Chemistry – Fleet Program

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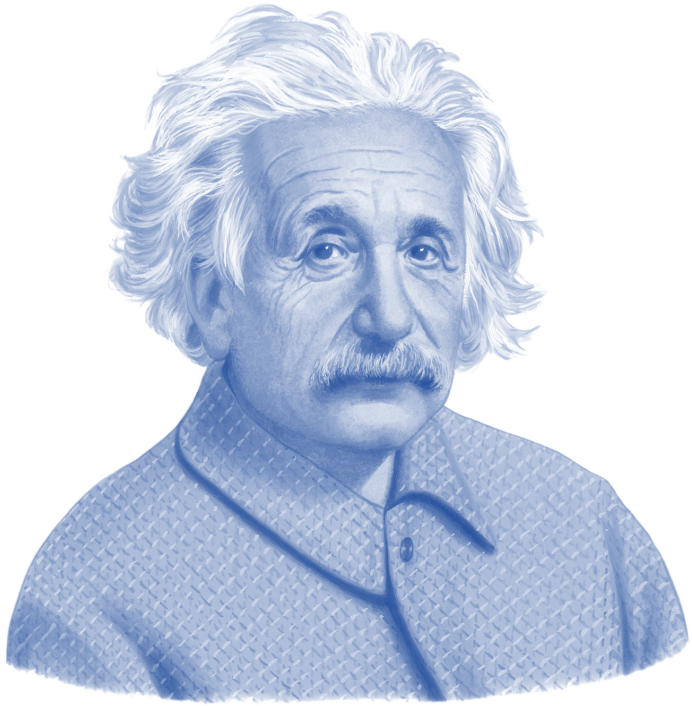
Air Cooled Condenser´s User Group

Querétaro, MEXICO – October 2019

Saavi ENERGIA

Chemistry Fleet Program

Food for Thought



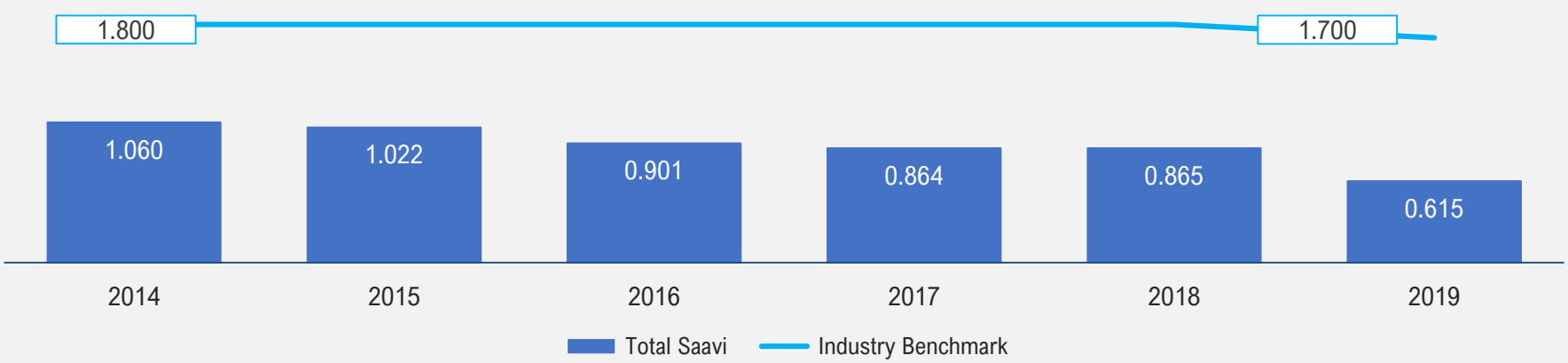
"INSANITY: DOING THE SAME THING OVER AND OVER AGAIN AND EXPECTING DIFFERENT RESULTS"

ALBERT EINSTEIN

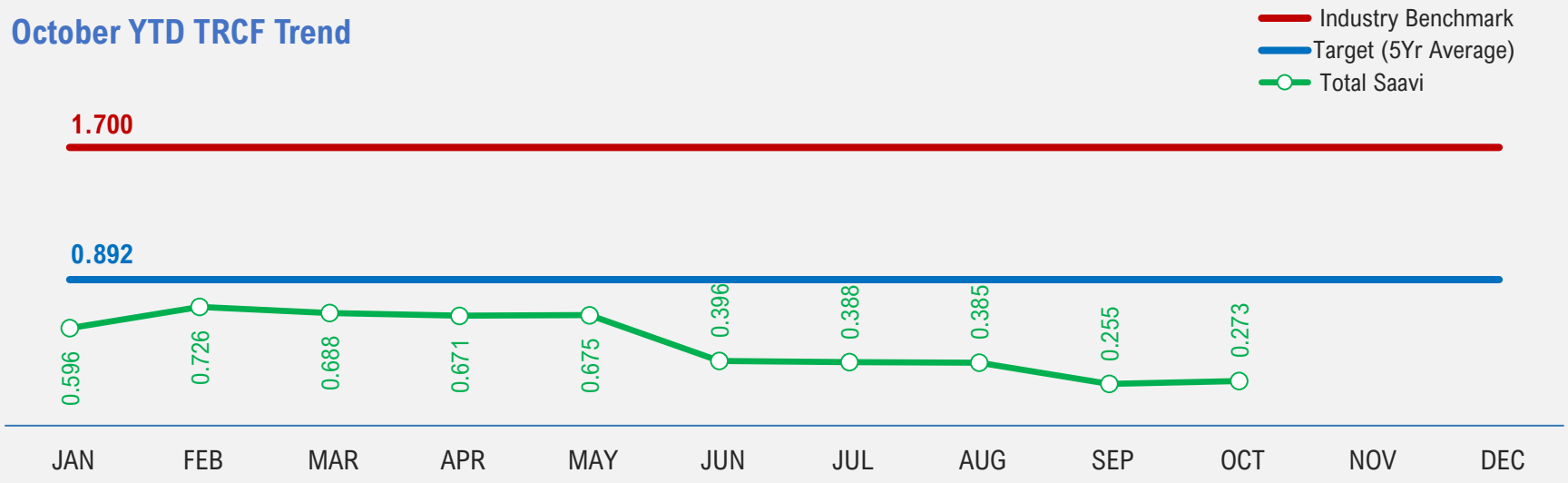
Safety Moment - a HSSE Performance

TRCF – Total Recordable Case Frequencies

TRCF 5 yrs Avg - Recent History



October YTD TRCF Trend



Assets Location

Saavi Energía

June 2019

Combined Cycles with an ACC

Saavi Energía

El Bajío Power Plant

Summer | Winter Capacity, *MWh*	631 | 648
Type | Configuration	CCGT | 1 x 1 x 1 + **ACC (ENEXIO – 5 bays x 7 rows)**
Fuel Type	Natural Gas | Liquid Fuel Oil (diesel)
Primary Technology	GE 7FA.04

San Luis de La Paz Power Plant

Summer | Winter Capacity, *MWh*	218 | 235
Type | Configuration	CCGT | 1 x 1 x 1 + **ACC (SPX – 4 bays x 3 rows)**
Fuel Type	Natural Gas
Primary Technology	GE 7FA.04

Chihuahua Power Plant

Summer | Winter Capacity, *MWh*	272 | 276
Type | Configuration	CCGT | 2 x 2 x 1 + **ACC (HAMON – 5 bays x 4 rows)**
Fuel Type	Natural Gas
Primary Technology	ALSTOM GT 11N2E

Projects Location

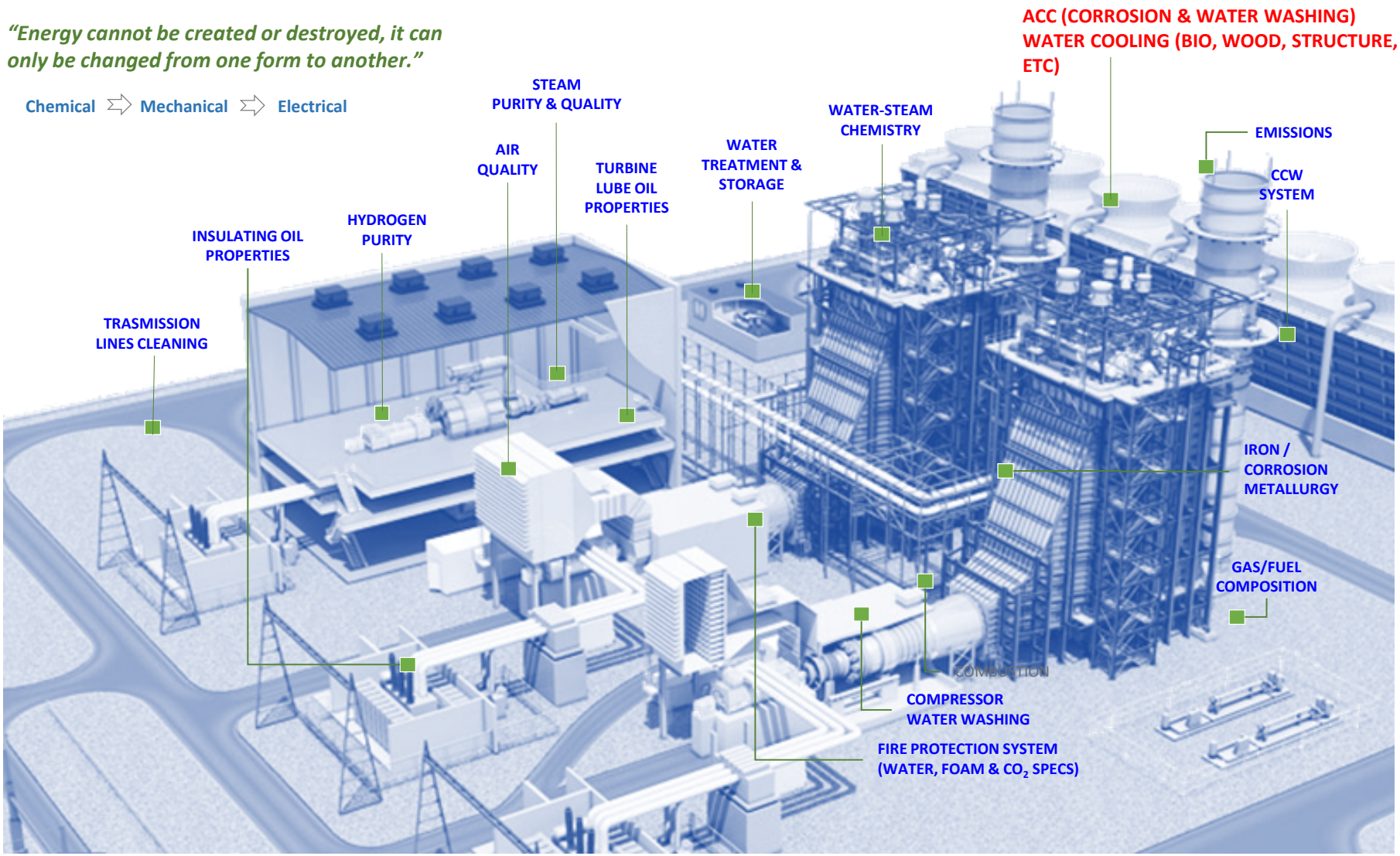
El Bajío (21°14'36" N | -100°36'31" W)
San Luis de La Paz (21°14'36" N | -100°36'31" W)
Samalayuca (31°20'3." N | 106°29'18" W)

How the Chemistry could impact your business?

Chemistry must to be part of your core operation

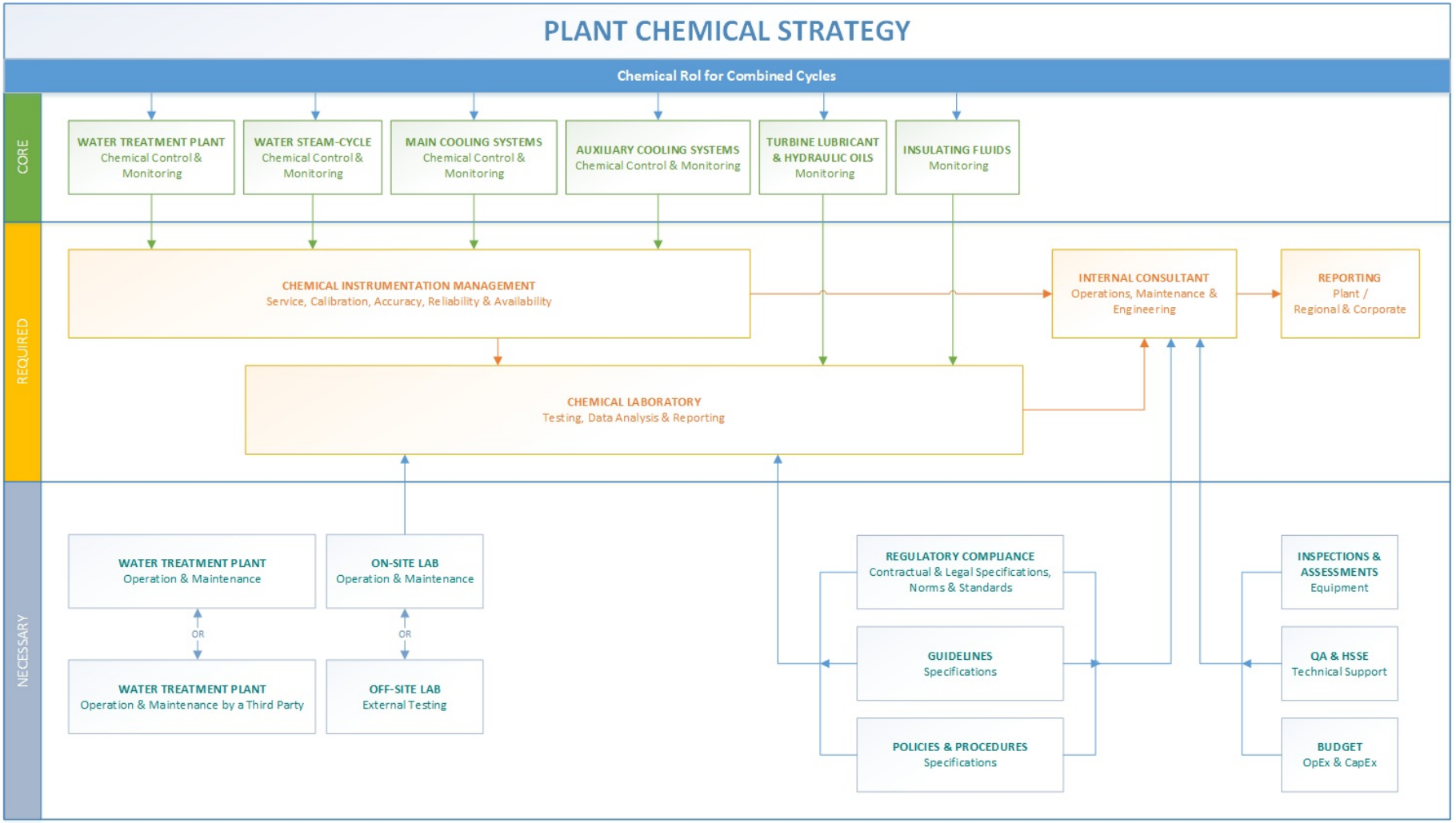
"Energy cannot be created or destroyed, it can only be changed from one form to another."

Chemical ⇨ Mechanical ⇨ Electrical



Chemical Program – Map

Chemistry must to be part of your core operation



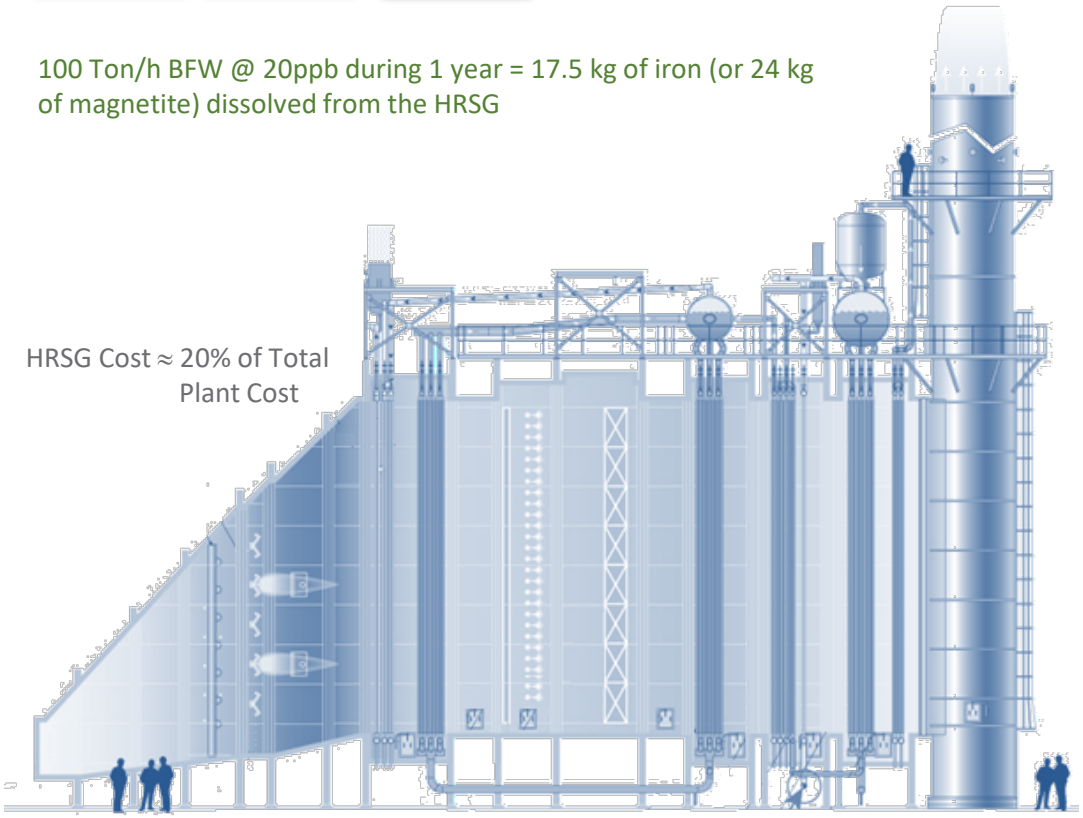
Chemical Program – Treatment (HRSG)

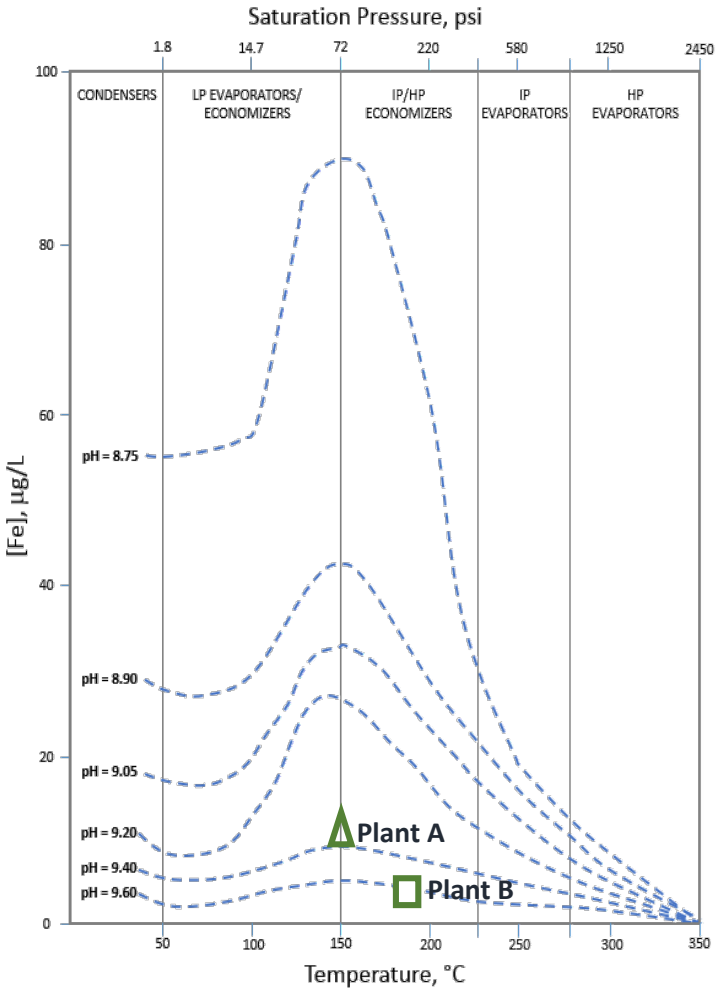
Chemistry must to be part of your core operation

EPRI ELECTRIC POWER RESEARCH INSTITUTE + IAPWS = Saavi ENERGIA CHEMICAL GUIDELINES

PT | AVT-O | AVT-R

100 Ton/h BFW @ 20ppb during 1 year = 17.5 kg of iron (or 24 kg of magnetite) dissolved from the HRSG





pH must be controlled properly within the recommended range

Chemical Program – Who's Who?

Chemistry must to be part of your core operation

Benchmarking

How many HRSG tube failures have there been over the last three years?

- ☐ 0 0
- ☐ 1 – 2 1
- ☐ 3 – 5 2
- ☐ 5 – 10 3
- ☐ More than 10 4

Subtotal (Points x 3) = _____

How many chemistry influenced failures have there been over the last three years (including FAC, corrosion fatigue, hydrogen damage, acid phosphate, caustic gauging, pitting)?

- ☐ 0 0
- ☐ 1 – 2 1
- ☐ 3 – 5 2
- ☐ 5 – 10 3
- ☐ More than 10 4

Subtotal (Points x 3) = _____

What % of the fundamental level of cycle chemistry instrumentation does the plant have?

- ☐ 100% 0
- ☐ 90 – 99% 1
- ☐ 70 – 89% 2
- ☐ Less than 70% 4

Subtotal (Points x 3) = _____

Is a reducing agent (oxygen scavenger) used in the condensate and feedwater during operation and shut-down?

- ☐ Yes 1
- ☐ No 2

Subtotal (Points x 2) = _____

What is the level of iron in feed water during steady-state operation?

- ☐ Less than 5 ppb 0
- ☐ 5 – 10 ppb 1
- ☐ 11 – 20 ppb 2
- ☐ More than 20 ppb 3
- ☐ Don't know 4

Subtotal (Points x 2) = _____

What is the level of iron in the low-pressure during steady-state operation?

- ☐ Less than 5 ppb 0
- ☐ 5 – 10 ppb 1
- ☐ 11 – 20 ppb 2
- ☐ More than 20 ppb 3
- ☐ Don't know 4

Subtotal (Points x 2) = _____

Does the plant have written action plans to address damaged tubing or potential damage to tubing?

- ☐ Yes 0
- ☐ No 1

Subtotal (Points x 1) = _____

Has temperature been monitored by specially installed thermocouples on low-pressure economizer, super-heater and reheater during start-up, shutdown, and operation to identify damaging thermal transients?

- ☐ Yes, all three 0
- ☐ Yes, on two 1
- ☐ Yes, on one 2
- ☐ No 3

Subtotal (Points x 2) = _____

Does the plant have written action plans to address root causes on tube failures or potential tube failures?

- ☐ Yes 0
- ☐ No 1

Subtotal (Points x 1) = _____

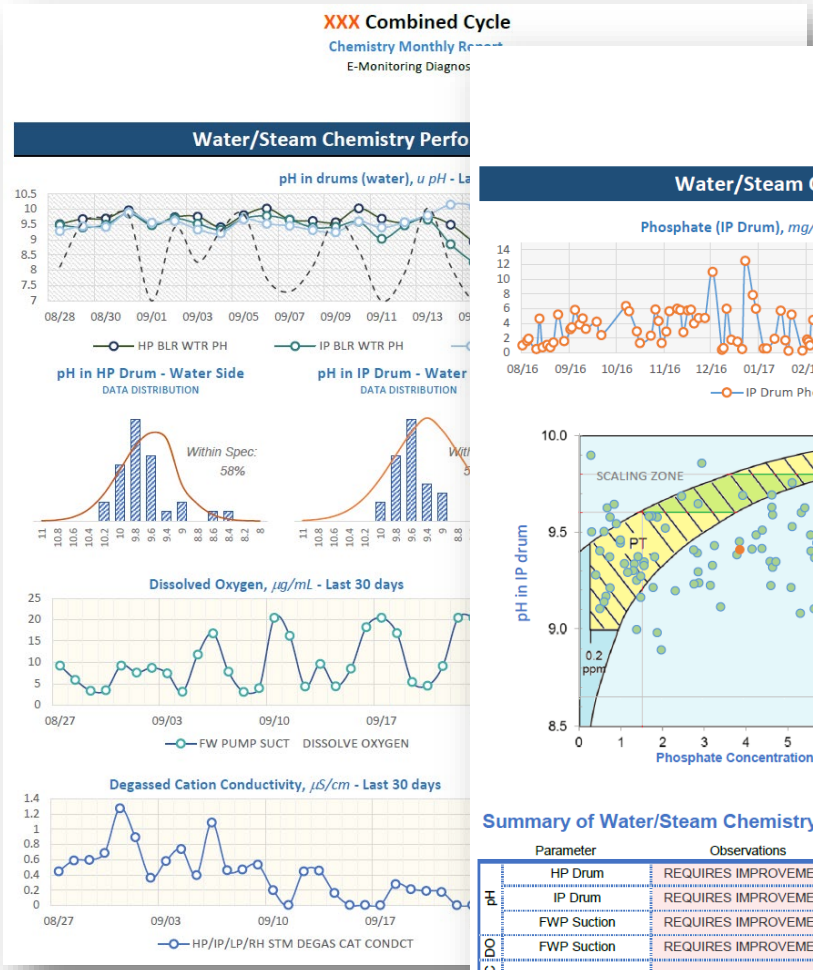
- Less than 5 points | World Class
- 6 – 10 points | Very Good
- 11 – 25 points | Above Average
- 26 – 40 points | Average
- 41 – 45 points | Below Average
- More than 45 points | Poor

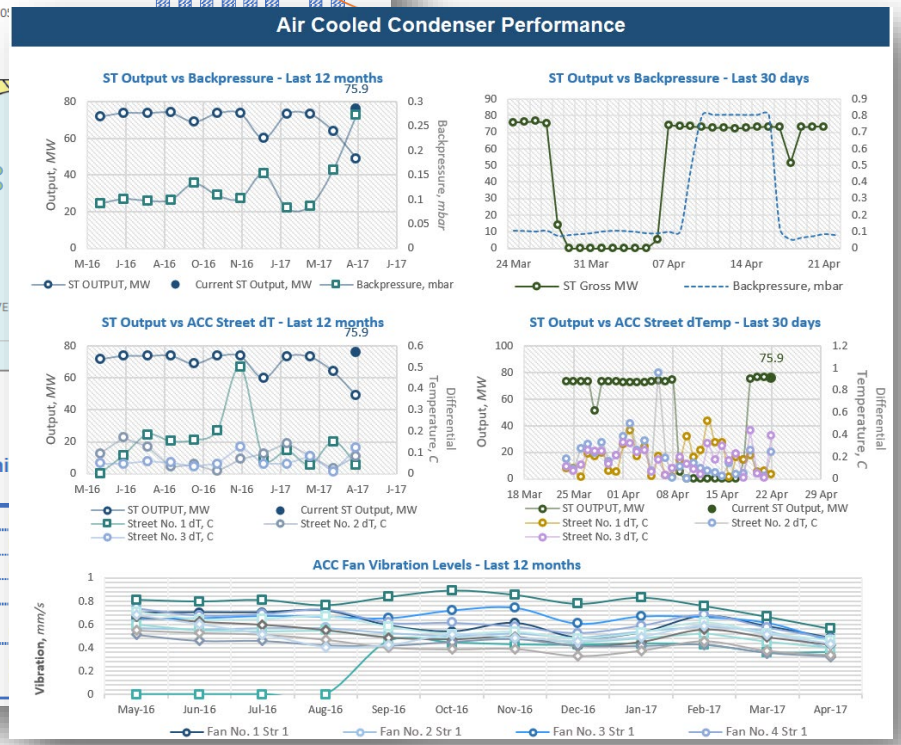
Level: _____

Observations: _____

Chemical Program – E monitoring

Chemistry must to be part of your core operation





Chemical Program – Treatments

Chemistry must to be part of your core operation

6.1 Phosphate Treatment (PT) – Generic Reference

HRSG chemical treatment : Phosphate Treatment (PT)
Metallurgy : All Ferrous
Oxygen scavenger : No
Condensate System : Water Cooling Tower

Do you know what the action levels are?
Is your Plant applying the proper Chemical Treatment?

	Parameter	Normal		Action Level: 1		Action Level: 2		Action Level: 3		Action Level: 4	
		No action required		*Return values to normal levels within 1 week.*		*Return values to normal levels within 24 hours.*		*Shutdown of the unit within 4 hours.*		*Immediate Shutdown is required to avoid unit's damage.*	
		DRUM	STEAM	DRUM	STEAM	DRUM	STEAM	DRUM	STEAM	DRUM	STEAM
LP	pH at 25°C	9.6 – 9.8		< 9.6 or > 9.8		< 8.8		< 8.6		< 8.5	
	Specific Conductivity at 25°C, *µS/cm*	10 – 45		45 – 55		55 – 70 / < 10		> 70			
	Cationic Conductivity at 25°C, *µS/cm*	≤ 45	≤ 0.2	< 90	≤`0.4	< 150	≤ 0.8	> 150	> 0.8		
	Dissolved oxygen, *ppb*	5 – 10									
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 6000	≤ 10	≤ 12000	≤ 20	≤ 24000	≤ 40	> 24000	> 40		
	Chloride (Cl), *ppb*	≤ 1500	≤ 2	≤ 3000	> 2	≤ 5000		> 5000			
	Sodium (Na), *ppb*	1000 – 6000	≤ 2		≤ 4		≤ 8		> 8		
	Phosphate (PO_4), *ppb*	1500 – 6000									
IP	pH at 25°C	9.6 – 9.8		< 9.6 or > 9.8		< 8.8		< 8.6		< 8.5	
	Specific Conductivity at 25°C, *µS/cm*	10 – 40		40 – 55		55 – 70 / <10		>70			
	Cationic Conductivity at 25°C, *µS/cm*	≤ 25	≤ 0.2	< 50	≤ 0.4	< 100	≤ 0.8	> 100	> 0.8		
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 6000	≤ 10	≤ 12000	≤ 20	≤ 24000	≤ 40	> 24000	> 40		
	Chloride (Cl), *ppb*	≤ 1200	≤ 2	≤ 2400	> 2	≤ 4800		> 4800			
	Sodium (Na), *ppb*	1000 – 6000	≤ 2		≤ 4		≤ 8		> 8		
	Phosphate (PO_4), *ppb*	1500 – 6000									
HP	pH at 25°C	9.6 – 9.8		< 9.6 or > 9.8		< 8.8		< 8.6		< 8.5	
	Specific Conductivity at 25°C, *µS/cm*	10 – 35	≤ 0.25	35 – 40	0.25 – 0.5	40 – 70 / < 10	> 0.5	> 70	> 0.5		
	Cationic Conductivity at 25°C, *µS/cm*	≤ 15	≤ 0.2	< 30	≤ 0.4	< 60	≤ 0.8	> 60	> 0.8		
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 570	≤ 10	≤ 1140	≤ 20	≤ 2280	≤ 40	> 2280	> 40		
	Chloride (Cl), *ppb*	≤ 500	≤ 2	≤ 1000	> 2	≤ 2000		> 2000			
	Sulphates (SO4), *ppb*										
	Sodium (Na), *ppb*	400 – 3500	≤ 2		≤ 4		≤ 8		> 8		
	Total Organic Carbon (TOC), *ppb*		≤ 100		≤ 200		≤ 400		≤ 400		
	Phosphate (PO_4), *ppb*	≤ 3600									

For each core parameter, EPRI has defined action levels:

- Normal – values are consistent with long term system reliability. A safety margin has been provided to avoid concentration of contaminants at surfaces and under deposits.
- Action Level 1 – there is a potential for the accumulation of contaminants and corrosion.
- Action Level 2 – the accumulation of impurities and corrosion will occur.
- Action Level 3 – experience indicates that rapid corrosion could occur, which can be avoided by shutdown of the unit.

Chemical Program – Treatments

Chemistry must to be part of your core operation

6.2 All Volatile Treatment Oxidizing (AVT-O) – Generic Example

Do you know what the action levels are?
Is your Plant applying the proper Chemical Treatment?

HRSG chemical treatment : AVT (O)
Metallurgy : All Ferrous
Oxygen scavenger : No
Condensate System : Air Cooled Condenser

	Parameter	Normal		Action Level: 1		Action Level: 2		Action Level: 3		Action Level: 4	
		No action required		*Return values to normal levels within 1 week.*		*Return values to normal levels within 24 hours.*		*Shutdown of the unit within 4 hours.*		*Immediate Shutdown is required to avoid unit's damage.*	
		DRUM	STEAM	DRUM	STEAM	DRUM	STEAM	DRUM	STEAM	DRUM	STEAM
LP	pH at 25°C	9.8 – 10.0		< 9.8 or > 10.3		< 9.2		< 9.0		< 8.8	
	Specific Conductivity at 25°C, *µS/cm*	9 – 25		25 – 40		40 – 60		> 60			
	Cationic Conductivity at 25°C, *µS/cm*	≤ 24	≤ 0.15	≤ 48	≤ 0.3	≤ 96	≤ 0.6	> 96	> 0.8		
	Dissolved oxygen, *ppb*	5 – 10									
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 6000	≤ 10	≤ 12000	≤ 20	≤ 24000	≤ 40	> 24000	> 40		
	Chloride (Cl), *ppb*	≤ 800	≤ 2	≤ 1600	> 2	≤ 3200		> 3200			
	Sodium (Na), *ppb*	1000 – 6000	≤ 2		≤ 4		≤ 8		> 8		
IP	pH at 25°C	9.8 – 10.0		< 9.8 or > 10.3		< 9.2		< 9.0		< 8.8	
	Specific Conductivity at 25°C, *µS/cm*	9 – 25		25 – 40		40 – 60		> 60			
	Cationic Conductivity at 25°C, *µS/cm*	≤ 24	≤ 0.15	≤ 48	≤ 0.3	≤ 96	≤ 0.6	> 96	> 0.8		
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 6000	≤ 10	≤ 12000	≤ 20	≤ 24000	≤ 40	> 24000	> 40		
	Chloride (Cl), *ppb*	≤ 800	≤ 2	≤ 1600	> 2	≤ 3200		> 3200			
	Sodium (Na), *ppb*	1000 – 6000	≤ 2		≤ 4		≤ 8		> 8		
HP	pH at 25°C	9.8 – 10.0		< 9.8 or > 10.3		< 9.2		< 9.0		< 8.8	
	Specific Conductivity at 25°C, *µS/cm*	4 – 20	≤ 0.25		0.25 – 0.5	> 20	> 0.5	> 30	> 0.5		
	Cationic Conductivity at 25°C, *µS/cm*	≤ 4	≤ 0.15	≤ 9	≤ 0.3	≤ 18	≤ 0.6	> 18	> 0.8		
	Total iron (Fe), *ppb*	≤ 10		≤ 10		≤ 15		> 15			
	Silica (SiO_2), *ppb*	≤ 570	≤ 10	≤ 1140	≤ 20	≤ 2280	≤ 40	> 2280	> 40		
	Chloride (Cl), *ppb*	≤ 150	≤ 2	≤ 300	> 2	≤ 600		> 600			
	Sulphates (SO4), *ppb*										
	Sodium (Na), *ppb*	400 – 3500	≤ 2		≤ 4		≤ 8		> 8		

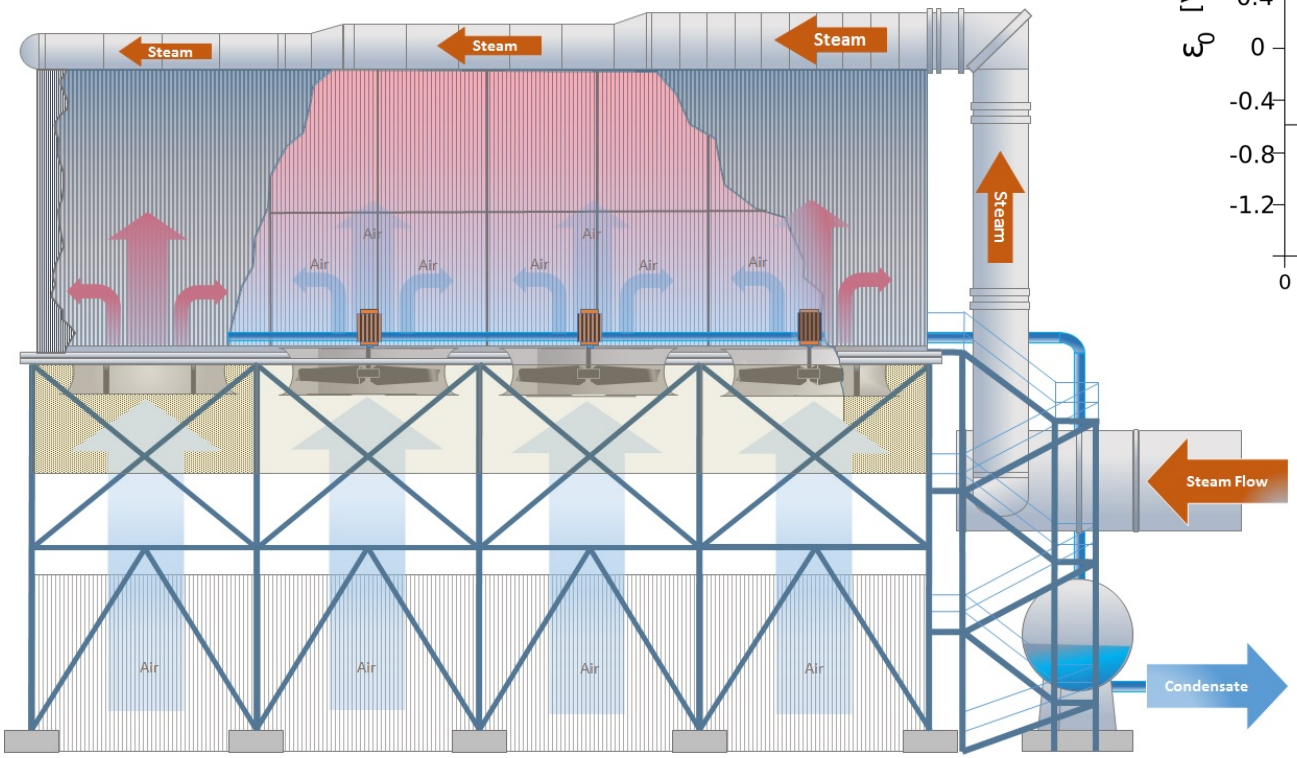
For each core parameter, EPRI has defined action levels:

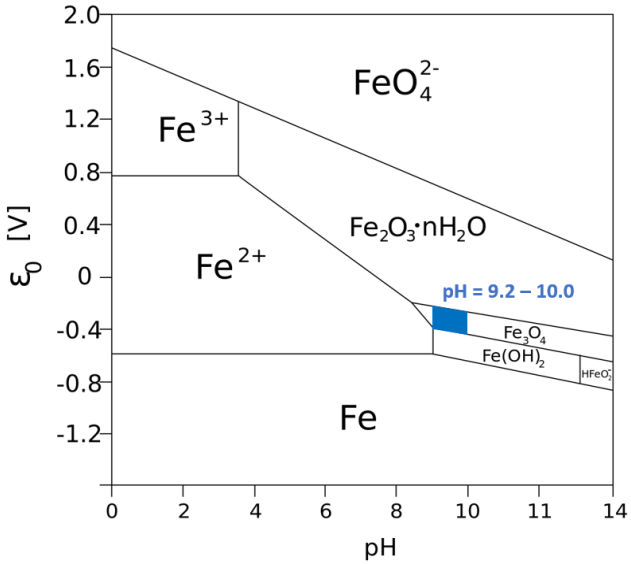
- Normal – values are consistent with long term system reliability. A safety margin has been provided to avoid concentration of contaminants at surfaces and under deposits.
- Action Level 1 – there is a potential for the accumulation of contaminants and corrosion.
- Action Level 2 – the accumulation of impurities and corrosion will occur.
- Action Level 3 – experience indicates that rapid corrosion could occur, which can be avoided by shutdown of the unit.
- Immediate Shutdown – there is clear evidence of rapid HRSG and / or turbine damage when severe contamination enters the unit.

Chemical Program – Treatment (ACC)

Chemistry must to be part of your core operation

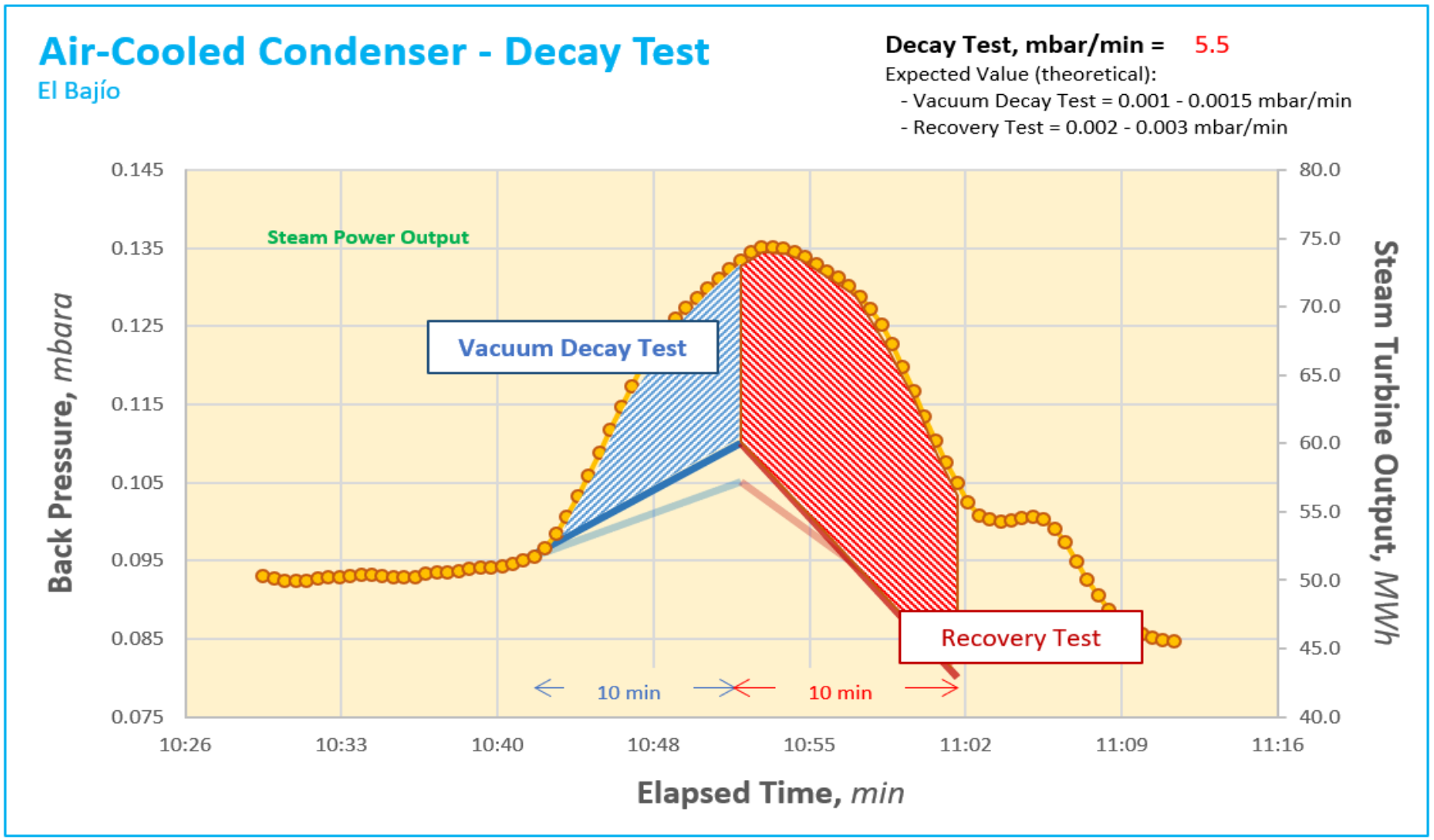
DAHI Index + Decay Test + PMs





ACC Performance – Decay Test

Chemistry must to be part of your core operation



ACC Performance – Decay Test

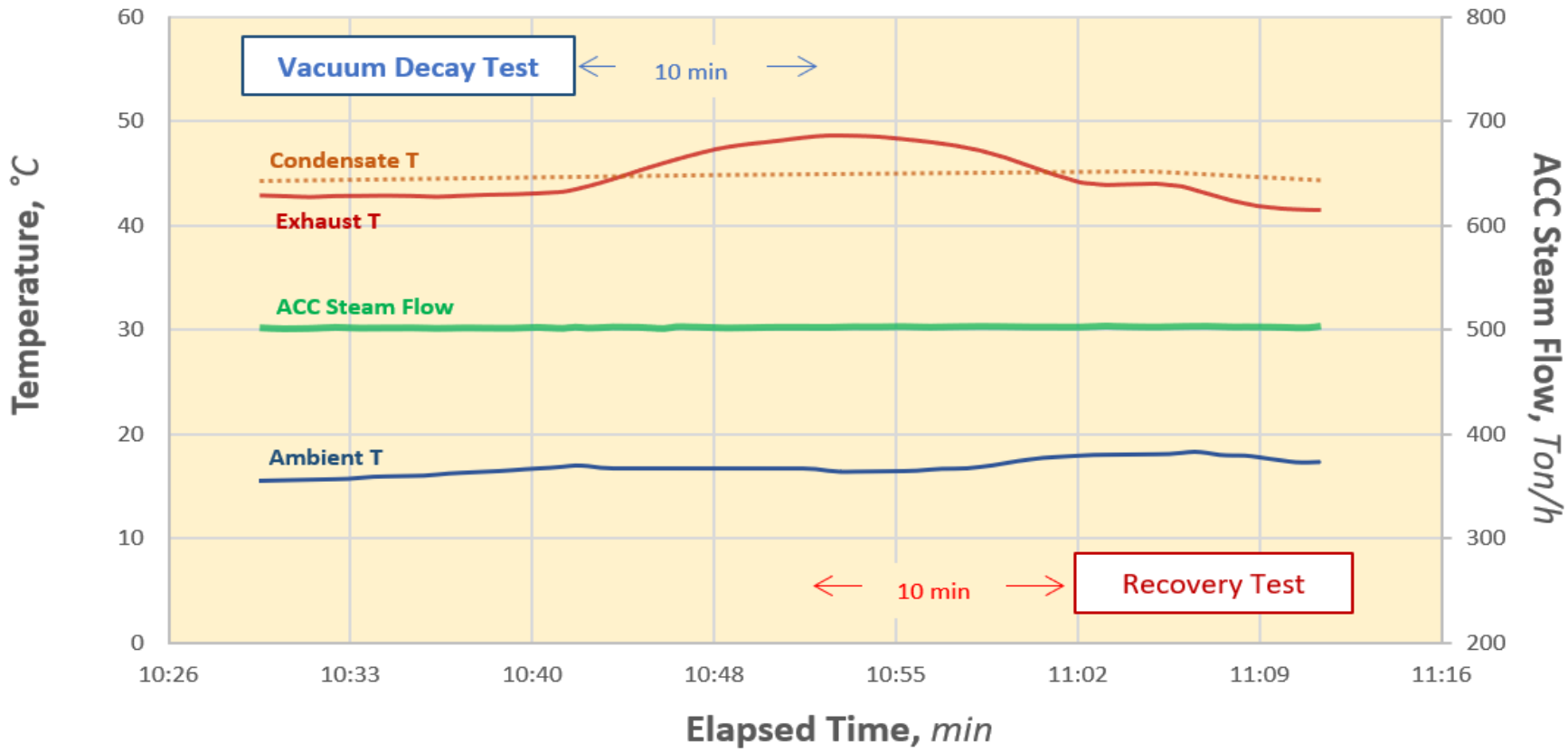
Chemistry must to be part of your core operation

Air-Cooled Condenser - Decay Test

El Bajío

Average Δ Ambient T, °C = 0.018

Average Δ ACC Steam Flow, ton/h = 0.050



ACC Performance – Decay Test

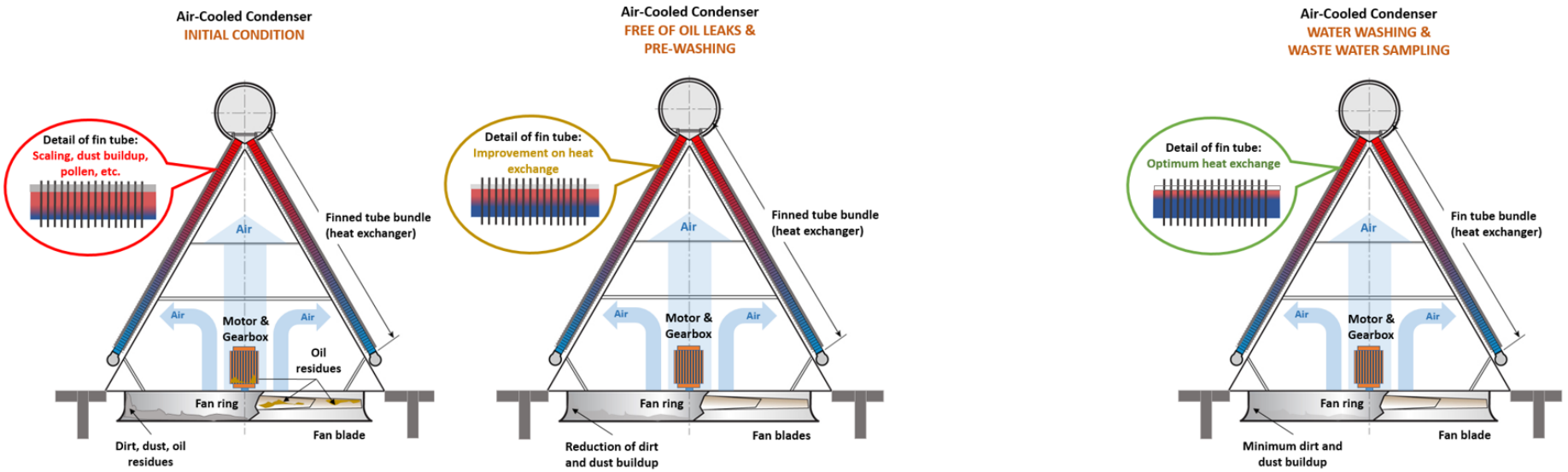
Chemistry must to be part of your core operation

Key indicators of air in-leakage:

- Increase of backpressure
  - Other factors such as fouled condenser tubes can contribute to increased backpressure, however, an air in-leakage inspection should be the first option as it can be performed online and for minimal cost
  - Condensate temperatures decrease because more fans are placed into service in order to maintain the desired back pressure set point resulting from a loss of cooling surface area
- Loss of vacuum in the ACC: cannot pull vacuum as deep
- Loss of heat transfer
- Increase of Plant heat rate
  - More operating fans result in condensate depression
- Increase of non-condensable gases
  - Longer than design evacuation time
  - Check datasheet guarantees for hogging duration
- Increase of direct measurement of air in-leakage
- Increase of chemical parameters, such as:
  - Dissolved oxygen
  - Cationic conductivity
  - Carbon dioxide
  - Iron
  - Silica
  - Sodium
  - Total Organic Carbon
- Increased chemical dosage
  - Oxygen scavenger
  - Amines
  - Phosphates
- Increase of corrosion
- Decrease of the hotwell temperature
- Failed decay test

ACC Performance – Cleaning

Chemistry must to be part of your core operation



T – 1

Current Condition

Oil residuals on surfaces
Dust accumulation in fin tubes
Waste water sample, high in:
- Total solids & Total suspended solids
- Oily residues
- Biological Oxygen Demand (BOD_5), etc.

T 0

Previous Outage: Pre-washing

Motor-gear boxes free of oil leakages
Fan blades free of oil spills and dust
Pre-wash of fin tubes (reduction of dust buildup)
Waste water sample, moderate in:
- Total solids
- Biological Oxygen Demand (BOD_5)

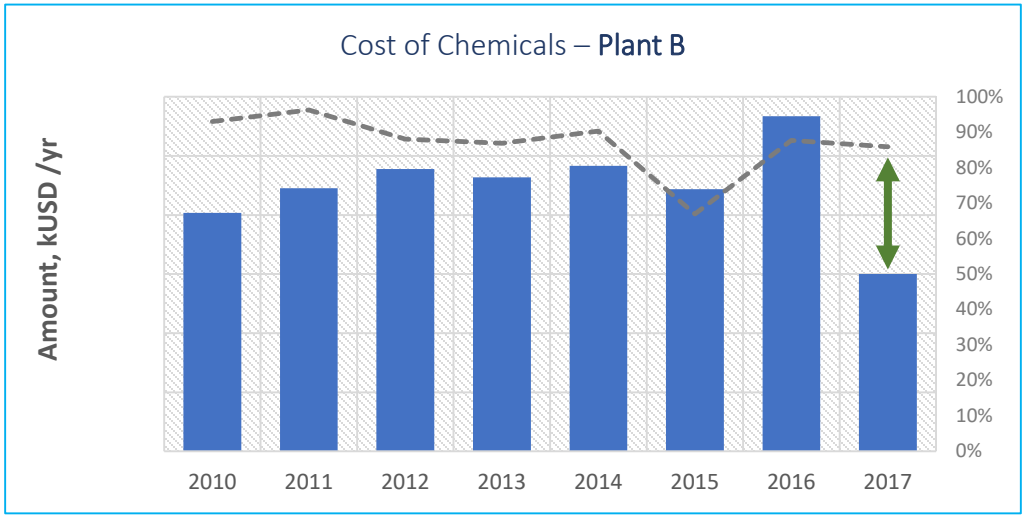
T + 3

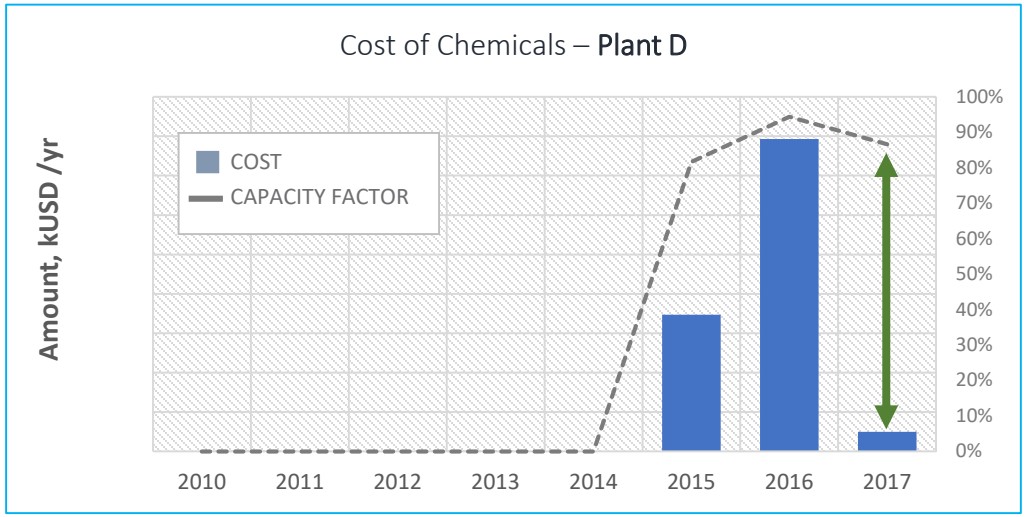
Water Washing

Motor-gear boxes free of oil leakages
Fan blades free of oil spills and dust
Pre-wash of fin tubes (minimal of dust buildup)
Waste water sample:
- In compliance with local regulations
- I.e. MX-NOM-001-SECRE / MX-NOM-002-SECRE

Chemical Program – Cost Optimization

Chemistry must to be part of your core operation





Is your Contractor your real business partner?

Do you challenge or just accept their recommendations?

Chemical Program – Summary

Chemistry must to be part of your core operation

- Safety
- Environment
- Reliability
- Availability
- Heat rate
- Performance
- Budget
- Plant's profitability
- Asset value