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SPIG

ACC Users Group

AIR COOLED CONDENSER
USERS GROUP

Power Capacity Improvement Through ACC Upgrades

San Diego, September 2014

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CONTENT

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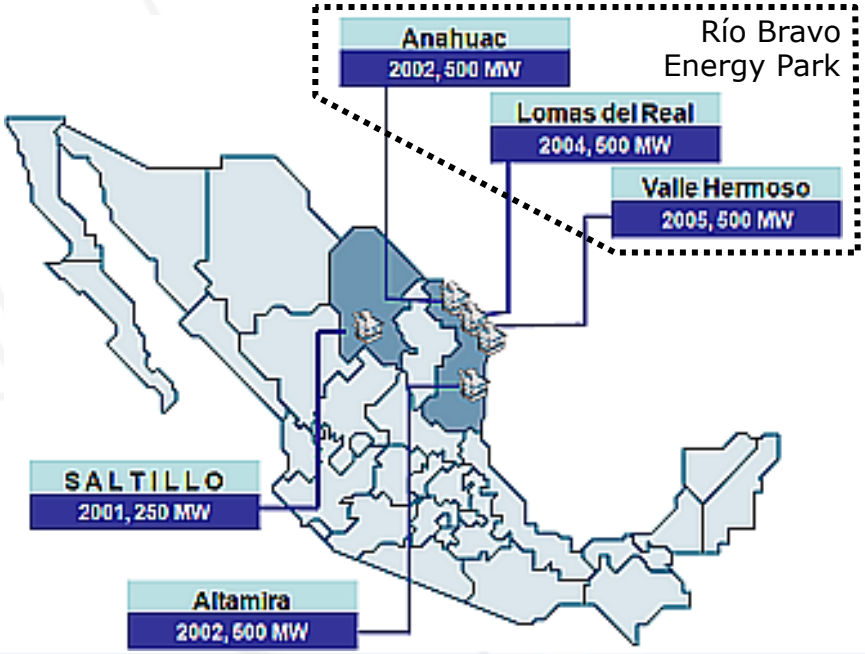
General Introduction

Falcon Group, a joint venture of Japanese Corporations (Mitsui + Mayor Utilities), currently has 5 Combined Cycle Power Plants in Mexico with direct O&M responsibility:

•Río Bravo Energy Park:	3 identical	2x2x1 500 MW's each.
•Central Saltillo:		1x1x1 250 MW's.
•Central Altamira:		2x1x1 500 MW's.

All 3 plants at Río Bravo and Central Saltillo use Air Cooled Condensers due to water availability restrictions.



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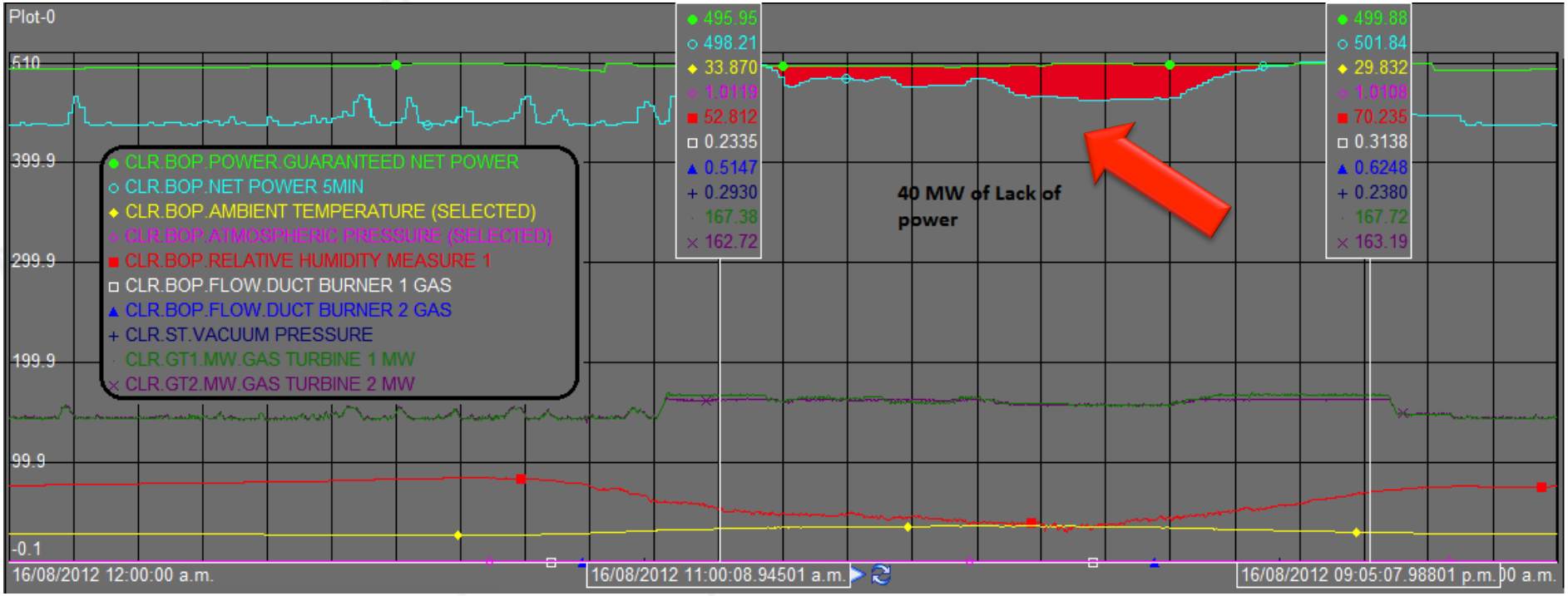
Problem Background

- Contract Power Output demanded by customer was unattainable during the summer months due to high steam turbine backpressure from the main condenser, which implied limiting both duct burner (even complete auxiliary firing shutdown), as well as sometimes even reducing combustion turbines output, to avoid a steam turbine trip on high backpressure.



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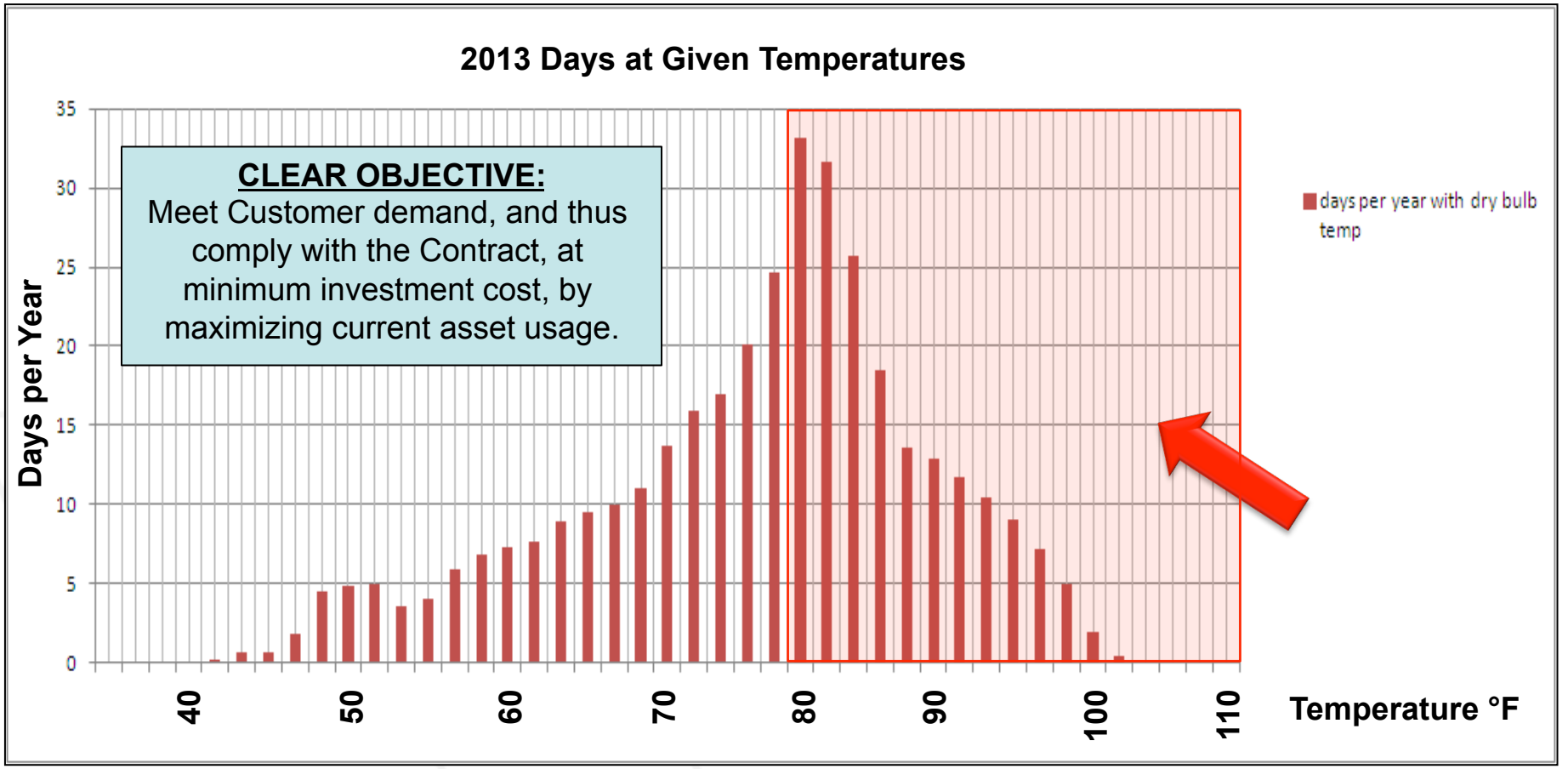
Problem Background

- This significant power output reduction due to steam condensing limitations, was due to ACC under-performance in summer and windy conditions.



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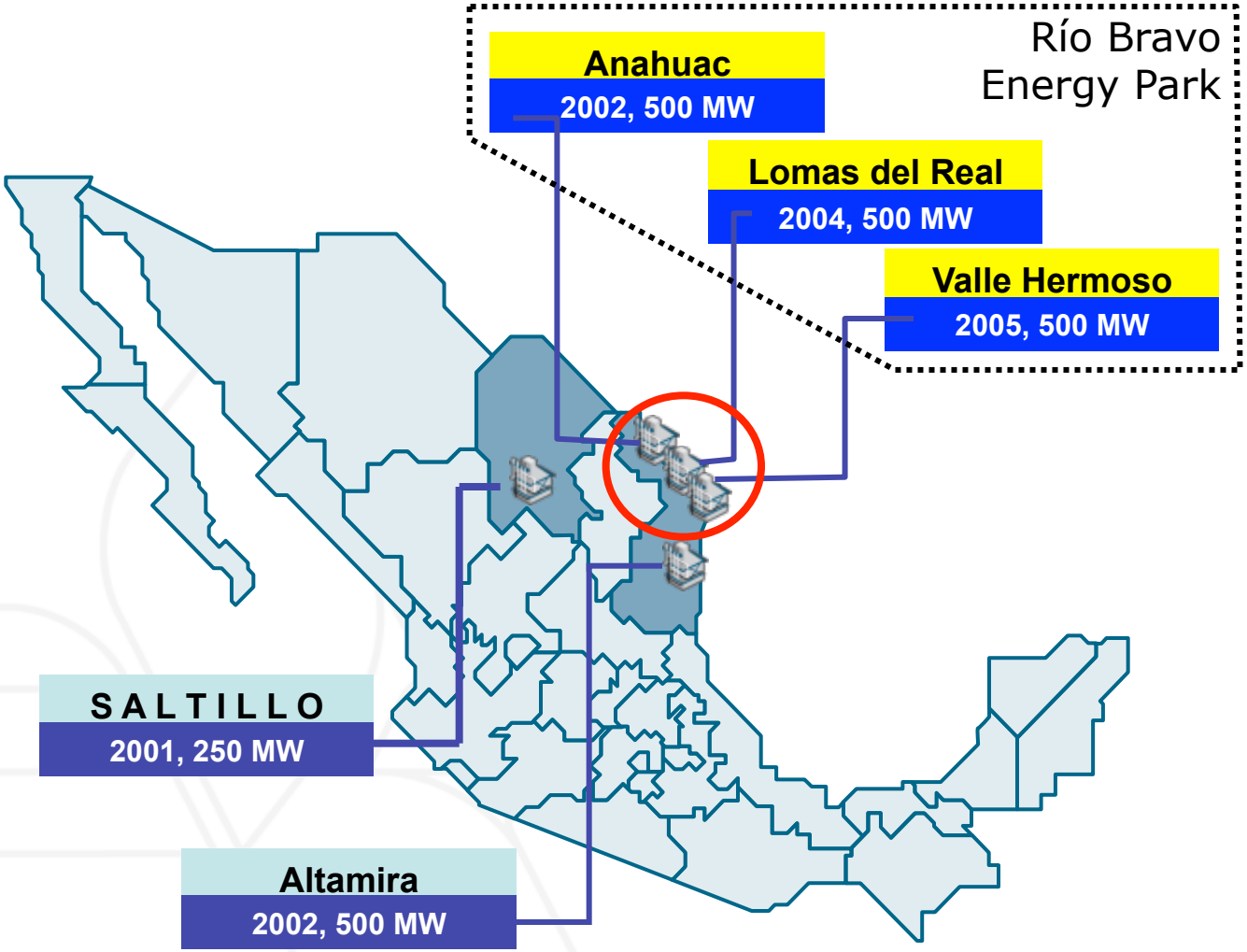
Río Bravo Energy Park



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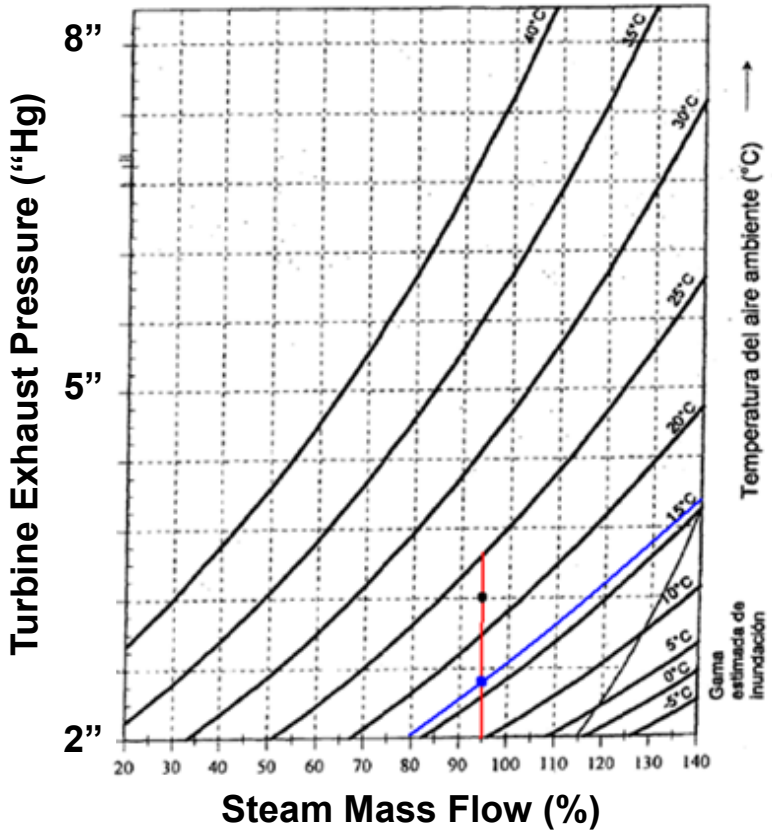
Río Bravo: Root Cause Analysis

- Even though condensers were originally correctly sized, specified and supplied, there has been ACC degradation through the years (severe fouling, tube damage).
- Performance is mostly affected by higher temperatures and winds.



Heat Rate= 335.86 MW =100%

Jan 19th 320 MW= 95.27%
16.673 °C
11 kPa of pressure

Design Point 95.27%
16.673°C
8.7 kPa

In this example, for 320 MW of condenser load, 16.7°C of ambient temperature, and **without wind,** we **<u>are 0.7 inHg</u>** higher than design point.

DESIGN DATA			
Medium		Exhaust steam	
Flow	kg/s	143	1.13 M # / Hr
Turbine exahust pressure	mbar	126	3.7 “Hg
Steam enthalpy	kJ/kg	2492	
Design Pressure	bar,g	0.5	14.8 “Hg
Design Temperature	°C	120	248 °F
Ambient air temperature	°C	24.7	77 °F
Ambient air pressure	mbar	1011.5	29.9 “Hg
Number of fans		32	
Fan shaft power consumption (per fan)	kW	82	
Motor capacity	HP	150 (112 kW)	

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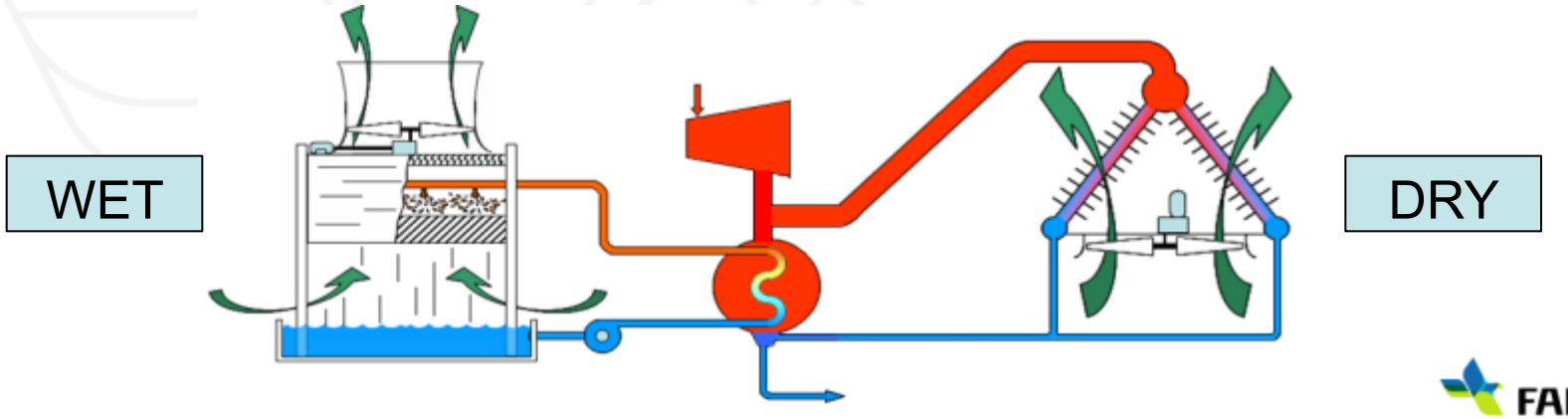
Rio Bravo: Chosen Solution – PCS 1/4

- Through several years and some expense, many options were evaluated using several common and "unconventional" methods, as well as several suppliers with aftermarket services.
- The chosen solution considered:
  - Río Bravo's ACCs have a good Fan Power to Area ratio.
  - There are additional water sources near the plants.
  - ACC enlargement was a very expensive option.
- With the help of SPIG USA, a Parallel Condensing System (PCS) was chosen as final solution: A system in which exhaust steam is simultaneously condensed in both a wet evaporative (SSC) and in the existing dry cooling systems (ACC):



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Rio Bravo: Chosen Solution – PCS 2/4

- Goal: Remove the steam turbine backpressure limitation during all periods with ambient temperature higher than 30°C (86°F, approximately 1,000 hours per year), by adding enough wet cooling capacity to the existing 32 cell ACC.

- Advantages of the Parallel Condensing System:
  - Combines performance of an SSC with water savings of an ACC.
  - Optimize water use to minimize condensing system costs.
  - Sized to augment the performance of the ACC within the available water limitations, while achieving the power generation goals.

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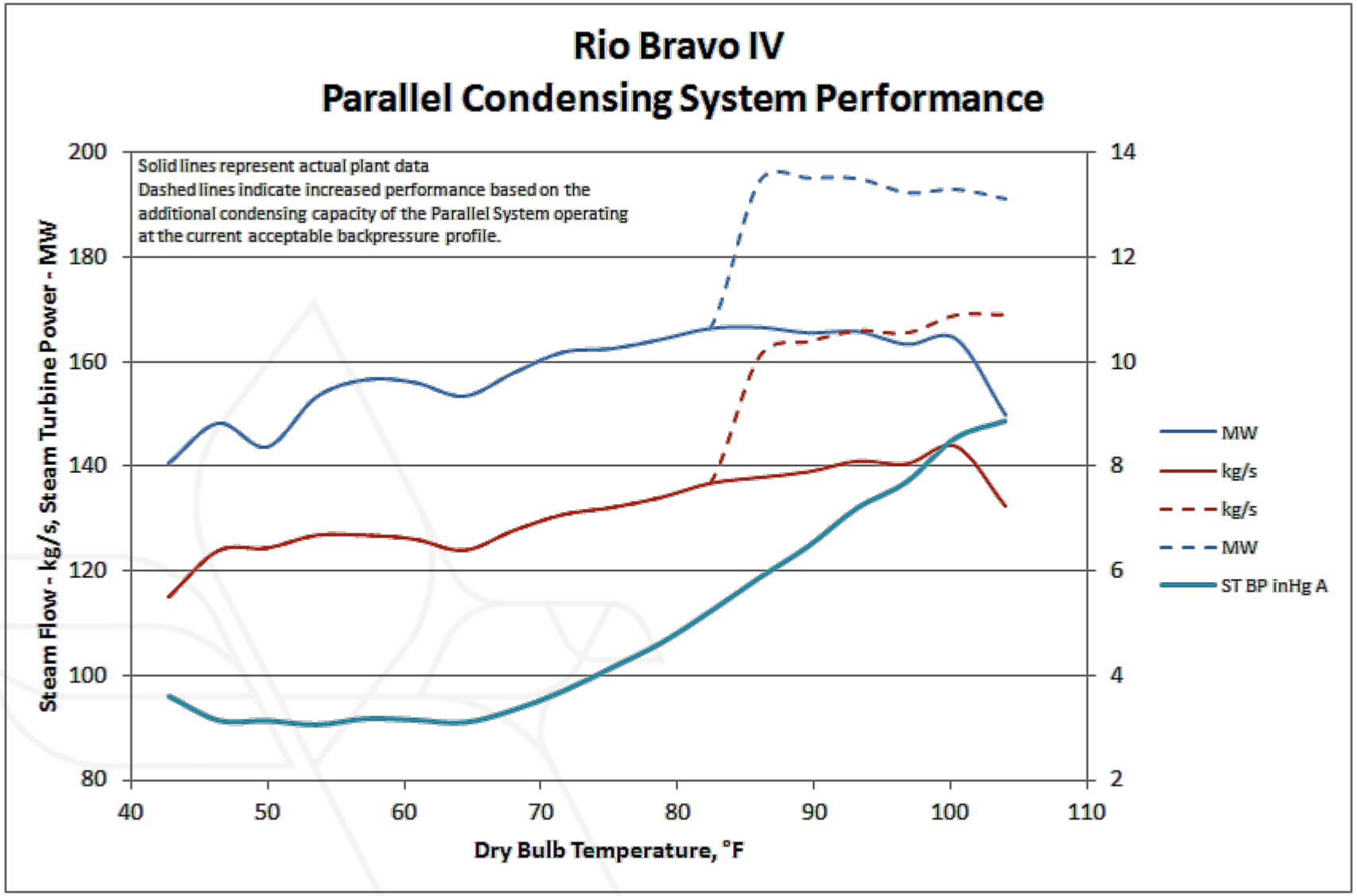
Rio Bravo: Chosen Solution – PCS 3/4



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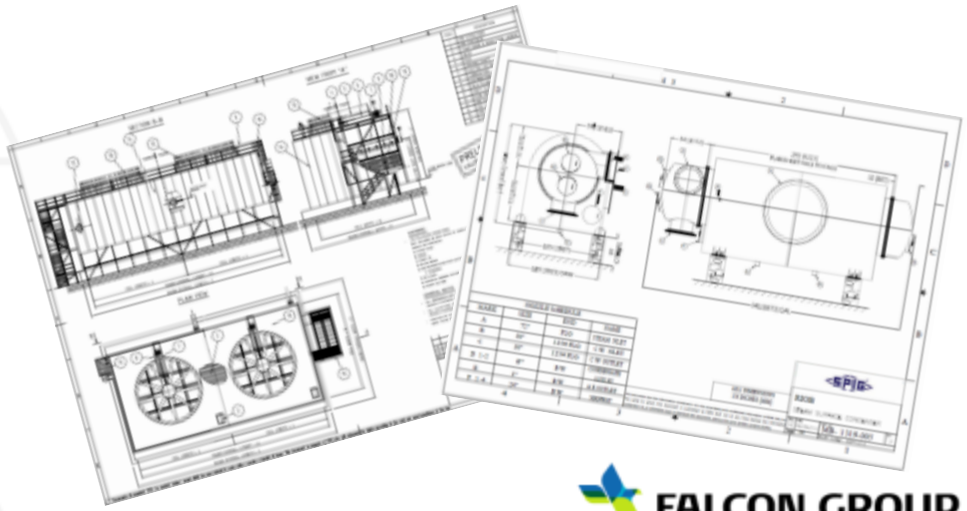
Rio Bravo: Chosen Solution – PCS 4/4

- After SPIG and Falcon Group evaluation, a PCS was designed to meet the objective at minimum cost and maximum reliability.
- The following tables show the main characteristics of these systems:

MAIN TECHNICAL DATA STEAM SURFACE CONDENSER						
SHELLSIDE				TUBESIDE		
Operating pressure	5.6 "Hg	bar	0.19	CW source		Cooling Tower
Duty		MW	53.38	Circulating Water flow	CMH	3,800
Surface Area	9,380 sqft	m2	871.50	Hot /Cold water temp	°C	46.5/34.5
Steam Flow Rate	180,000 # / Hr	kg/s	22.60	Cleanliness Factor	%	85
LMTD	62 °F	°C	16.50	Number of Passes		2
Material			SA516-70	Material		SA516-70

116 / 94 °F

MAIN TECHNICAL DATA WATER COOLING TOWER			
Type			Exhaust steam
No of cells/fans			2
Circulating Water flow		CMH	3,800
Hot (inlet) water temp	116 °F	°C	46.5
Cold (outlet) water temp	94 °F	°C	34.5
Wet bulb temp	74 °F	°C	23.3
Drift Loss		%	≤0.05
Evaporation Loss %		%	1.7
Number of blades			6
Fan speed		RPM	180
Driver rated capacity		kW	55



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Rio Bravo: Project Execution – PCS 1/3

TOWER

Rio Bravo: Project Execution – PCS 2/3

CONDENSER BOX

Rio Bravo: Project Execution – PCS 3/3

WATER PIPES & COMMISSIONING

Rio Bravo: Results – PCS 1/5

The most relevant results after PCS installation in the 3 Río Bravo plants are, to date:

- Auxiliaries consumption increase by about 500 kW's when PCS is in operation due to cooling water pumps, blowdown and make-up pumps, as well as cooling tower fans.
- Complete elimination of the backpressure limitation, with a significant sustained improvement of up to 80 mBar.
- Power output increase in excess of 20 MW's due to condenser pressure reduction and now the possibility of increasing condenser load, thus greater steam flow through the turbine and more power.
- Heat rate improvement due to the lower condenser pressure and thus lower backpressure on the steam turbine (more "free" power).

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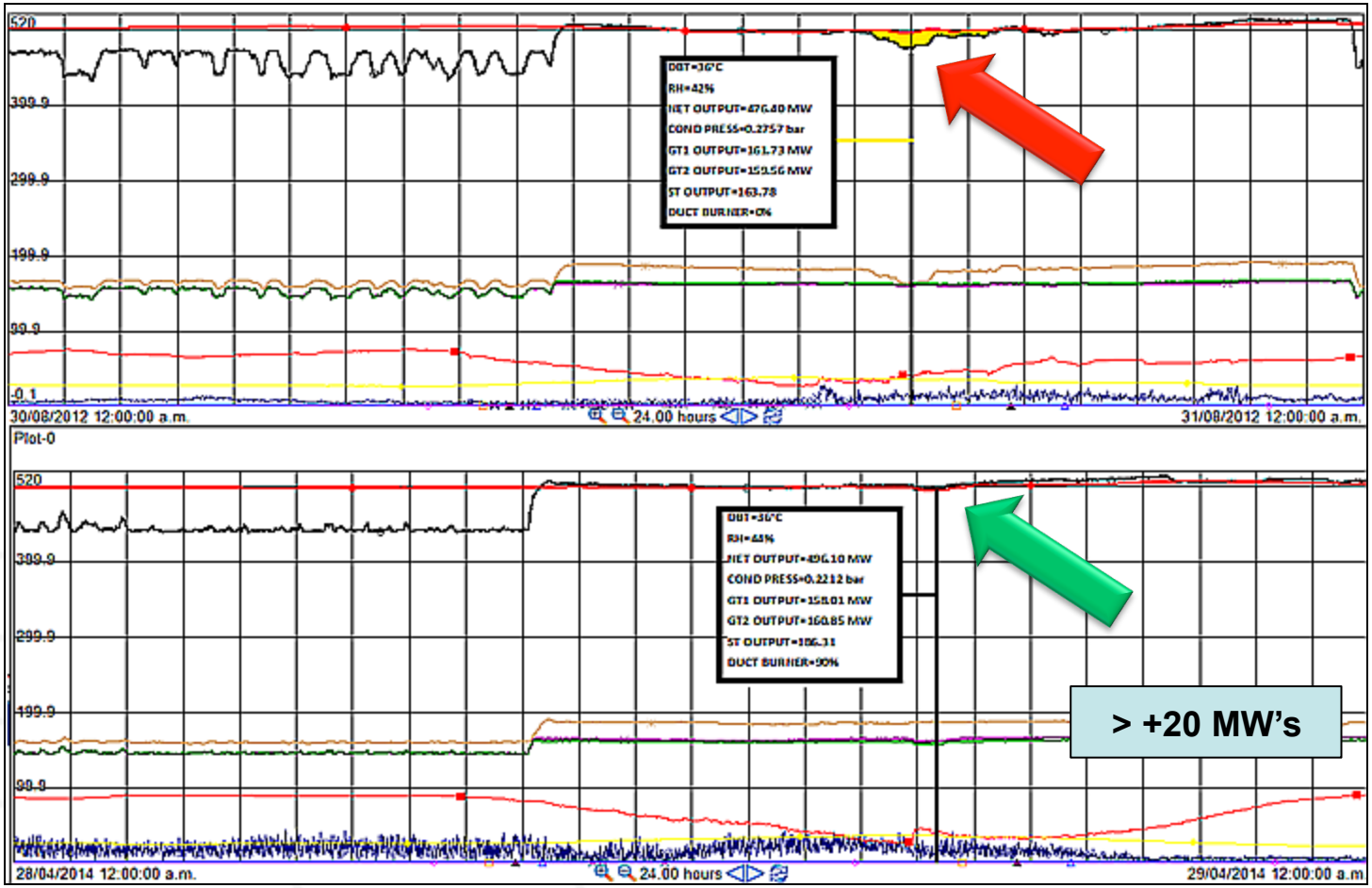
Rio Bravo: Results – PCS 2/5

No more power output limitations, no more plant de-rating…



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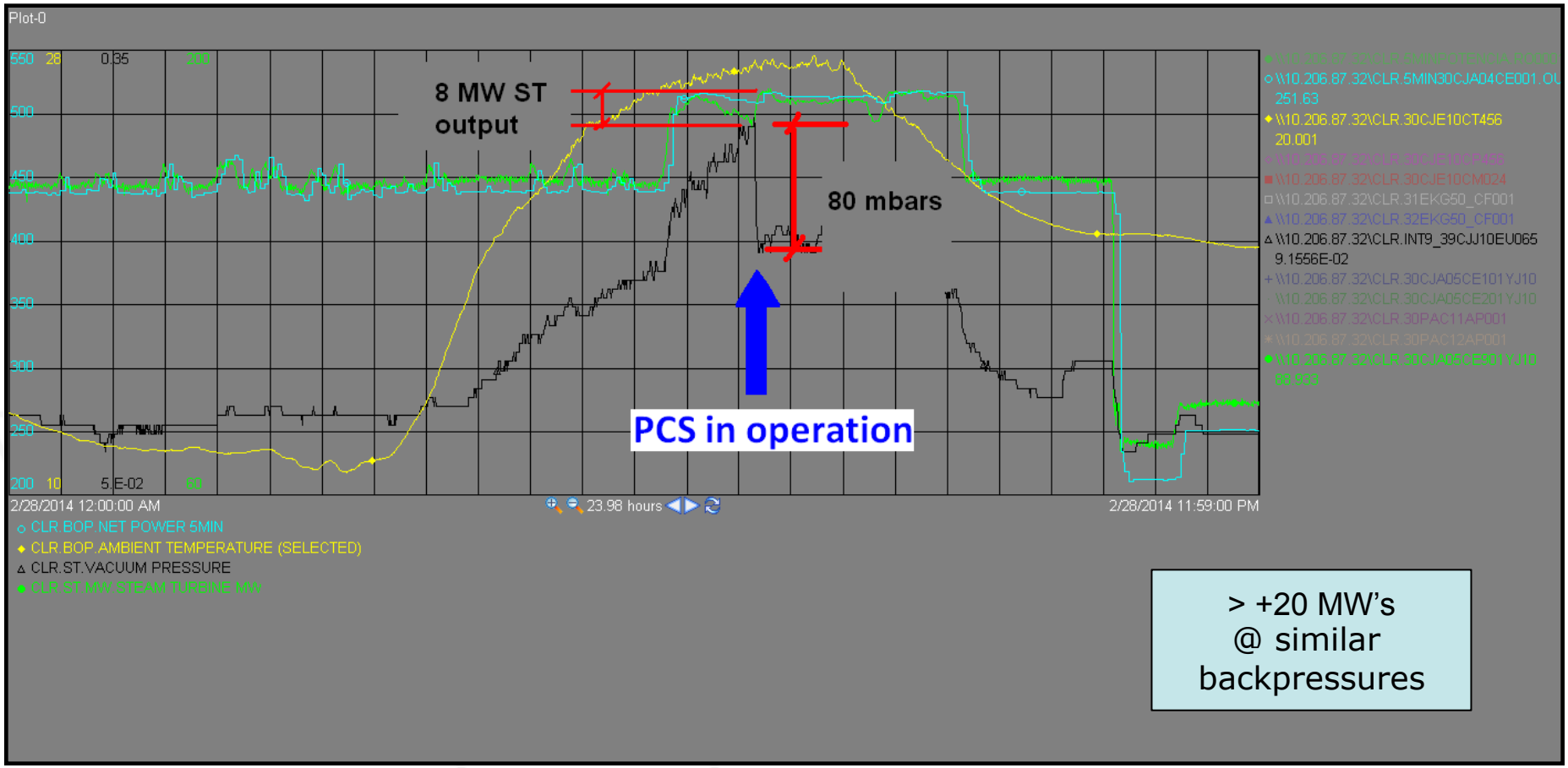
Rio Bravo: Results – PCS 3/5

As soon as the wet cooling "booster" kicks-in, the Plant meets contract power, gains +8 MW's and simultaneously backpressure drops by 80 mBars (2.36 inHg).



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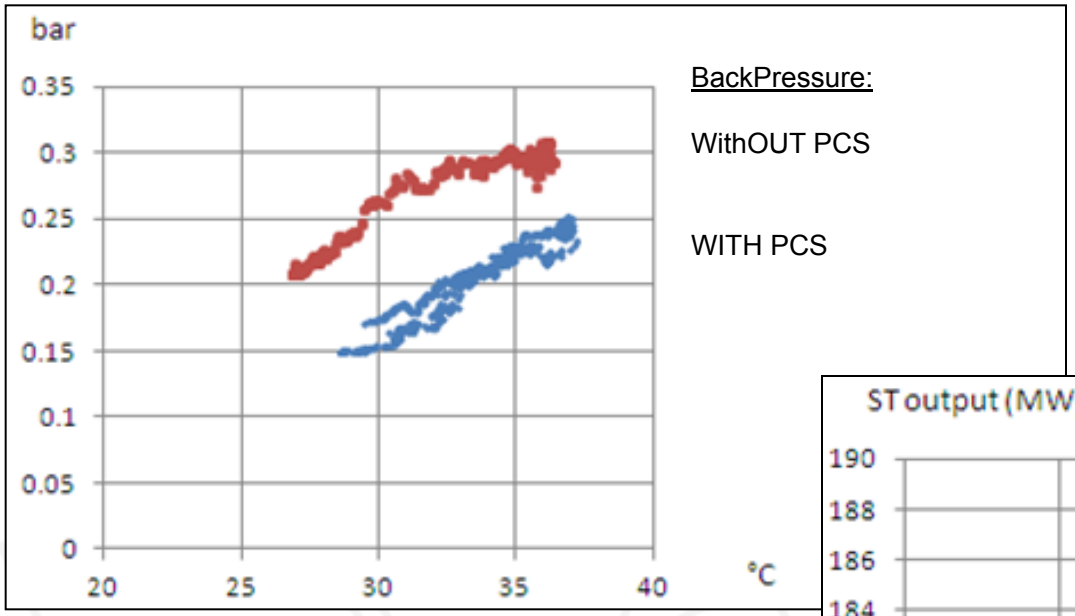
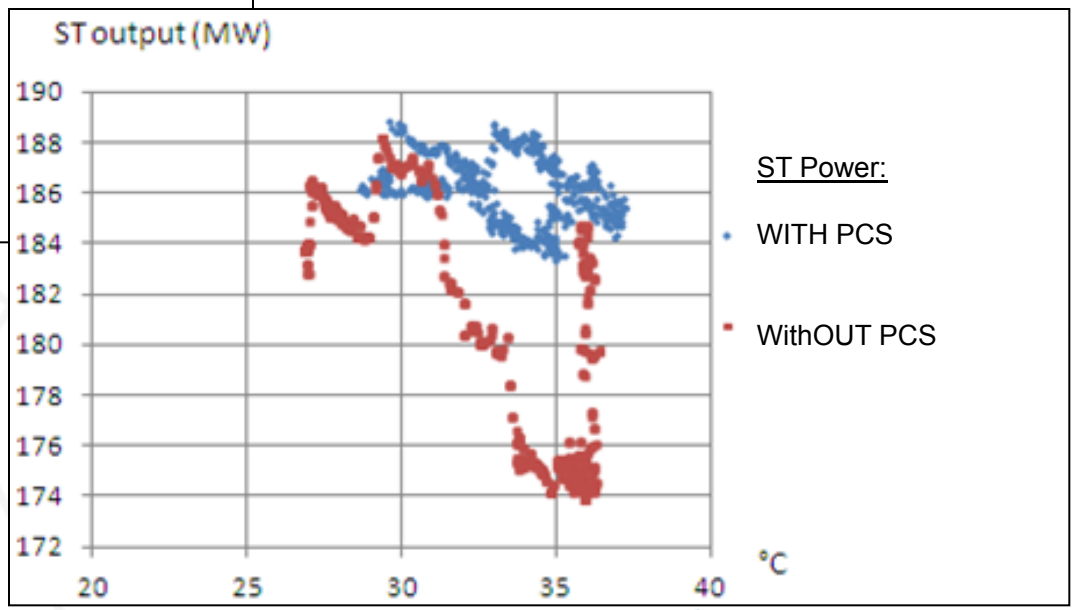
Rio Bravo: Results – PCS 4/5

The PCS results in consistent and repeatable operational reliability under adverse summer conditions.





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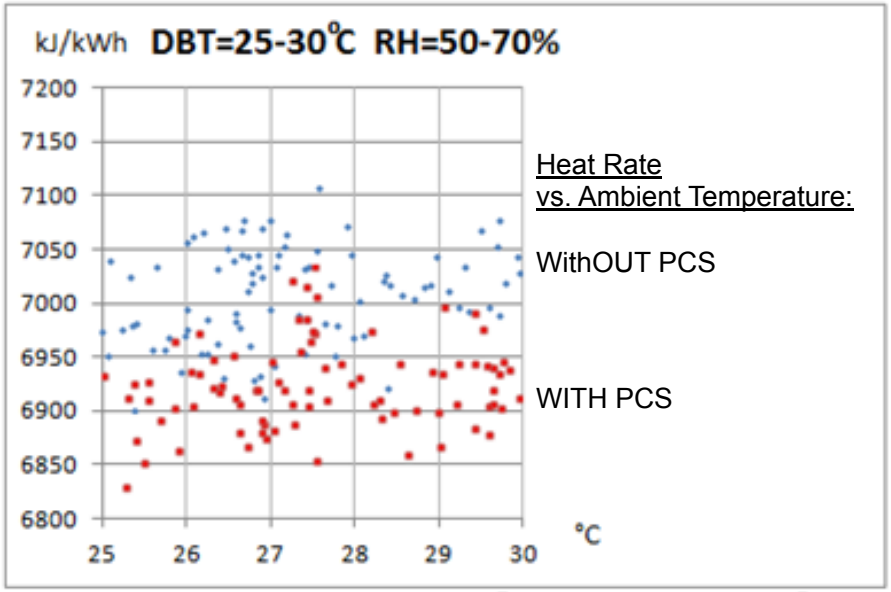
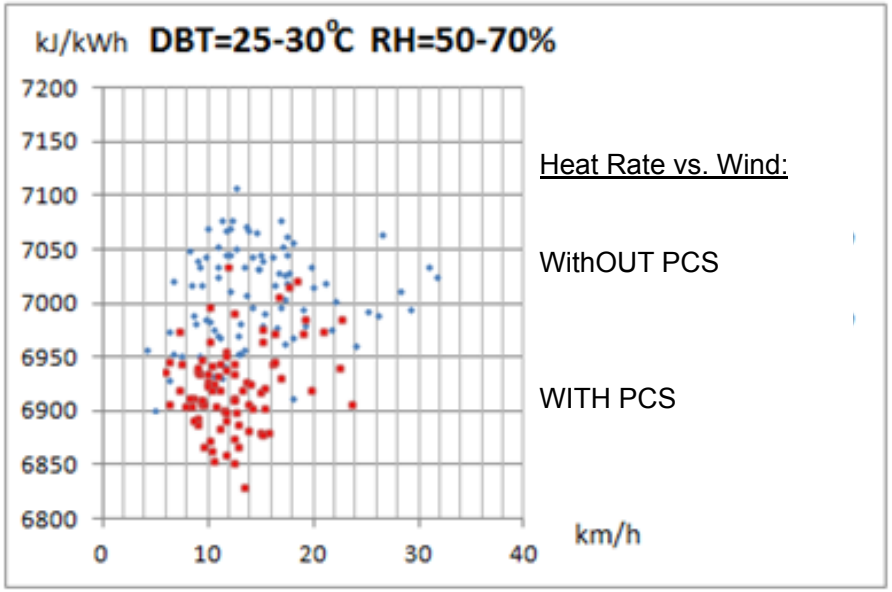
Rio Bravo: Results – PCS 5/5

After some operational time…

•PCS operation results in a clear improvement of Plant heat rate with temperatures higher than 25°C (77°F) & humidity lower than 70%.

•For lower temperature and higher humidity the increment in auxiliary consumption is more than the steam turbine power output gain, and there is no heat rate improvement, thus PCS operational limits are consistent with design expectations.





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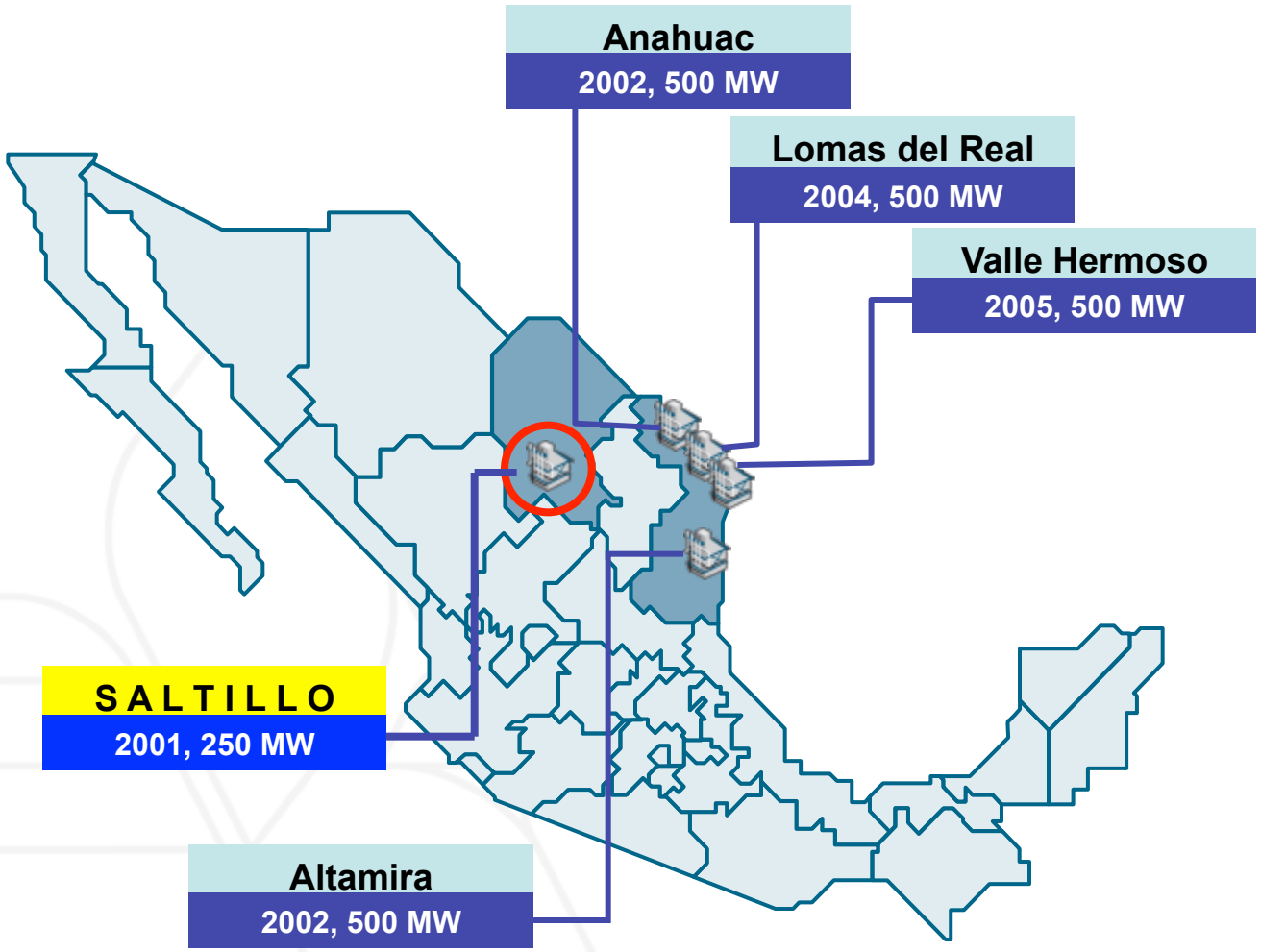
Central Saltillo



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Saltillo: Root Cause Analysis

- Saltillo, although ACC operation was right on design specifications or better, it was found that Fan Power to Condensing Surface Ratio was much lower than other plants. That is, we had the surface area, but we were lacking fan power to increase air mass flow.
- Same was seen when comparing Fan Power to Steam Mass Flow. We had the asset, but were under-utilizing it…

Plant	# Fans	HP / Fan	Total HP	Exchange surface (m2)	Relation (HP / m2):	% CSO:
Saltillo	15	100	1500	556964	0.00269	0%
Rio Bravo III	32	150	4800	629264	0.00763	183%
Plant A	20	91.189496	1823.78992	302620	0.00603	124%
Plant B	40	140.80731	5632.2924	N/A		

Plant	# Fans	HP / Fan	Total HP	Steam Flow (kg/s)	Ratio (HP / kg/s)	% Over CSO
Saltillo	15	100	1,500	81	18.5	0%
Rio Bravo III	32	150	4,800	155	31.0	67%
Plant A	20	91	1,824	68	26.9	45%
Plant B	40	141	5,632	134	41.9	126%

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Saltillo: Chosen Solution – Fans Uprate 1/2

- No water source, at all, to consider a Parallel Condensing System.
- Therefore, solution must focus on increased dry cooling capacity, at minimum cost (no additional cells or ACC enlargement).
- Thus, ACC fan system upgrade from 100 HP to 200 HPs, which entail replacing electrical switchgear, cabling, motors, gearboxes and fans, as well as structural checks for load bearing and resonance issues.
- With 200 HPs, Saltillo comes right between the ratios seen for other ACCs regarding power to surface and power to steam flow:

Planta	# Fans	HP / Fan	Total HP	Exchange surface (m2)	Relation (HP / m2):	% CSO:
Saltillo	15	200	3,000	556964	0.00539	100%
Rio Bravo III	32	150	4,800	629264	0.00763	183%
Plant A	20	91	1,824	302620	0.00603	124%
Plant B	40	141	5,632	N/A		

Plant:	# Fans:	HP / Fan:	Total HP:	Steam Flow (Kg/s):	Ratio (HP / Kg/s):	% Over CSO:
Saltillo	15	200	3,000	81	37.0	100%
Rio Bravo III	32	150	4,800	155	31.0	67%
Plant A	20	91	1,824	67.9	26.9	45%
Plant B	40	141	5,632	134.28	41.9	126%

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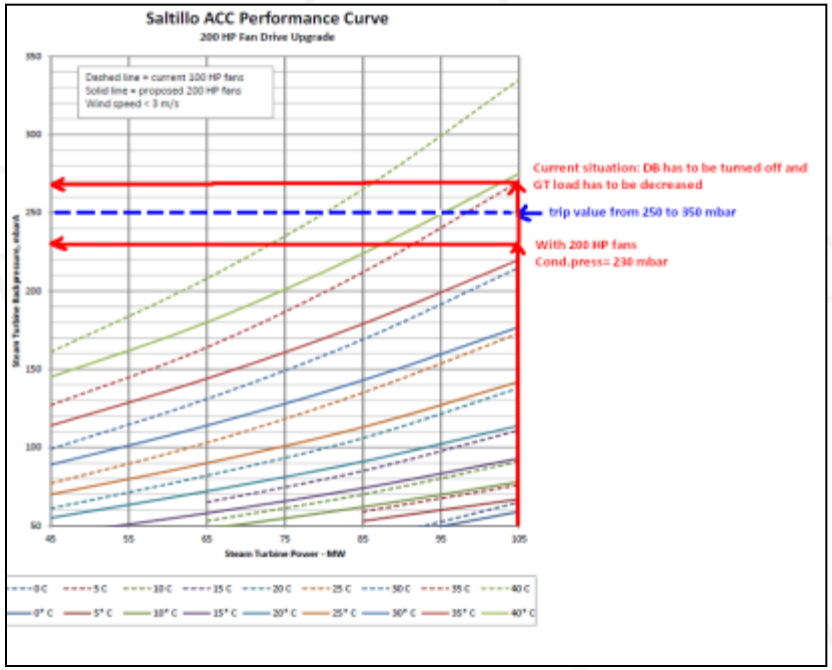
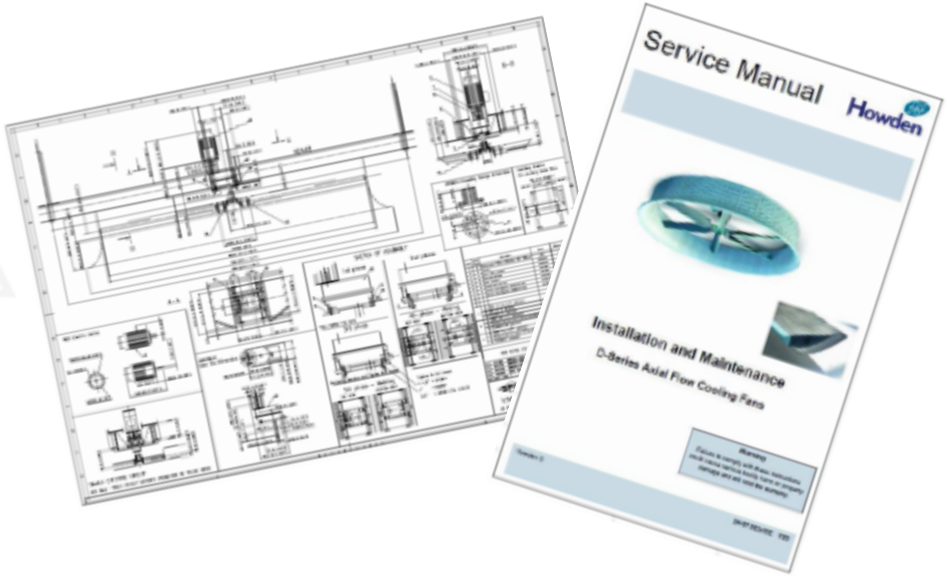
Saltillo: Chosen Solution – Fans Uprate 2/2

After SPIG engineering & procurement, and Falcon Group evaluation, 15 new motors, gearboxes and fans were selected. The main differences with the original supply are:

- Significantly improved ACC performance under adverse conditions.
- No additional water needed.
- 9 vs. 4 blades, which inherently minimizes vibration and resonance.
- 730 vs. 542 m^3/s air flow, 125 vs. 71 Pa static pressure.
- 1.12 to 2.24 MW's auxiliaries consumption increment.





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Saltillo: Project Execution – Fans Uprate 1/2

ORIGINAL SUPPLY

UPRATED

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Saltillo: Project Execution – Fans Uprate 2/2

ORIGINAL SUPPLY

UPRATED

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Saltillo: Results – Fans Uprate 1/3

The most relevant results after fans upgrade in Saltillo are, to date:

- Auxiliaries consumption increase by about 1.12 MW's due to larger fan drive system.
- Complete elimination of the backpressure limitation, with a significant and sustained improvement of at least 120 mBar (3.5 inHg).
- Power output increase due to condenser pressure reduction and now the possibility of increasing condenser load, thus steam flow through the turbine and more power.
- Heat rate improvement due to lower condenser pressure and thus lower backpressure on the steam turbine (more "free" power).

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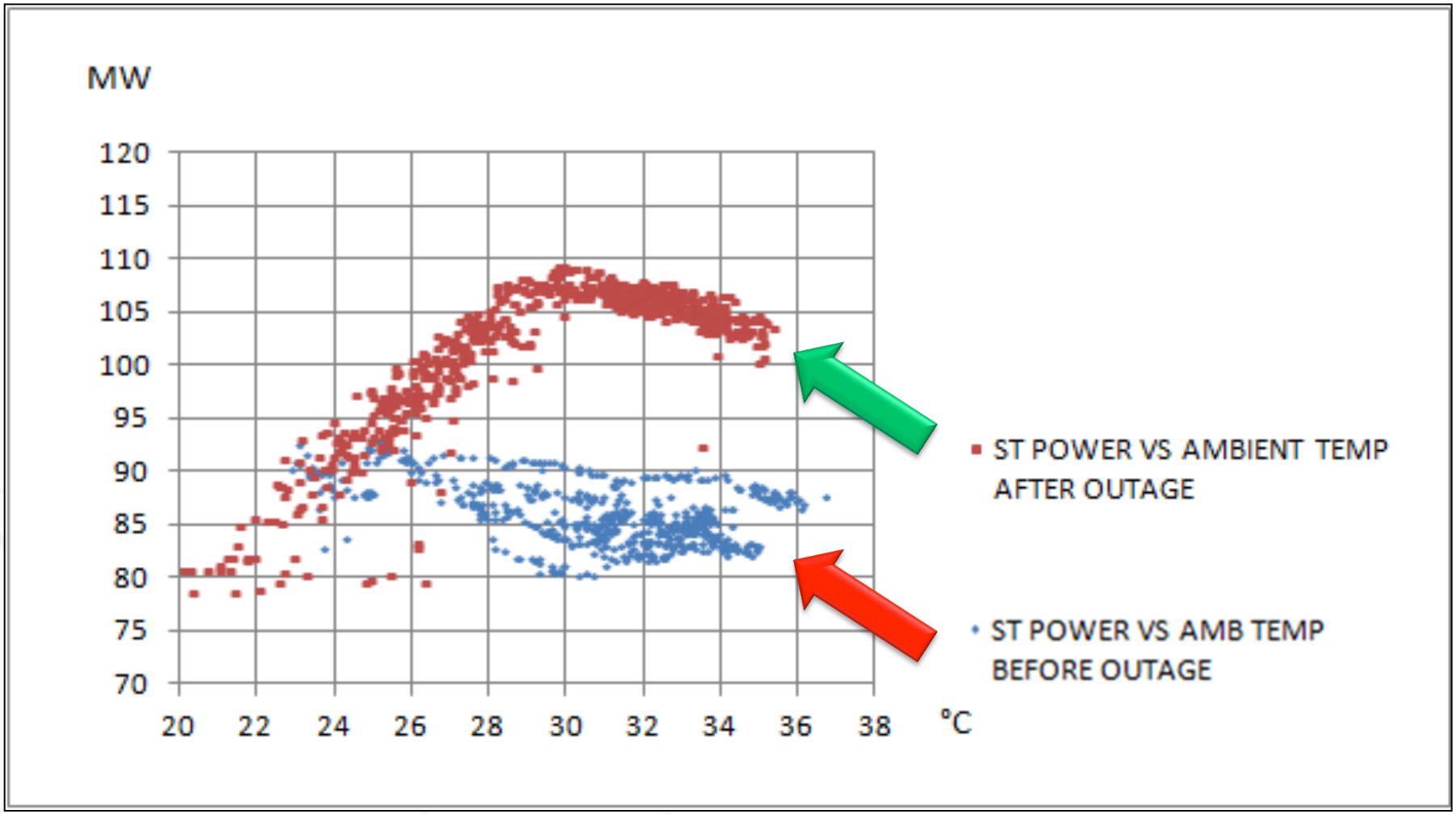
Saltillo: Results – Fans Uprate 2/3

No more power output limitations, no more plant de-rating…



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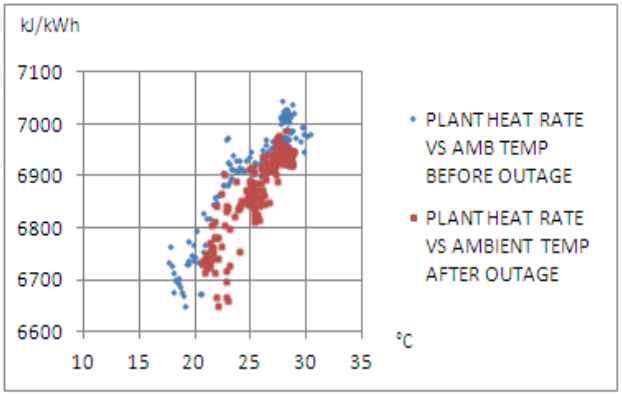
Saltillo: Results – Fans Uprate 3/3

After some operational time…

•Better vacuum results in a clear improvement of Plant heat rate at higher than 20°C (68°F) temperatures. Up to a 1.5% better plant heat rate for ambient temperatures around 26°C (79°F).

•For lower temperature the increment in auxiliary consumption is more than the steam turbine power output gain, and there is no heat rate improvement. If all fans remain on at low temperatures, the heat rate is worse than before. Currently analyzing to maximize power, heat rate and thus asset and investment returns:

- Optimal angle of attack during summer and winter.
- Number, position and sequence of fans to turn off below 20°C.



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THANK YOU