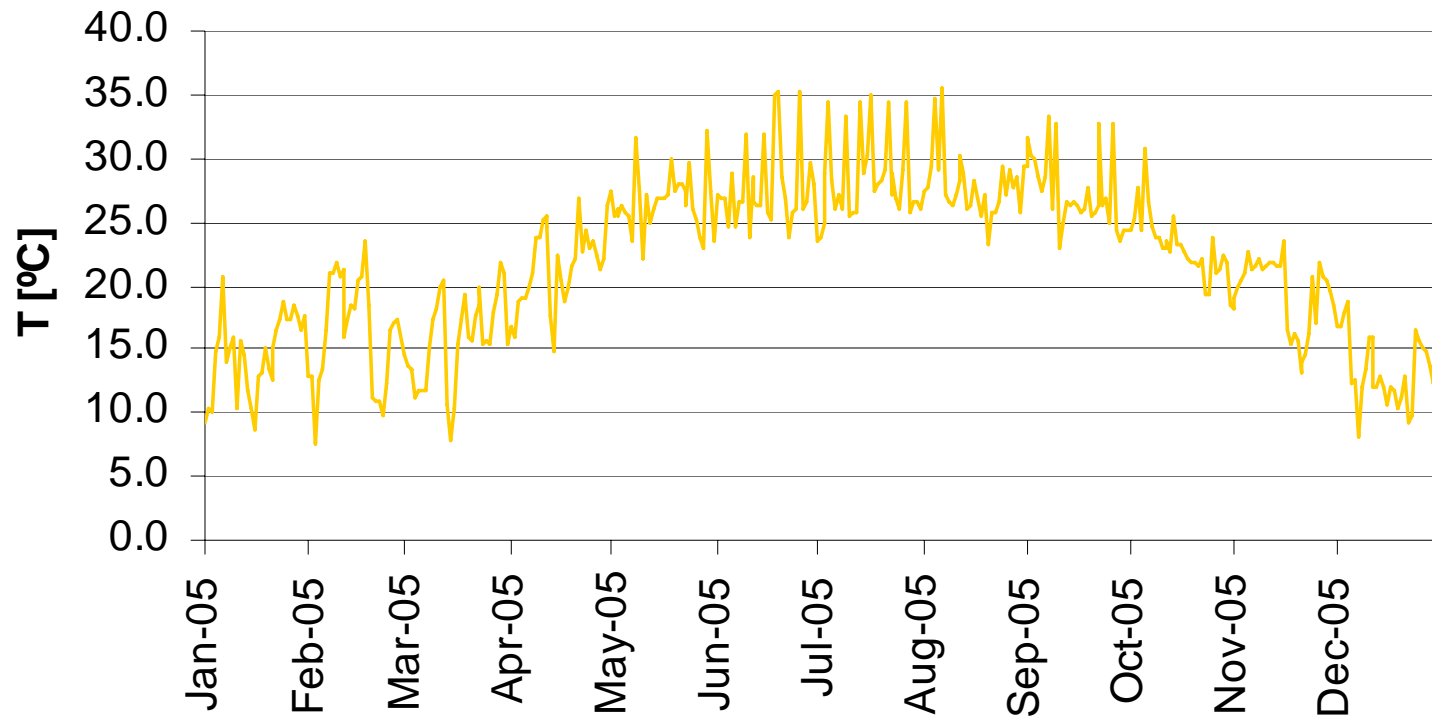
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Yearly Wet Bulb Temperature

Yearly Wet Bulb Temperature Profile



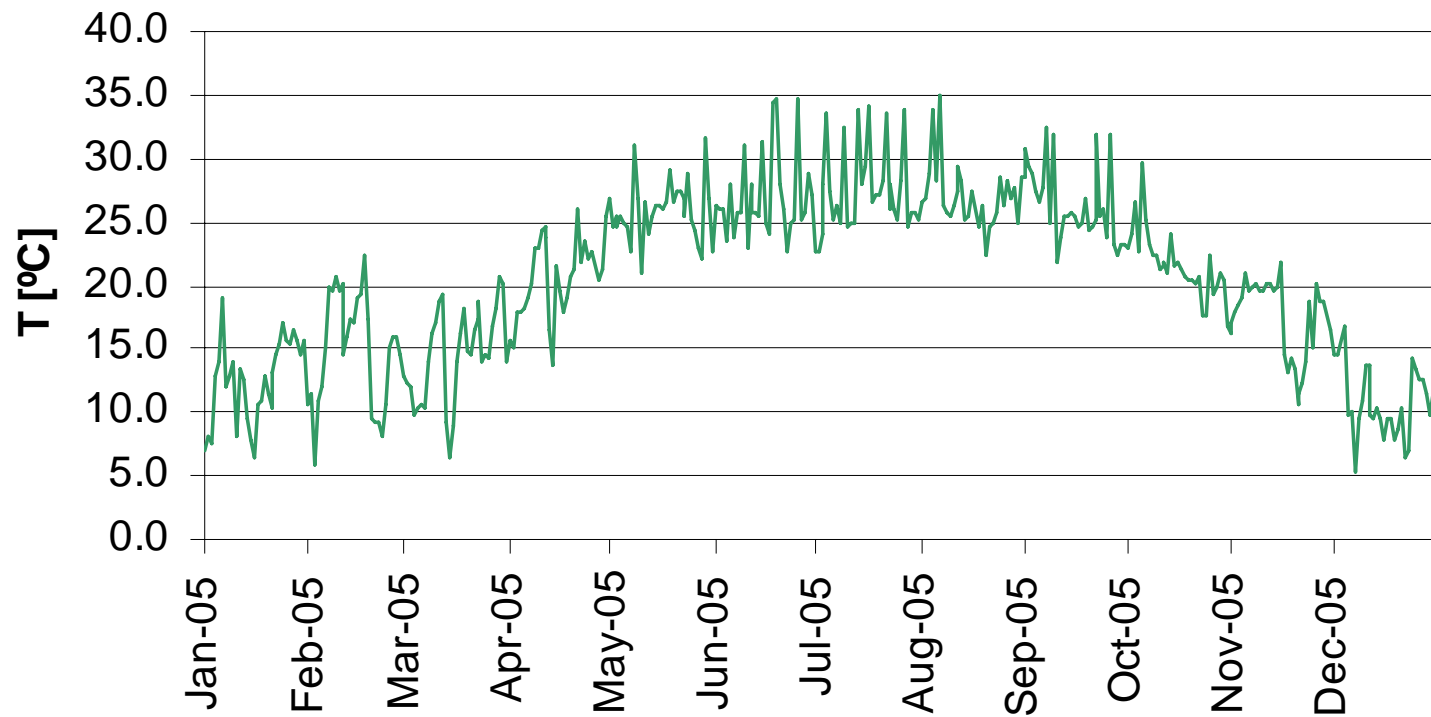
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Yearly Air Dew Point

Yearly Air Dew Point Profile



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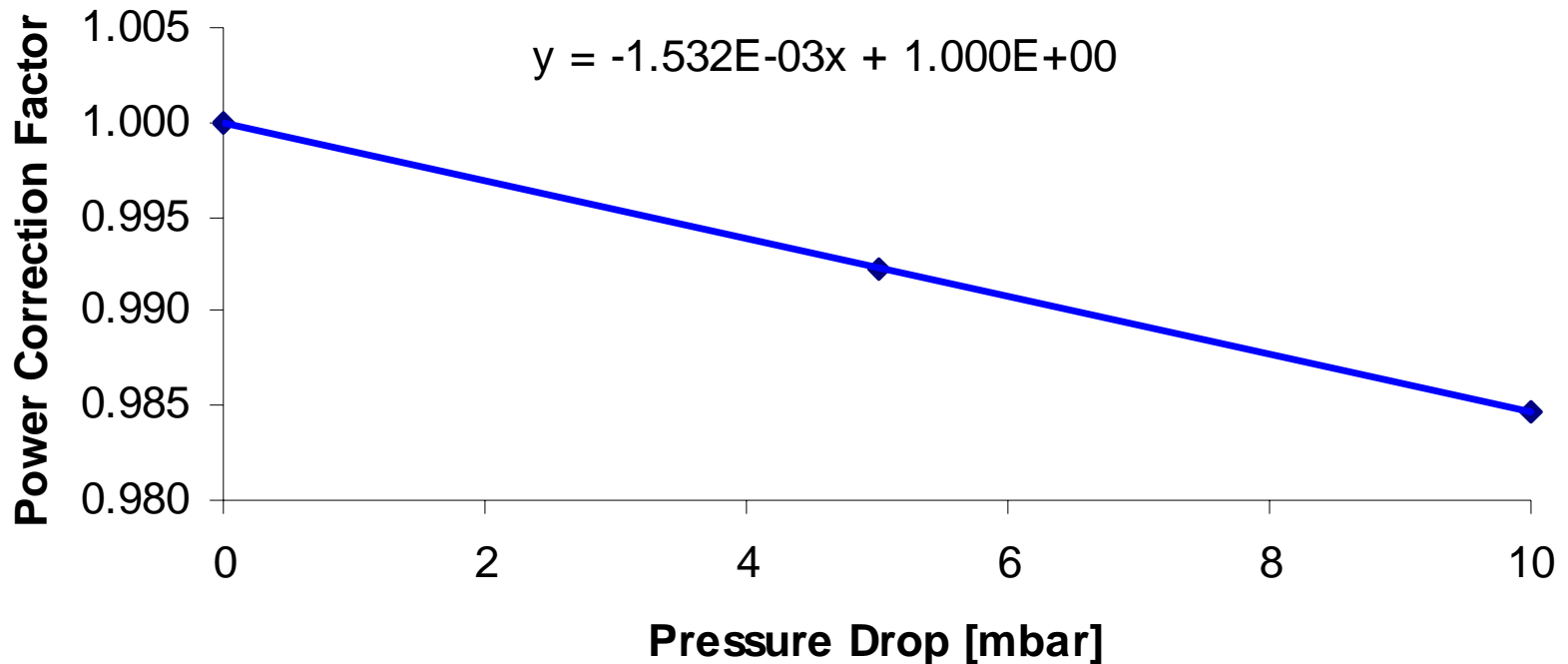
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Power Augmentation

GT Power vs Inlet Pressure Drop

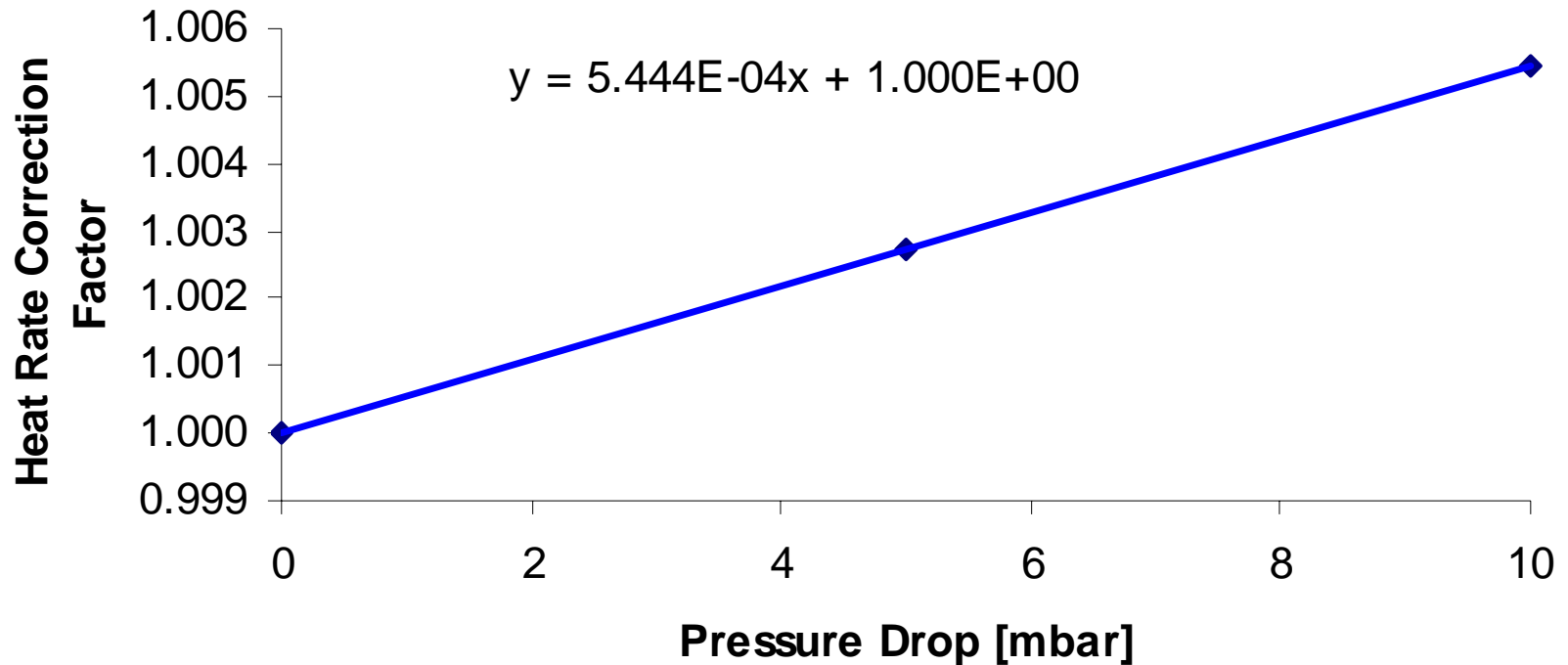
Power vs Air Inlet Pressure Drop



The correction curves have been adjusted by linear correlation for pressure drop variations and non-linear correlation for temperature changes. These formulae are used in the later calculations.

Power Augmentation Heat Rate vs Inlet Pressure Drop

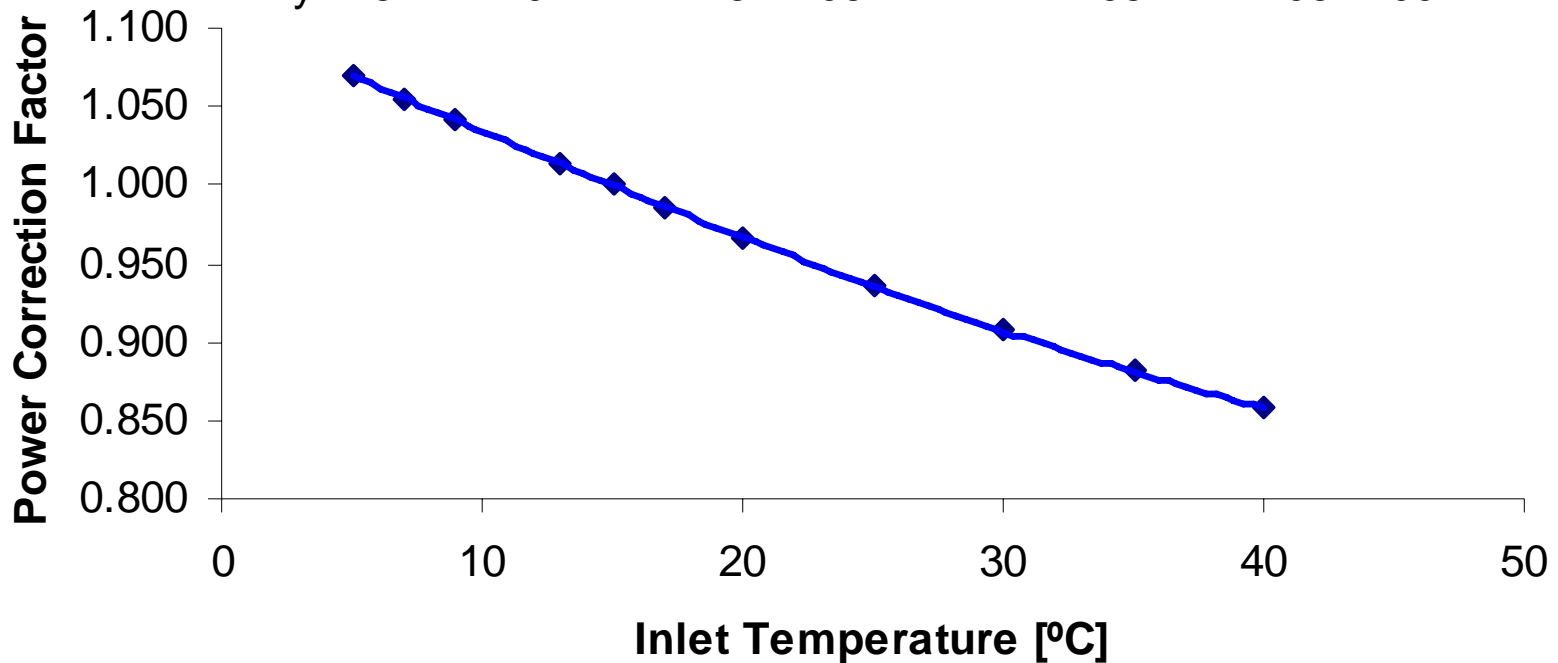
Heat Rate vs Air Inlet Pressure Drop



Power Augmentation GT Power vs Air Inlet Temperature

Power vs Air Inlet Temperature

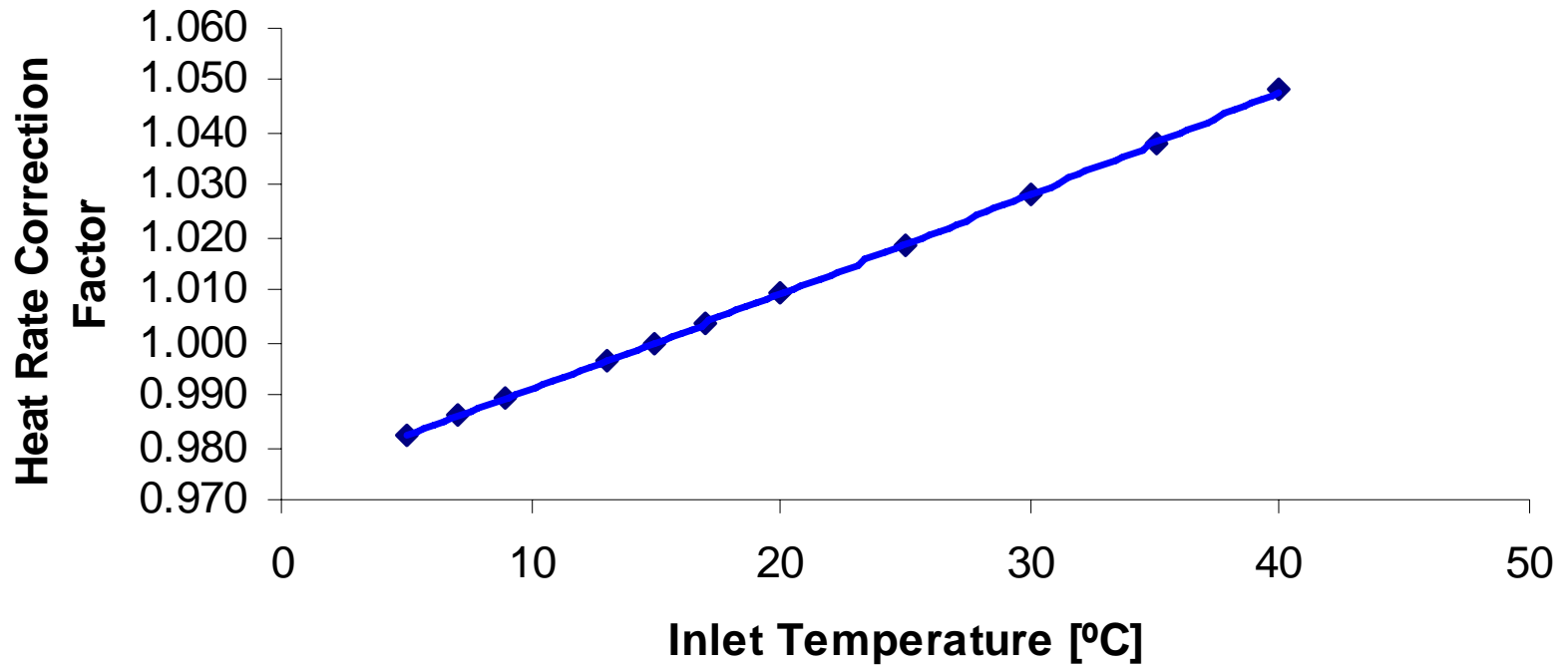
$$y = 6.124E-07x^3 + 1.252E-06x^2 - 7.214E-03x + 1.106E+00$$



Power Augmentation Heat Rate vs Air Inlet Temperature

Heat Rate vs Air Inlet Temperature

$$y = -3.519E-08x^3 + 6.392E-06x^2 + 1.646E-03x + 9.741E-01$$



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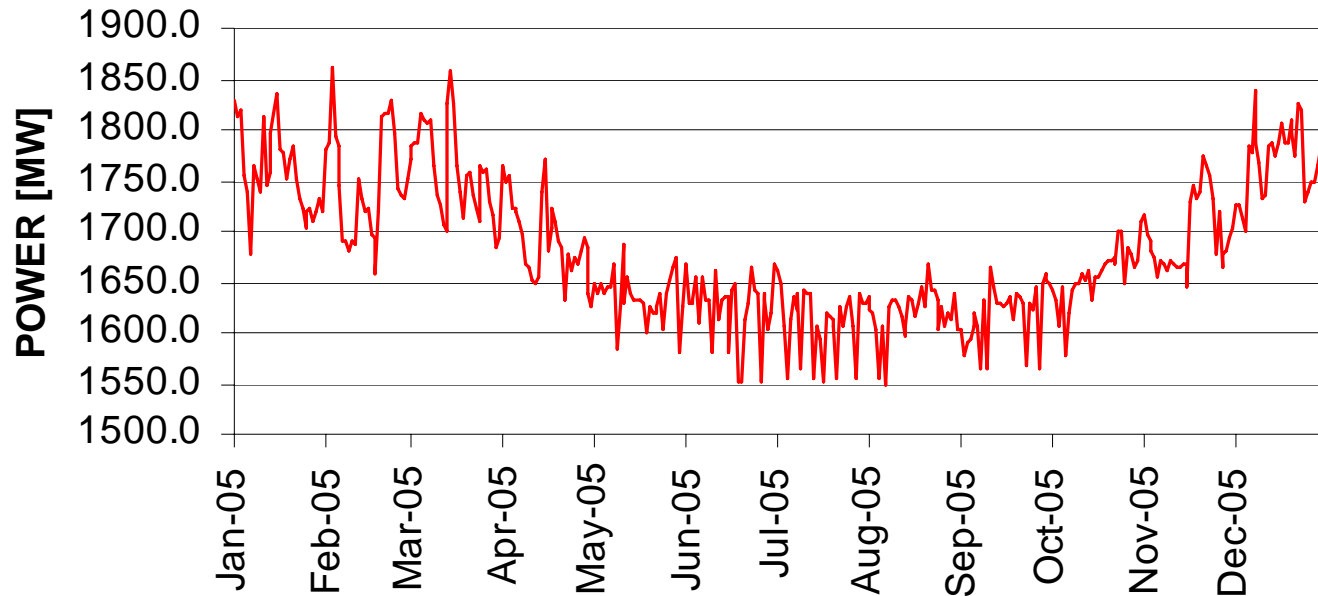
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Power Production

The gas turbine power production varies according to the ambient conditions. The power production of the eight gas turbines is shown below:

Yearly Gas Turbines Power (without chiller)



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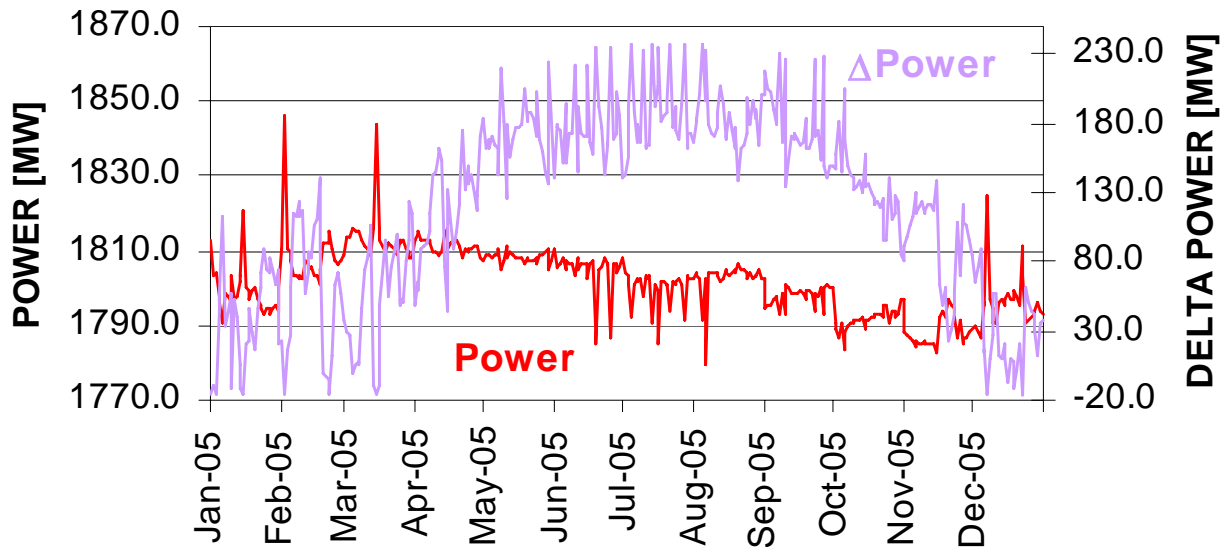
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Power Production

If the chiller is installed in each gas turbine air inlet, the power will be modified as shown below:

Yearly Gas Turbines Power (with chiller)



Indicated power considers the gas turbine power production minus electric consumption because of water/glycol solution pumping.



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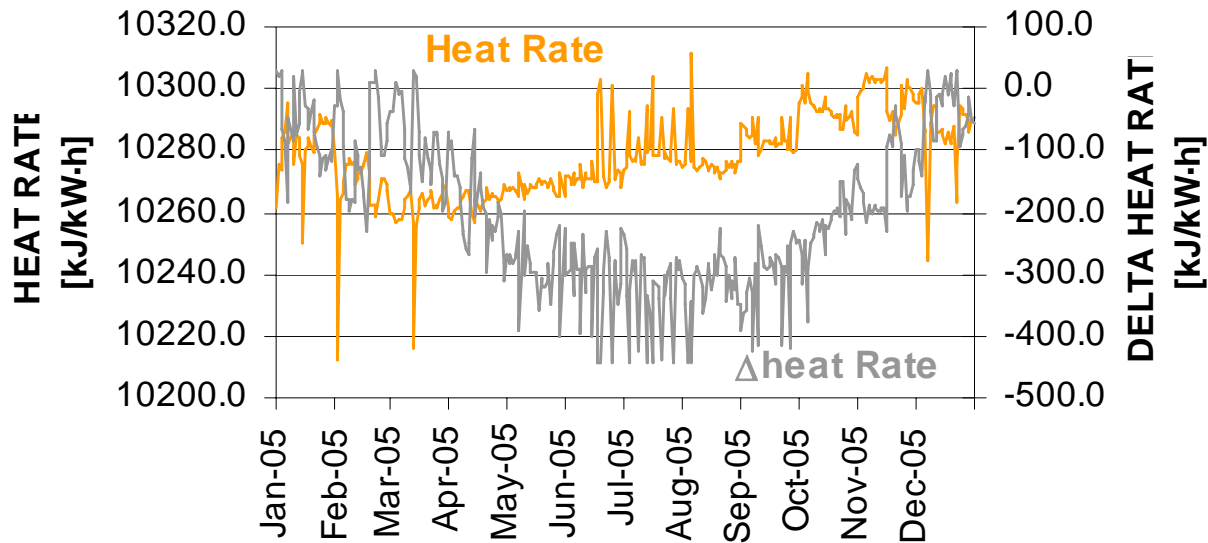
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Power Production

On the other hand, the heat rate is affected as shown below:

Yearly Gas Turbine Heat Rate (with chiller)



Overall gas turbine power production would increase, largely during hot weather, while during cold weather it would decrease as no significant air inlet temperature drop could be obtained and a chiller would act as an air restriction (pressure drop at air inlet).



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Economics

Operating Hours per year	Overall Profit due to Power Augmentation [MM \$/year]:	Overall Expense due to Heat Rate Augmentation [MM \$/year]:	Net Profit [MM \$/year]:
8,760	104.92	37.14	67.78
7,000	83.84	29.68	54.16
7,500	89.83	31.80	58.03
7,000	83.84	29.68	54.16
6,500	77.85	27.56	50.29
6,000	71.86	25.44	46.42

Heat rate effect has been evaluated in comparison with power augmentation. Net profit (margin) considers income from power augmentation and expense because of fuel consumption increase.



Economics

Chiller Pressure Drop Sensitivity

Operating Hours per year	Overall Profit due to Power Augmentation [MM \$/year]:	Overall Expense due to Heat Rate Augmentation [MM \$/year]:	Net Profit [MM \$/year]:
8,760	92.90	33.36	59.54
7,000	74.24	26.66	47.58
7,500	79.54	28.56	50.97
7,000	74.24	26.66	47.58
6,500	68.93	24.76	44.18
6,000	63.63	22.85	40.78

The economic evaluation has been performed for a pressure drop of 10 mbar



Economics

Chiller Pressure Drop Sensitivity

Operating Hours per year	Overall Profit due to Power Augmentation [MM \$/year]:	Overall Expense due to Heat Rate Augmentation [MM \$/year]:	Net Profit [MM \$/year]:
8,760	80.88	29.55	51.33
7,000	64.63	23.62	41.02
7,500	69.25	25.30	43.95
7,000	64.63	23.62	41.02
6,500	60.02	21.93	38.09
6,000	55.40	20.24	35.16

Similarly to before, the economic evaluation has been performed for a pressure drop of 15 mbar



Economics

Wet Bulb Temperature Sensitivity

Operating Hours per year	Overall Profit due to Power Augmentation [MM \$/year]:	Overall Expense due to Heat Rate Augmentation [MM \$/year]:	Net Profit [MM \$/year]:
8,760	125.62	44.57	81.05
7,000	100.38	35.62	64.76
7,500	107.55	38.16	69.39
7,000	100.38	35.62	64.76
6,500	93.21	33.07	60.14
6,000	86.04	30.53	55.51

An economic evaluation has been performed for a wet bulb temperature of 8°C



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Economics

Wet Bulb Temperature Sensitivity

Operating Hours per year	Overall Profit due to Power Augmentation [MM \$/year]:	Overall Expense due to Heat Rate Augmentation [MM \$/year]:	Net Profit [MM \$/year]:
8,760	84.80	29.91	54.89
7,000	67.76	23.90	43.86
7,500	72.60	25.61	46.99
7,000	67.76	23.90	43.86
6,500	62.92	22.19	40.73
6,000	58.08	20.49	37.59

Similarly, an economic evaluation has been performed for a wet bulb temperature of 12°C



Conclusions

- Study results indicate that process integration of cold energy recovery from an LNG terminal in a power plant has the potential to provide a highly reliable and operable facility with enhanced economics
- Utilizing a very conservative assessment for a retrofit with known and unknown elements of constructability risk (additional structural support, piping, pump costs, etc) a CAPEX deduct of \$10.5 MM was estimated, allowing a conservative potential investment gain ranging from \$30 MM to \$43 MM
- This potential profit margin projects a simple pay back of the installation in the range of 1 to 1.5 years





Thank you. Any questions?

Augusto Bulte
Proposal Manager - LNG & Power Projects
Foster Wheeler Iberia
augusto_bulte@fwiberia.fwc.com
www.fwc.com



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