CS Energy's Kogan Creek Power Station Chemistry Experience

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CS Energy - Apology

The authors apologise that they were unable to make this presentation in person at this ASME ACC meeting. Thanks to Barry Dooley for making this presentation.

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Presentation Background

In this presentation we will cover our Air Cooled Condenser (ACC) and Flow Accelerated Corrosion (FAC) experience at Kogan Creek Power Station (1 X 750 MW unit) as well as additional details related to two proposed projects for the Kogan Creek 750 MW unit – the Kogan Hybrid Cooling Project and the Kogan Solar Boost Project.

Part of this paper is based on a recent CS Energy paper at the Fossil FAC International Conference at Washington – June 29 to July 12.

Presentation Content

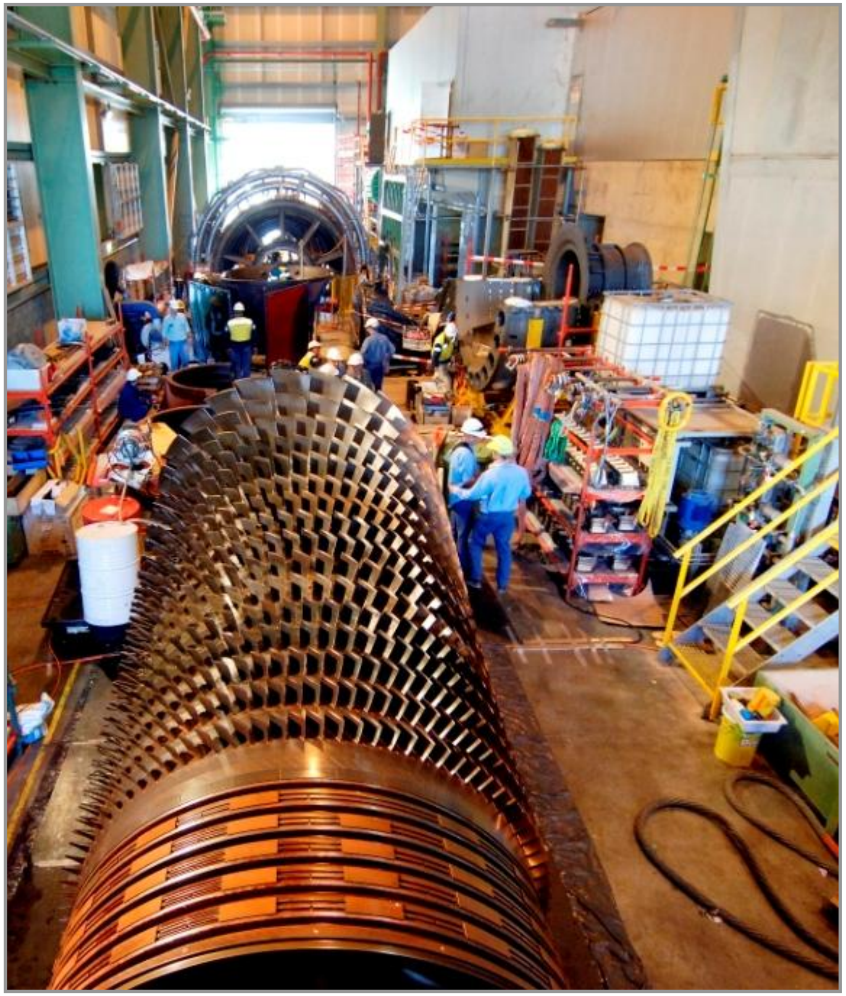
- CS Energy Introduction
- CS Energy – Kogan Creek ACC / FAC experience
- Kogan Chemical Cleaning Experience
- Proposed Kogan Hybrid Cooling Project (KHCP)
- Proposed Kogan Solar Boost Project (KSBP)
- Asset Management / FAC Component

CS Energy Overview

CS Energy operates Queensland's largest power station portfolio, capable of generating more than 3600 megawatts of electricity and supplying around 30 percent of Queensland's electricity demand. 25% of CS Energy's generation portfolio is gas fired.

CS Energy

- **Employs** more than 650 people across Queensland / Australia.
- **Operates** four power stations in Queensland.
- **Uses** coal, natural gas, coal seam methane and landfill gas.
- Plant types cover sub-critical and super-critical coal, gas fired CCGTs and boilers with one dry cooled super-critical unit.
- **Is** Queensland's largest gas consumer.
- **Participates** in the national electricity market as well as being the major electricity generator for the remote (non NEM) regional market in Queensland's North West Minerals province.
- **Formed** in 1997 from the dis-aggregation of the Queensland Electricity Industry who had constructed and operated all generating plant till that time.



CS Energy's Operations

CS Energy Plant

STATION	SIZE MW	TYPE	START DATE	OP HRS May 2010
SWANBANK B	4X120	SUB-CRITICAL COAL	1969 - 1973	
SWANBANK E	1 X 380	GAS – CCGT	2002	46,298
CALLIDE B	2X350	SUB-CRITICAL COAL	1988 - 1989	B1 187,000 B2 177,000
CALLIDE C - 50/50 JV	2X 405 @ MCR OVERLOAD	SUPERCRITICAL COAL	AUG 2001 NOV 2001	C3 68,651 C4 65,713
MICA CREEK A MICA CREEK B MICA CREEK C	4X33 2X35 GT – 1 X 36 ST 35 55 MW	GAS FIRED BOILERS CCGT – REPOWERED TURBINE CCGT OCGT CCGT	1960 – 1970 A5 – 1985 A6 – 1997 A7 – 1997 1999	
KOGAN CREEK	1 X750	SUPERCRITICAL COAL - ACC	DEC 2007	21,443

Presentation Context

The aim of this presentation is to provide an integrated view of FAC management covering:

- FAC experience at ACC cooled Kogan Creek Power Station (KCPS)
- The implications / consequences of FAC at KCPS
- The FAC preventative and corrective actions
- FAC management as part of an comprehensive Asset Management process
- Proposed Kogan Hybrid Cooling Project
- Proposed Kogan Solar Boost Project

Kogan Creek – Chinchilla

Kogan Creek Power Station is the newest addition to CS Energy's diverse portfolio (2007).

750 MW, single shaft – super-critical - Benson Boiler – coal.

Direct Dry cooled

Oxygen treatment – S Steel LP Heaters – C Steel HP heaters

Main steam – 27.1 MPa – 546 ^oC

Reheat – 566 ^oC

Econ Inlet Temp 271 ^oC

2x 50% Consep Polishers - cartridge pre-filters

Pre-service HF chemical clean
ACC Hot clean (similar to steam blows)
Rifled spiral tubes

Original Design Chemistry

- Oxygenated Treatment (OT)
- Feedwater pH 8.0-8.5
- Hydrogen Cycle Condensate Polishing
- Condensate Polisher Trip >62.5C
- 5um nominal condensate filters (spiral wound)

The feedwater pH for normal OT treatment for control of single phase FAC in the feedwater system was not compatible with the required pH to prevent 2 phase FAC in the ACC

ACC Chemistry Challenges

1. Flow Accelerated Corrosion (FAC)
2. Corrosion Product Transport
3. High Condensate Temperatures
4. Polisher trips on high condensate temperature
5. Contractual considerations in negotiating a change to the feedwater pH – OEM opinions varied

ACC - 2 Phase FAC

- Materials, turbulence (geometry, velocity), temperature and chemistry.
- Chemistry the only variable factor available after construction.
- Resultant high iron in condensate.

FAC – Issues

- Metal loss within the ACC condensate system
- Particulate loading on filters and polishers
- High iron in feed water
- Potential Iron Deposition in the boiler / turbine
- Concern regarding furnace tube creep life and potential for circumferential cracking
- Need to reduce FAC in the ACC
- Need to consider a boiler chemical clean as a preventative measure

Effect of pH on corrosion

- The effects of pH levels on corrosion of ACC is well documented
- Increased pH levels result in decreased corrosion rates
- Significant time delay between pH changes and stabilisation of corrosion rates.

Implemented Solutions

- Increased pH to reduce corrosion within the condensate system.
- Operate condensate polishers in ammonia cycle to allow for increased condensate pH.
- Increase polisher thermal trip set point (from 62.5 C to 70 C).
- Improved condensate filter performance by replacing the filter cartridges

FAC Corrective Actions

Initial pH 9.0 7/12/07 – 9.5 pH from 23/6/08 - 9.8 pH from 20/4/09

OT from 80 ppb to 35 ppb and back to 80 ppb Oxygen

Polisher trip at 70C – NH_3 cycle polishing to manage FAC

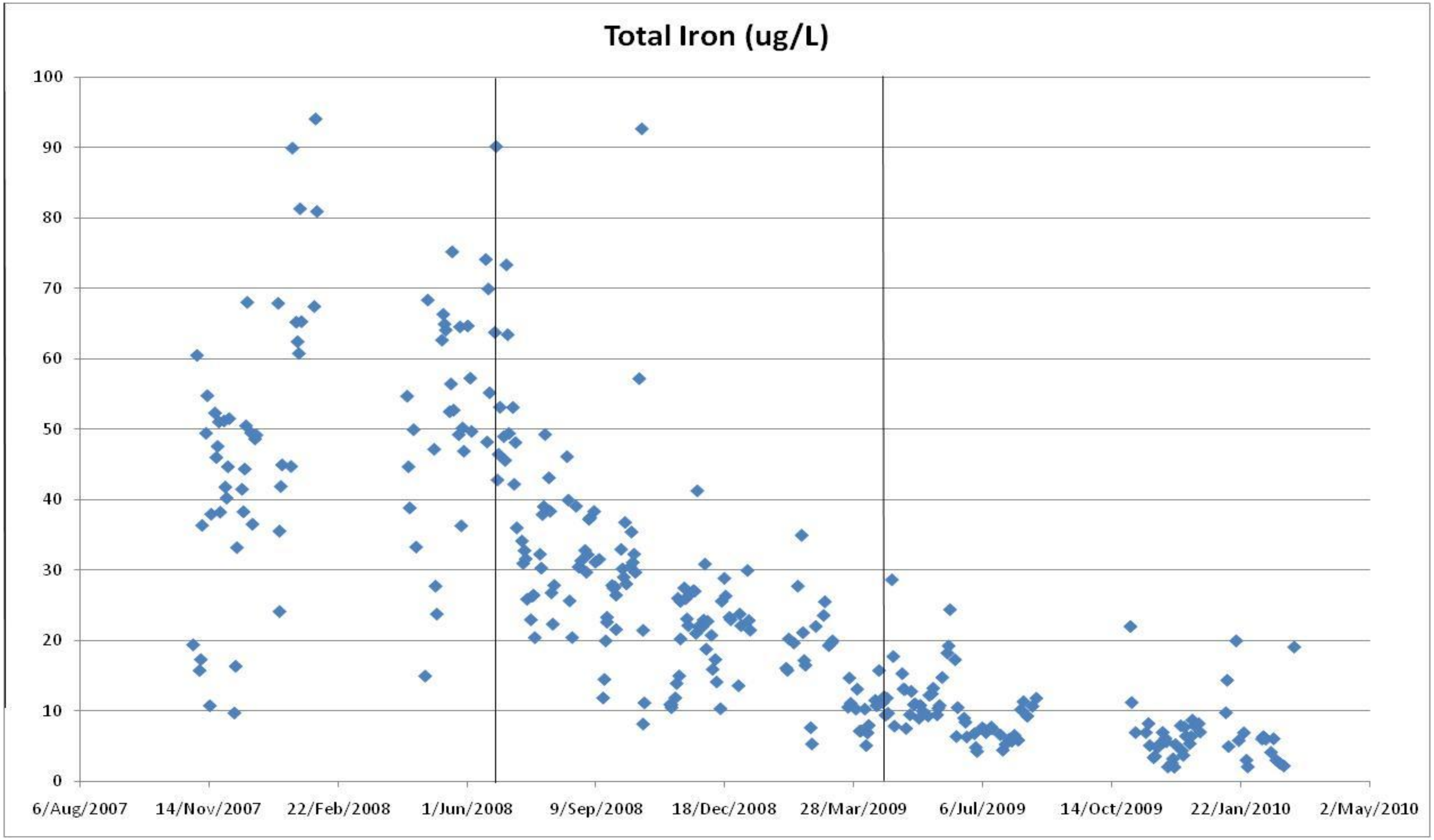
5um absolute condensate filters (pleated) installed Oct 2008

Post Service HF clean due to boiler deposits (result of FAC) Sept 09

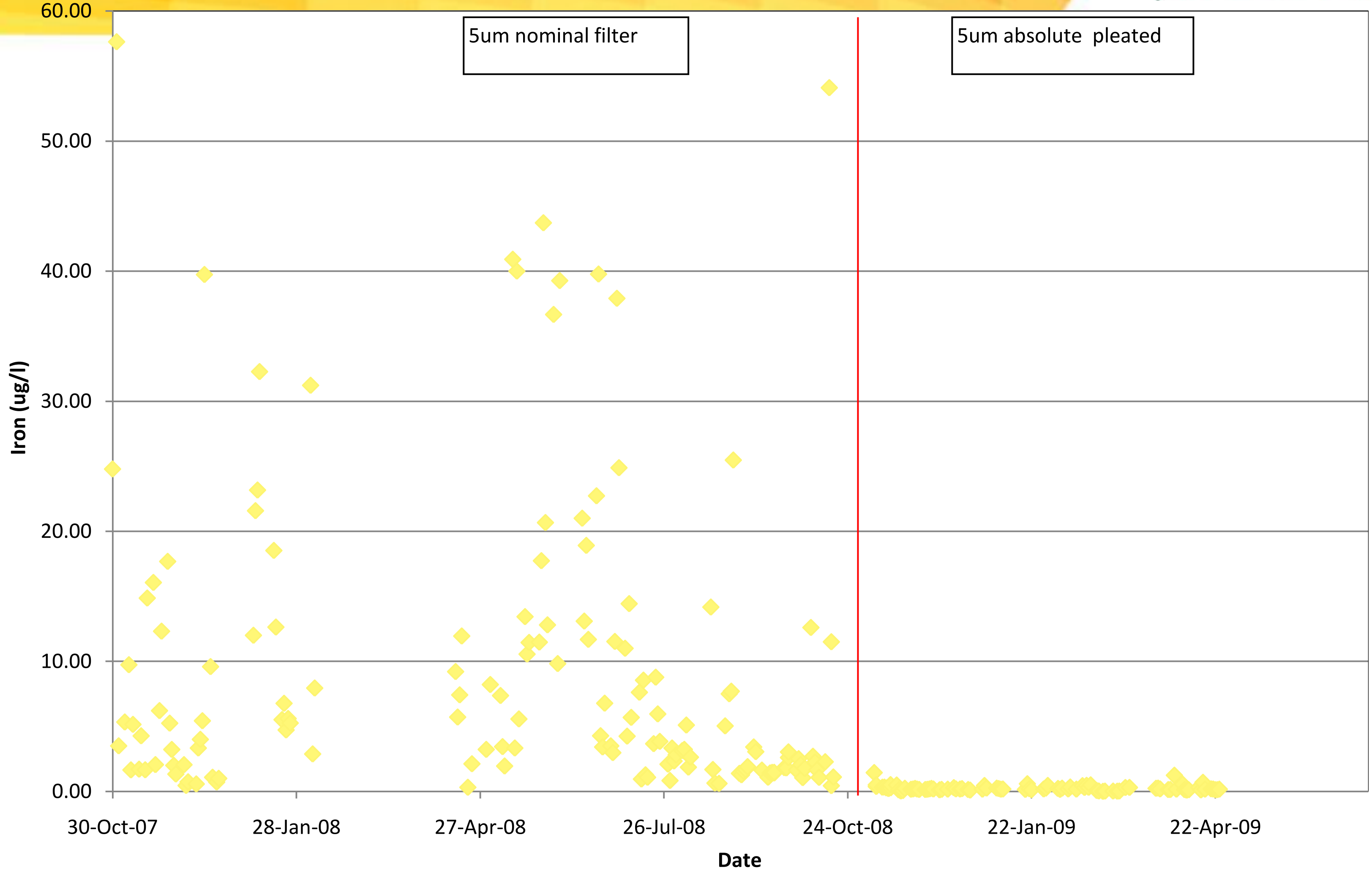
Recently commenced comprehensive Fe study on heater drains

FAC not just about material loss – deposition in boilers (turbines), fouling of polisher resins etc

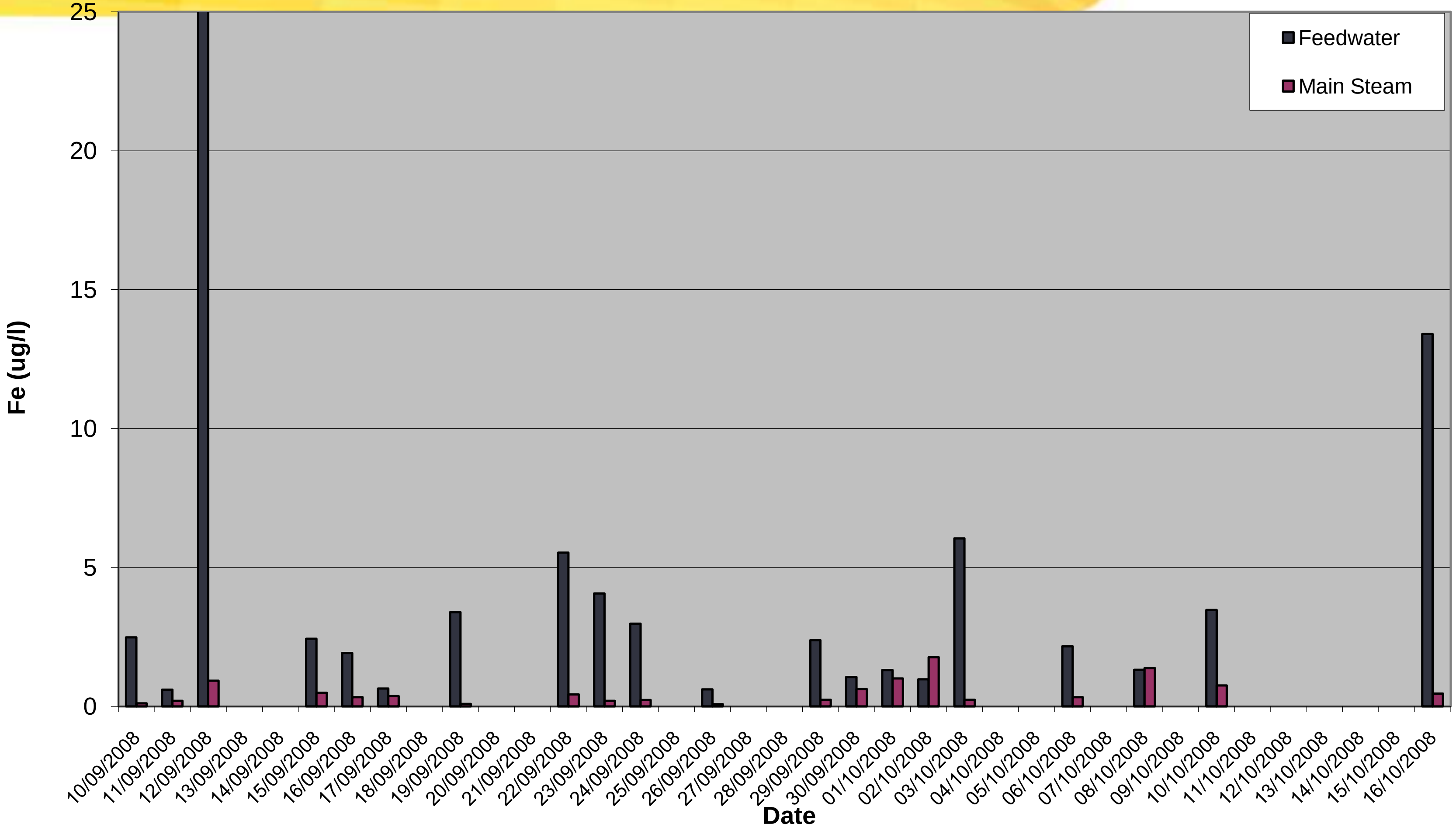
Iron levels before Polisher

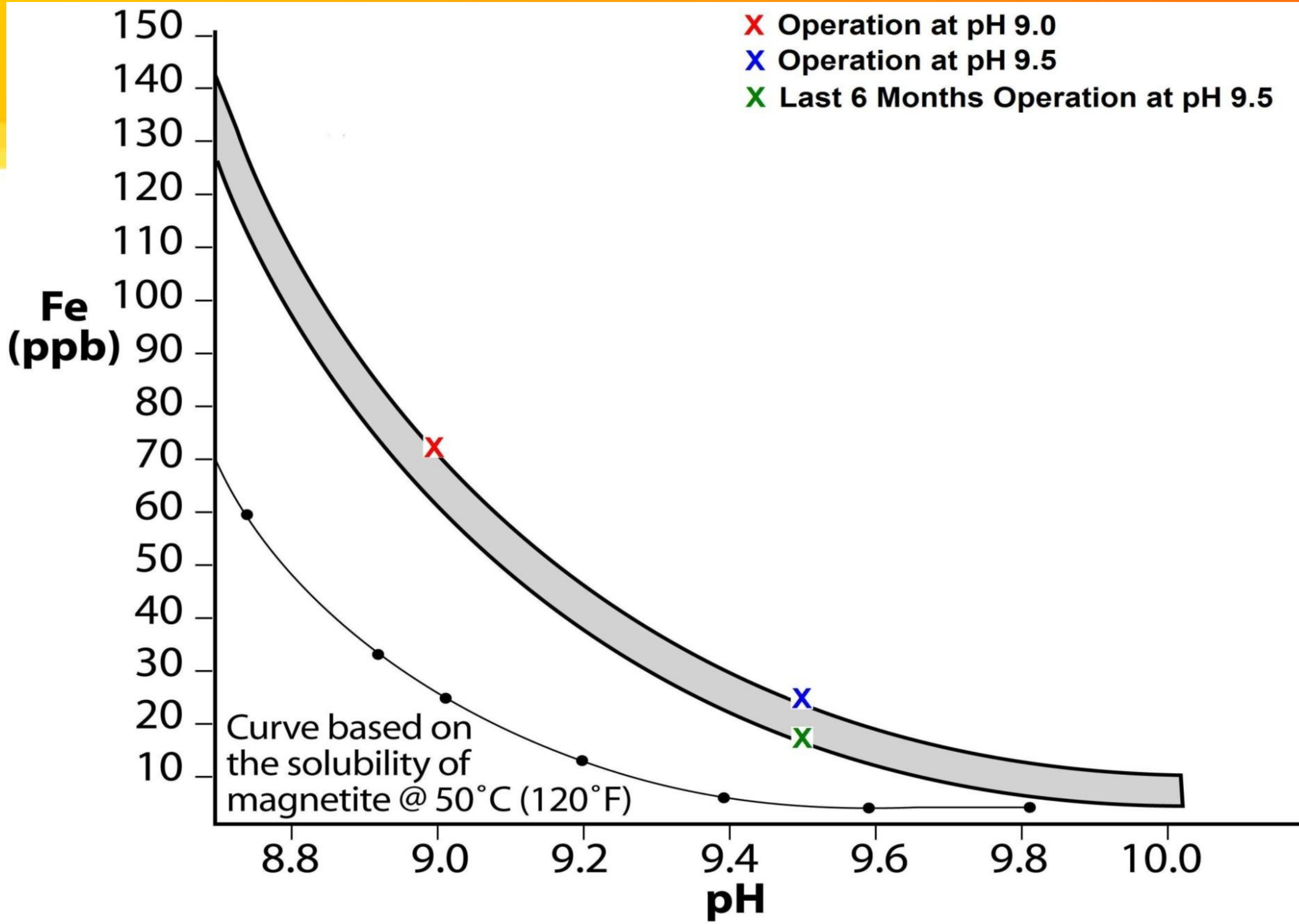


Condensate Iron (ug/l) downstream CPP



Iron in Feedwater and Steam




X Operation at pH 9.0
X Operation at pH 9.5
X Last 6 Months Operation at pH 9.5
Fe (ppb)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Curve based on the solubility of magnetite @ 50˚C (120˚F)
8.8
9.0
9.2
9.4
9.6
9.8
10.0
pH

ACC Corrosion

- Corrosion is found throughout the turbine exhaust, exhaust steam ducting and condenser tube inlets.
- Corrosion also occurs for a significant distance along the length of the condenser tube.
- The addition of oxygenated (make-up) water to the condenser tubes does not appear to make a significant difference to corrosion in the tubes
- ACC Condenser tube photos follow >


EP2


EP2


EP2


EP0

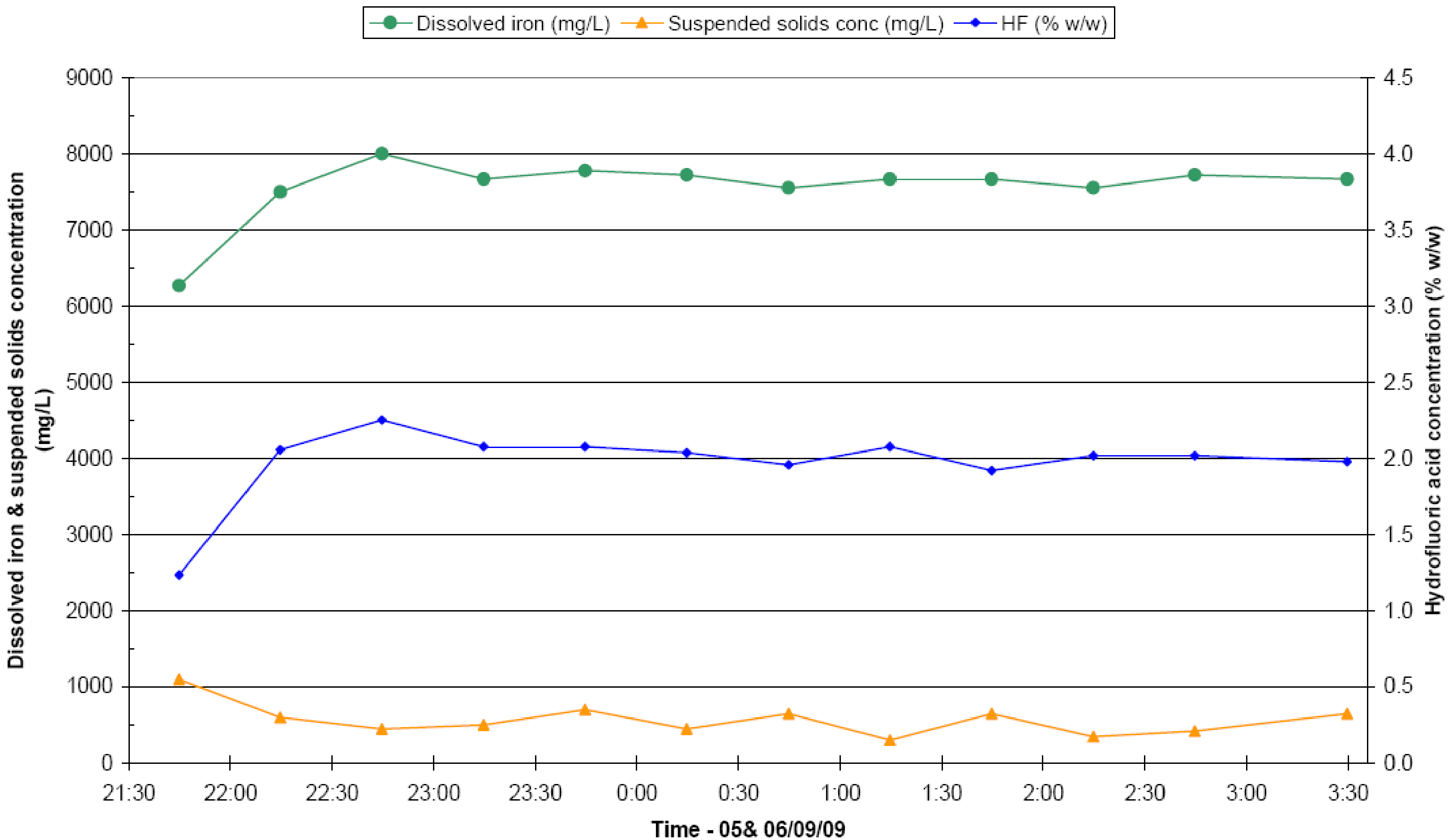
FAC Consequence - Boiler Tube Deposition

- Most significant deposition is not at the high heat flux areas of the boiler
- Indication that heat flux is not the most significant factor in determining deposit locations in the KCPS boiler (possibilities include fluid velocity and dryness factor – particularly in vertical wall tubes where a single spiral tube splits into 2 vertical tubes.

Deposit Thickness and Location – prior to Sept 2009 HF clean

Tube Location	Inner Layer (µm) (Indigenous oxide)	Outer Layer (µm) (Deposited Material)
Spiral Waterwall FL23800 FS	2.5	7.5
Spiral Waterwall FL23800 NFS	3.7	7.2
Spiral Waterwall FL30300 FS	2.0	11.8
Spiral Waterwall FL30300 NFS	8.2	24.7
FL38700 FS	33.8	86.3
FL38700 NFS	2.8	65.6
FL42000 FS	2.5	22.9
FL42000 NFS	4.2	25.8

Kogan Creek Boiler Chemical Clean - Dissolved Iron, Suspended Solids & Hydrofluoric Acid Trends



Hydrofluoric acid chemical clean trends

FAC - Boilers Deposition Summary

- Mechanism of hematite deposition is not clear and appears to be significantly different to duplex magnetite
- Metallurgical sampling procedure is very important to observe soft loose hematite scale overlaying duplex oxide
- Evidence of increased deposition in low mass flow tubes
- Different chemical cleaning procedures are required compared to AVT(R) boilers
- Further work is required to understand and prevent hematite deposition as well as understanding the influence of Hematite on tube metal temperature and Duplex oxide growth. Also need to refine the chemical cleaning of hematite / duplex oxide in supercritical boilers

Future FAC Challenges – Kogan

- Addition of 44MW solar boost – potential for FAC in Solar Steam Generator – temperature should be high enough to minimise but surface area is very large – similar to ACC issue – spot loss not the problem but the transport of corrosion product could be an issue into steamside HP Heater 6 .
- Potential addition of hybrid wet cooling system 33% to 50% – potential changes in flows and turbulence of exhaust steam (changes in FAC?). Plenty of non FAC challenges (polisher management, condenser leaks etc)

- Need to set up comprehensive FAC Management Program

Kogan Creek - Summary

- Corrosion within an ACC can cause multiple problems (condenser, boiler, possible in turbine)
- Once through boilers with an ACC can be very sensitive
- Corrosion and corrosion product transport can be addressed early through plant design
- Operational plants have options available to reduce and manage corrosion and corrosion product transport
- Detailed iron monitoring required
- Detailed identification required of potential FAC areas
- Detailed NDT programs underway for FAC
- Need to review status of steam side of heaters as well as feedwater side

Proposed Kogan Hybrid Cooling Project (KHCP)

Proposed Features - 1

- The likely availability of RO treated water from regional Coal Seam Methane (CSM) producers has resulted in the potential for hybrid dry/wet cooling at Kogan Creek.
- The concept is to take RO / CSM water and use it for an evaporative cooling tower to assist cooling by the ACC.
- The hybrid cooling system is an augmentation to normal operation of the unit and should be implemented to improve output without compromising normal unit availability and reliability.
- Subsequent use of blowdown water from this cooling tower to offset the site's present bore water use as also proposed.

Proposed Features - 2

- Condensate is pumped from the new condenser to the existing condensate system.
- The wet cooling system must be capable of independently operating or shutting down without impact (other than back pressure achieved) on the operation of KCPS.
- Some water treatment for the water brought to site or the blow down from the new cooling tower may be required. The site water balance may need adjustment to maintain the site zero discharge.

Proposed Features - 3

- Site layout: nominally interconnect is as close as possible to the turbine on the steam exhaust ducts to allow short steam duct length and minimal pressure drop from turbine exhaust. Expect to be limited by duct clearance for condenser height and possibly steam flow interaction with ACC tee-off ducts.
- Location of the new cooling tower will need to ensure no adverse effects on the existing ACC either from warm air being drawn into the ACC or from drift depositing on the ACC finned tubes.

Proposed Features - 4

- Nominal size of cooling tower and condenser is to take 33% cooling load at design conditions and condenser vacuum corresponding to 66% steam flow to the existing Air Cooled Condenser (ACC, 12.3 kPa abs). At higher temperatures the wet system would take a greater proportion than 33% as generally wet bulb increases less than dry bulb temperatures (and the cooling tower range and approach increase).
- Operation would be continuous, so as to provide the minimum possible vacuum (greatest unit efficiency) at all times of operation, but the hybrid cooling system could be shut down at any time and the unit would return to standard efficiency (ACC only) operation.

Proposed Features - 5

• A common term for air cooled and wet cooled systems functioning together is parallel air cooling (PAC) - normally developed as an addition of air cooling to an existing evaporative or once through wet cooled system for the purpose of reducing water use.

•The KCHC project is not such a case. The KCHC system aims to utilise water produced as a consequence of extracting coal seam gas/methane.

•The most significant point of differentiation is that the wet cooled condenser is not located directly under the turbine, so a new steam duct integration of the new condenser is required – including condensate collection and integration with the existing condensate system.

Cooling Tower Data Summary

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Table 1 Cooling Tower Data Summary

	Unit	33% Cooling	50% Cooling
Back Pressure	kPa	12	10
Steam Temperature	°C	49.5	46
Cooling Range	°C	14	13
CW Flow	m^3/sec	5.15	8.3
Heat Load	MW	300	450
Cold Water	°C	26.5	26
CT Approach	°C	9	8.5
Number of Cool Tower Cells	–	5	10
Fan Power CT	kW	700	1050
CW Pump Power	kW	1100	1750
Total Auxiliary Power	kW	1800	2800

The Nominal Design is for 33% cooling

Possible Water Quality

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Table 2 Supplied Water Quality Data

Analyte	Unit	RO Permeate [1]	Lagoon Gully Pond [2]	Kogan Bore Water [2]
pH	pH	6.75	8.6	8.45
Conductivity	µS/cm	185[3]	5000	3150
TDS	mg/l	130	3126.3	1906
TSS	mg/l	0.1	16	4
TDS/Conductivity			0.63	0.61
Calcium as $CaCO_3$	mg/l	0.1	20.5	3.58
Magnesium as $CaCO_3$	mg/l	0.02	16	2.69
Sodium as Na	mg/l	54	1130	788.64
Potassium	mg/L	0.3	25.5	6.44
Iron as Fe	mg/l	0	0.025	0.001
Copper as Cu	mg/l	0	0.001	0
Zinc as Zn	mg/l	0	0.02	0
Chloride as Cl	mg/l	21	974	246
Sulfate as SO_4	mg/l	0.1	0.9	1.19
Total Phosphate as PO_4	mg/l		0.35	0.03
Silica as SiO_2	mg/l	0.3	27.2	20.93
Fluoride	mg/l	0.1	1.6	2
Alkalinity as $CaCO_3$	mg/l		1240	1521
M alkalinity	mg/l	66	1123.4	1428
Anions		1.83	53.36	36.17
Cations		1.59	50.52	34.57
% Balance		-0.07	-0.03	-0.05
Calc EC		182	5821	3669
Calc TDS		132	3634	2667

Source of data:
1. Water quality provided from CSG producer.
2. Water quality provided from CS Energy
3. Conductivity of RO permeate was not provided (estimate only)

The design water is CSM RO permeate – other site water sources are bore water from the Australian Great Artesian Basin

Site Water Balance

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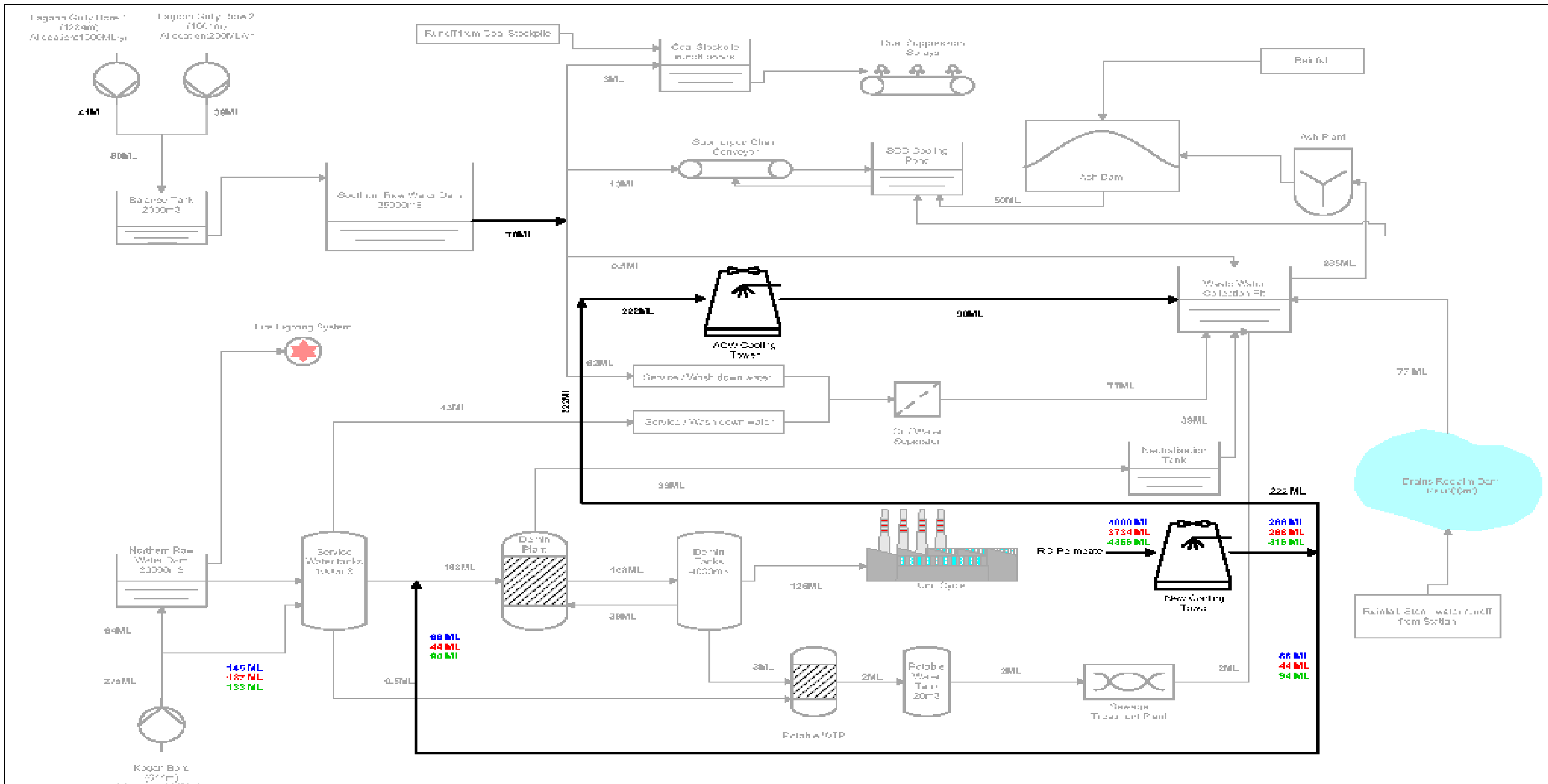

Kogan Creek Power Station – Water Balance Overview Calendar Year 2009

Blue —— Evaporation Factor of 0.9
Red —— Evaporation Factor of 0.84
Green—— Evaporation Factor of 0.98

Figure 3 Site Water Balance

Site Layout

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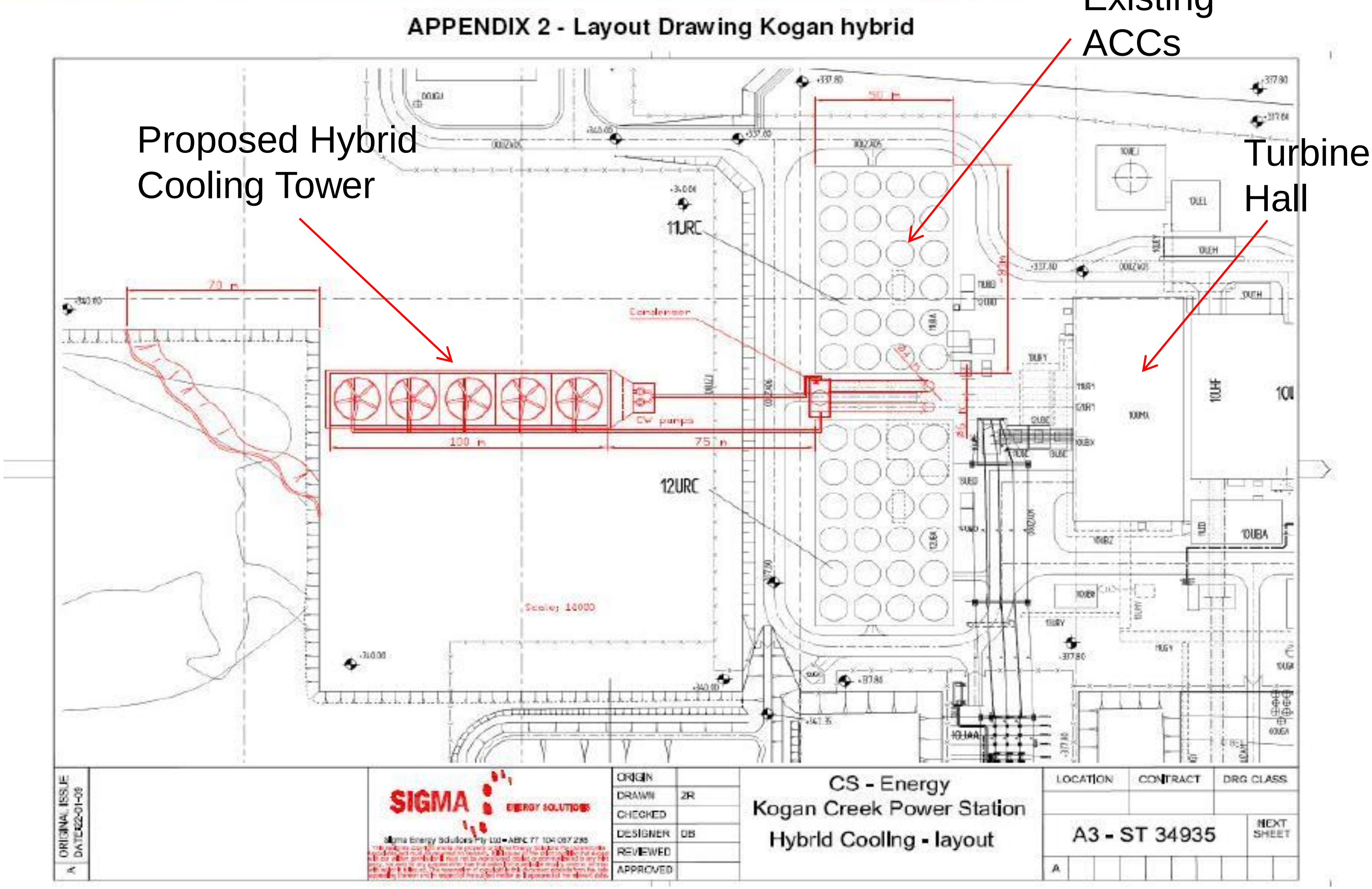


Chemistry Considerations KHCP - 1

- Steam Condenser (SC) design:
  - 2 phase FAC risks
  - Condenser tube materials – isolatability on CW side / steam side – on-line CW leak detection and plugging.
- Condensate polisher capability with a cond. pH of 9.8 to manage any steam condenser CW leaks – silica etc. Current design CONSEP ammonia cycle – 2 X 50 %.
- Upgraded Unit cycle chemical instrumentation – rapid detection of condenser leaks.
- Ability to quickly remove SC from service.

Chemistry Considerations KHCP - 2

- Design for Steam condenser (steam and water side) for standby, short / medium and long term storage and flushing cycles to return SC to service.
- Impact on overall site water balance to maintain site Zero Discharge (ZD) for process waters.
- Installation of additional water treatment plants to maintain ZD if necessary – including robust design to cater for appropriate disposal and storage of site water and site salt load.

Proposed Kogan Solar Boost Project (KSBP)

- AREVA's solar collector and steam generation technology (Compact Linear Fresnel Reflector).
- Approx 500m x 600m area (30 hectares).
- 44 MW peak (23 MW average) additional electrical output.

Kogan Creek Solar Boost Project

Overview

CS Energy has partnered with solar thermal technology provider AREVA on a 44 megawatt solar thermal addition to the existing 750 MW Kogan Creek Power Station in south west Queensland.

How it will work

The project will augment Kogan Creek Power Station's feedwater system to increase the station's electrical output and fuel efficiency. It will do this by using solar technology to heat feedwater entering the boiler, supplementing the conventional coal-fired feedwater heating process. This means that steam that was previously diverted from the turbine to the feedwater system can instead be used to generate extra electricity.

Benefits

The solar addition will enable Kogan Creek Power Station to produce more electricity with the same amount of coal, making the coal-fired plant more fuel efficient and reducing its greenhouse intensity.

Size

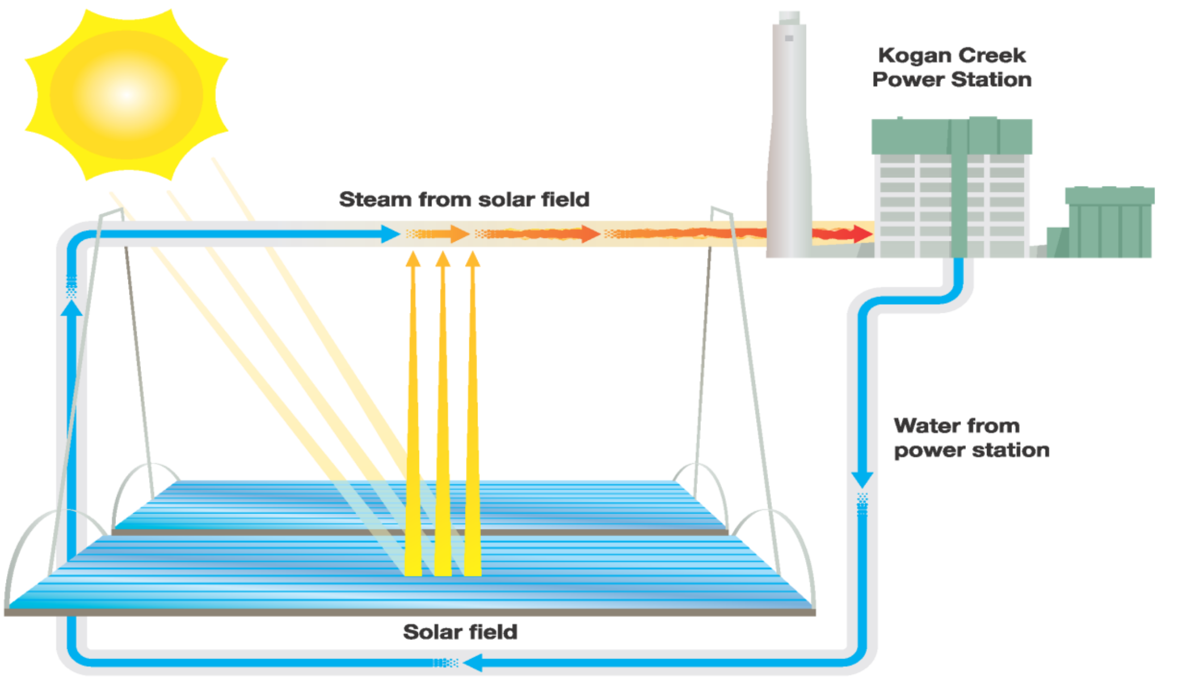
The project will be the largest deployment of AREVA's solar thermal technology anywhere in the world and the largest solar project of any kind in the southern hemisphere.

Key facts

What	Solar addition to existing 750 MW Kogan Creek Power Station
Who	CS Energy (Queensland Government owned electricity generator) and AREVA (AREVA recently acquired Ausra Inc. to lead its new Global Solar Power business unit. The company has operations in Australia and the United States). The Australian and Queensland governments have provided financial support for the project.
Capacity	44 MW peak (23 MW average) additional electrical output. This will equate to 40 gigawatt hours of electricity per year.
Number of extra homes powered	5,000
Greenhouse gas emissions avoided	35,600 tCO_2 equivalent.
Technology	AREVA's solar collector and steam generation technology (Compact Linear Fresnel Reflector).
Land area	Approx 500m x 600m area (30 hectares).
Jobs created	Peak construction workforce of 120.
Capital cost	$98.8 million
Timeframe	Operational by 2012

Solar Boost Schematic

Kogan Creek Solar Boost Project



At peak solar conditions, the solar field will enable Kogan Creek Power Station to generate an extra 44 megawatts of electricity, enough to power 5,000 homes.

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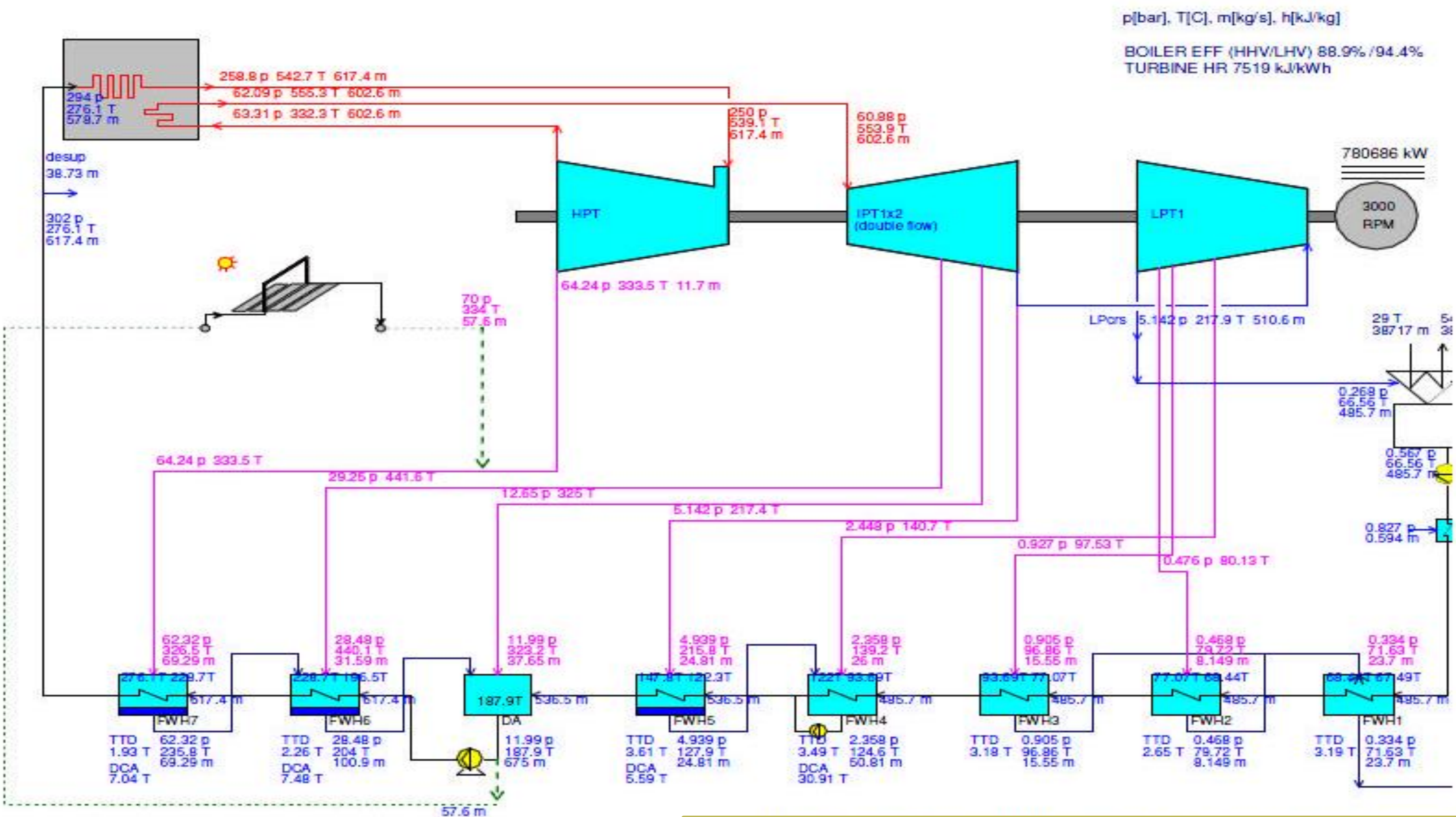
AREVA

Aerial View - Schematic

Solar Boost Cycle



Indicative Details

net power 36,255 MW

average mass flow: 22,5 kg/s

peak mass flow 57,6 kg/s

number of units 14

calculation of surface based on the straight parts of boiler tubes (bends and fittings are neglected):

area of tubes **2" Sch 80**	**- 3" Sch 160**
DN 60,3 x 5,54	- 88,9 x 11,10
inner diameter 0,04922m	- 0,0667m
length 400m	- 400m
tubes per unit 6	- 2
inner surface per unit 371,11m²	- 167,64m²

area total 7542,43m²

Chemistry Issues – Solar Boost - 1

The following chemistry aspects need to be assessed regarding the proposed Solar Boost Project:

- A key issue is the iron contamination risk due to single and two phase FAC in the Solar Steam Generator (SSG).
- Noting that the Kogan chemistry is pH 9.8 – Oxygen treatment.
- A COMSY FAC assessment has been conducted – higher chromium steels are being considered.
- Design decision – return from SSG either (a) to bled steam to HP heater 6 or (b) into the Cold Reheat line – potential iron contamination risk into boiler (a) or into IP turbine (b).

Chemistry Issues – Solar Boost - 2

- Iron contingency management options need to be considered – filtration possibility – iron measurement into and ex the SSG.
- Chemistry aspects of system start up and shutdown need to be considered – including the daily solar cycle.
- To avoid excess make – up water use for the daily plant cycling will need to decide short term storage / operation options including recycling of the SSG water before feed forward.
- Consider the medium and long term storage options for SSG – hot – dry – nitrogen.
- Consider optimum chemistry regime and monitoring.

CS Energy - Asset Management

- CS energy is currently reviewing and up dating its Asset Management systems which will include FAC
- System hierarchy:
  - Asset Management Policy – Asset Strategy, Whole of Life Plan for each asset
  - Chemistry Directive
  - FAC Directive – including consideration in any mod
  - Yearly plant risk reviews and expert audits
  - Specific Plant Strategies and Procedures
  - Specific FAC NDT scopes for overhauls

Briefly – What is Asset Management?

Formal definition

“The life cycle management of physical assets to achieve the stated outputs of enterprise”

Asset Management Council

- *Life Cycle Management = engineer, procure, install, commission, operate, maintain, improve...!*
- *Outputs are generation reliability and cost performance – always*
- *Available to take advantage of spot market opportunities*
- *Delivered within the limits of what the business can afford!*

Put simply

“ Good Asset Management

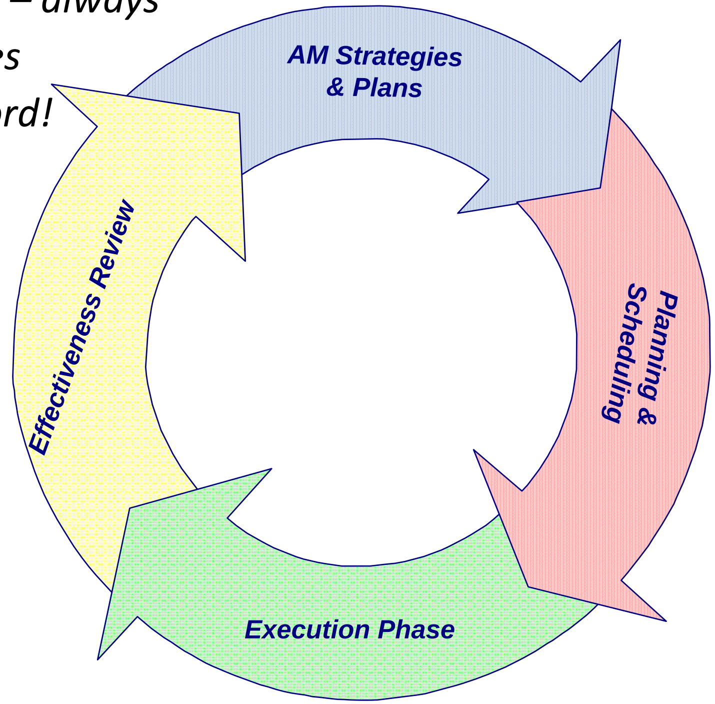
Equals Achieving:

Good Safety Performance

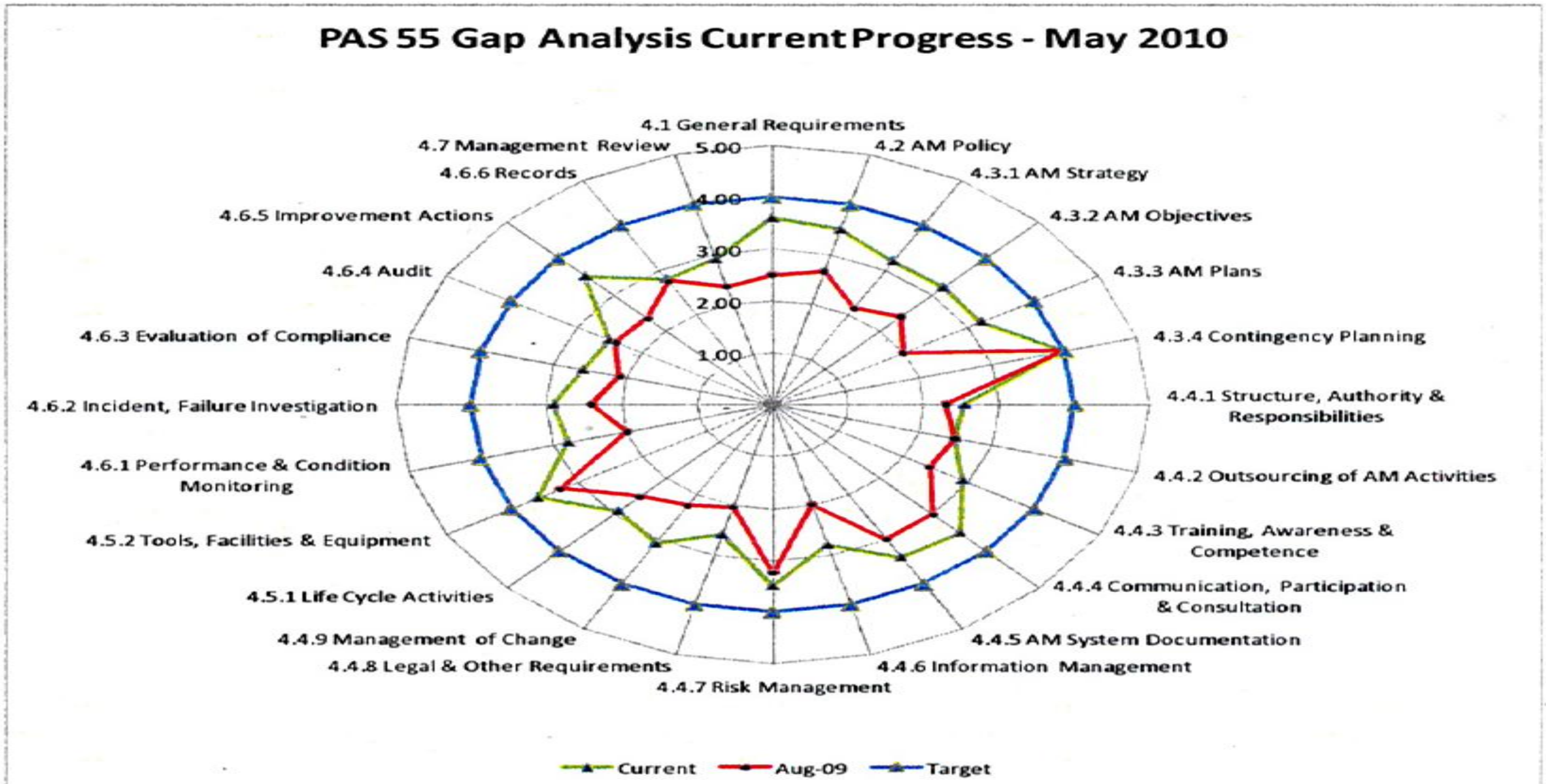
Good Reliability Performance

Good Economic Performance

~ Over the life of the Asset”



Asset Management Project



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- The Washington FAC paper was an update by the lead author Ian Richardson on a Kogan ACC paper he presented in June 2009 to the Boston EPRI Conference.
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Thank You

QUESTIONS