Callide Oxyfuel Project: Overview of Commissioning Experience

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OCC3

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Presentation Overview

- Purpose of the presentation is to provide an overview of the Callide Oxyfuel boiler and CO_2 capture plant (CPU) commissioning experience and outcomes
- Items covered include:
  - Process overview and mass balance data
  - Environmental approvals
  - Hazardous area assessments (toxic gas release)
  - Oxy-combustion process overview and commissioning outcomes
  - CPU process overview and commissioning outcomes
  - Concluding comments

Callide Oxyfuel Project – Milestones achieved

- 1st Oxyfiring – 12 Mar. 2012
- 1st full Oxyfuel mode – 19 Mar. 2012
- 1st flue gas to CO_2 Capture Plant (Low Press. section) – 14 Sep. 2012
- Oxyfuel operation without H_2O remover - 2 Weeks in Early Oct12
- 1st Liquid CO_2 11 Dec. 2012
- Oxyfuel demonstration - Over 3650 hours as at end August 2013
- CO_2 capture – Over 1100 hours as at end August 2013
- Overall budget = AUD 235 million
- Operation funded to end of 2014
- Safety – Zero Lost Time Injuries

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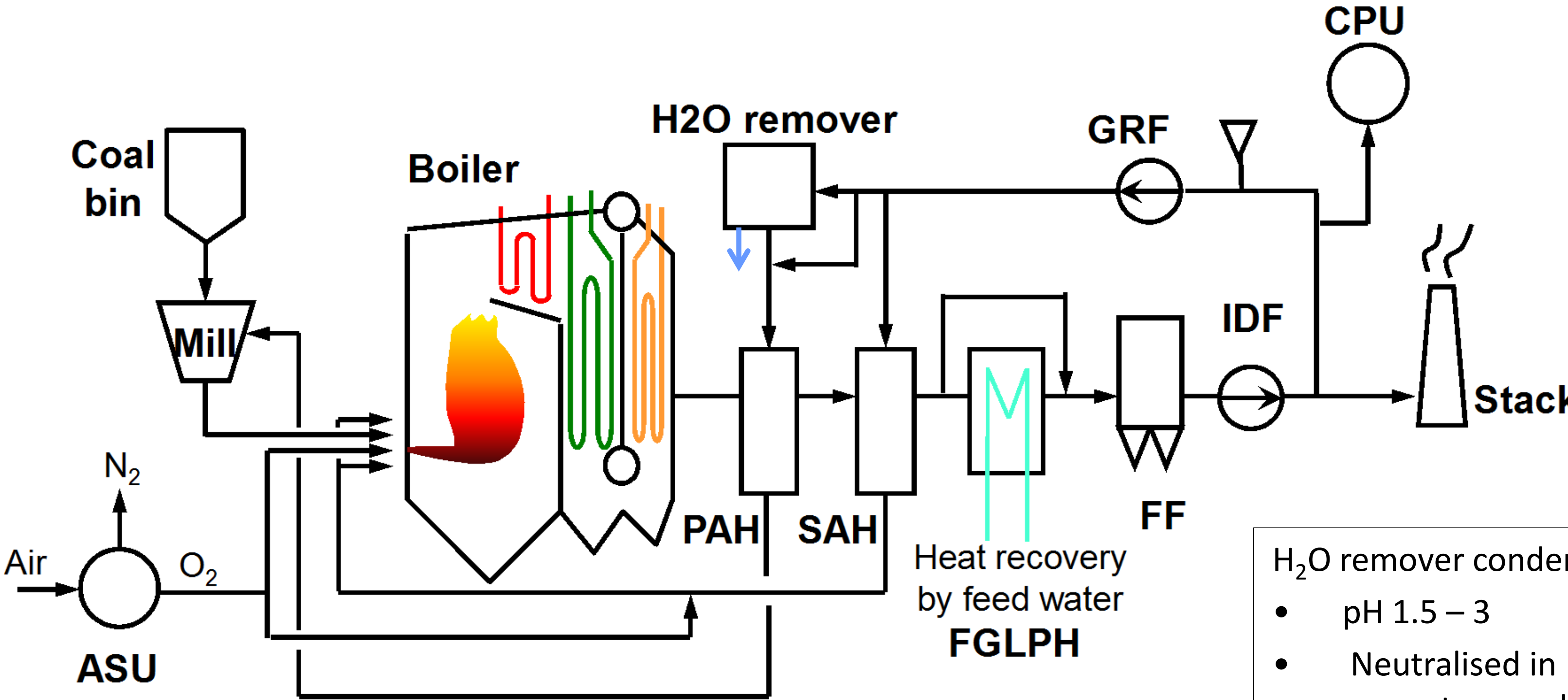
Oxyfuel process schematic

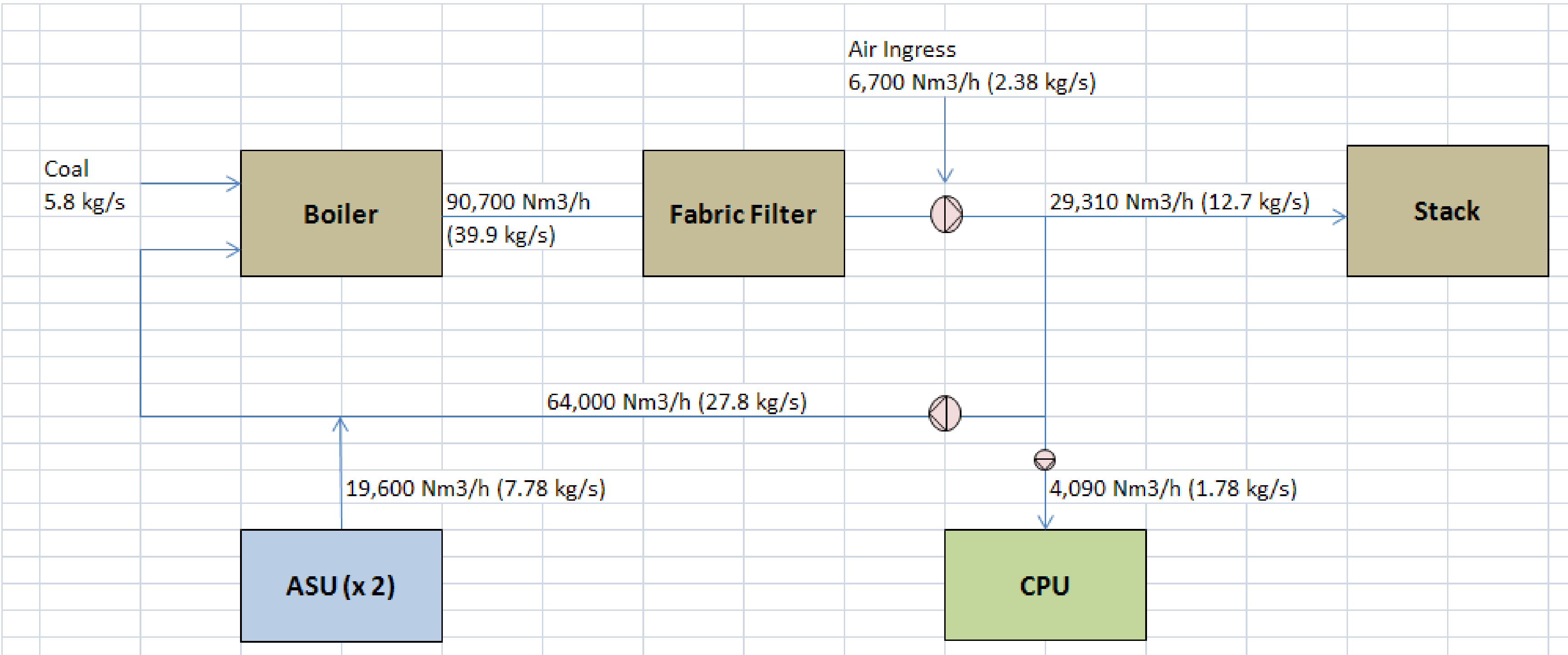


H_2O remover condensate:

- pH 1.5 – 3
- Neutralised in separate vessel with 30 – 50% caustic

Boiler/Stack/CO2CPU - Flue gas mass balance

Indicative at 30 MWe (100% load factor)



COP – Environmental Authority

Boiler (CA4)

- Coal sulfur ≤ 0.35 mass % as-received (monthly average)
- Particulates ≤ 100 mg/Nm3 (@ 12% CO_2) on 4 hour moving average (80% of a given month) – 1 registered release point (CA2 – Stack)
- NOx - Continuous monitoring:
  - Air mode ≤ 850 ppmv (normalised to 7% O_2) – 1 registered release point (CA2 - Stack)
  - Oxy-mode ≤ 70 g/s (1 hour moving average) as measured by CEMS on stack inlet

ASUs (CA5 & CA6)

- No licence limits

CPU (CA7)

- There is one major release point for normal operation which is positioned above the coldbox. Other vents exist for start-up and emergency discharge.
- NOx limited to 70 g/s as reference level at the stack inlet (Release Point CA2)

Overall site

- Limits on runoff, stormwater and seepage: pH 6.5 – 9.0; Dissolved O2 > 2 mg/L; Suspended Sol. ≤ 100 mg/L; Total dissolved solids ≤ 1450 mg/L; Chloride (Cl) ≤ 400 mg/L.
- Process waters are treated on site and discharged with ash to the ash dam.
- Agreed by Minutes of Meeting with the EPA that plant performance data will be scientifically published in the public interest.

Oxyfuel Boiler & CPU – Hazardous area assessment (1)

- Hazardous Area is an area in which a toxic or flammable gas atmosphere is or may be expected to be present in quantities such as to require special precautions.
- Potential hazards with the ASUs, Boiler and CPU can arise from:
  - Coal dust clouds exceeding 50 mg/Nm3)
  - Uncontrolled release of flue gas (predominantly CO_2 but also containing SO_x, NO_x, CO)
  - Controlled release of flue gas from registered release points including main vents, PSVs and TSVs
  - Controlled and uncontrolled release of Ammonia from the refrigeration plant
- Hazardous areas are divided into three zones (Zone 0, 1 & 2) according to the likelihood of a toxic or flammable gas being present and their persistence/frequency.
- Assessments methodology applied is as per AS/NZS/IEC 60079.10.1:2009 (Annex A & B).
- Oxyfuel boiler has 1 registered release point – the Stack.
- CPU area has 1 major release point for normal operation and several other release points for start-up and emergency operation.

Oxyfuel Boiler & CPU – Hazardous area assessment (2)

	OSHA STEL (ppm)	Australian MSDS STEL (ppm)	LEL (ppm)	UEL (ppm)
CO2	5,000	30,000		
CO	50			
NO	25	35		
NO2	5			
SO2	5	5		
SO3	0.28			
NH3		35	148,000 (14.8 mol. %)	250,000 (25 mol. %)
STEL - Short Term Exposure Limit				
LEL - Lower Explosion Limit				
UEL - Upper Explosion Limit				

O_2 is also a potential hazard:

$O_2 < 19$ mol %

$O_2 > 23$ mol %

Assessment Methodology

- Determine release rate for each gas component (chocked or un-chocked flow, initial concentration, T, p).
- Determine local conditions (ambient temperature, ventilated or enclosed), and select a Safety Factor according to the Standard.
- Determine theoretical concentration within the affected envelope.
- Select a certain size of leak (eg., around the circumference of a flange/gasket pipe section), and calculate the theoretical release rate and concentration.
- Compare the concentration with the STEL or Explosion limits (SAFE or UNSAFE).

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Oxyfuel Boiler & CPU – Hazardous area assessment (3)

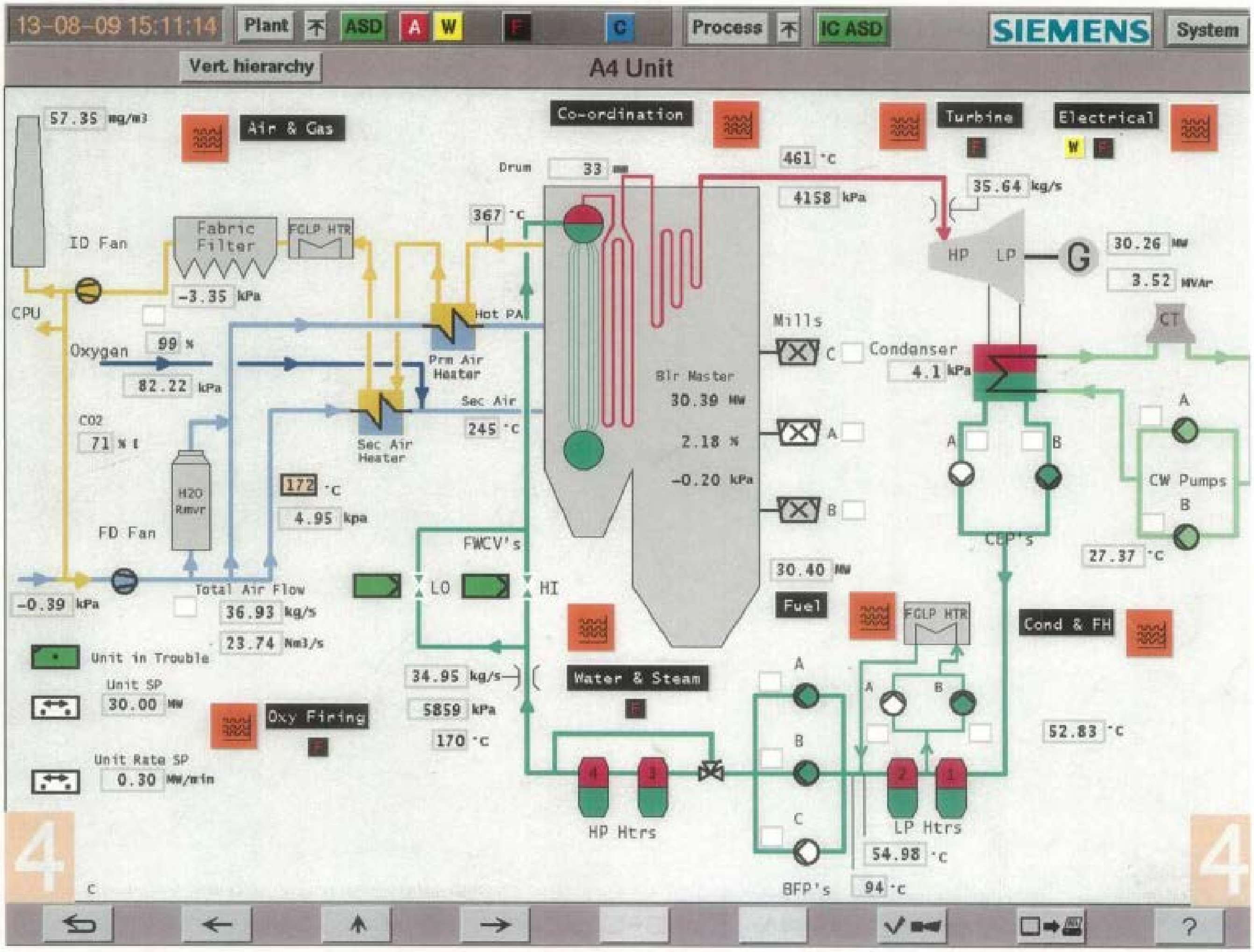
Safe Guards

- Operators do plant walk-downs every shift.
- Fixed CO_2 detectors in CPU compressor house have been installed (3 measurement points) as well as inside the Process and Air Liquide R&D Modins (used for process control and monitoring gas analysis).
- Personal CO_2 monitors must be worn around boiler in oxy-firing mode.
- Personal CO_2 and NO_2 monitors must be worn in CPU plant area.

Commissioning experience

- Some leaks have occurred due to material failures on old boiler heat recovery sections (e.g., Secondary Air/Gas Heater); which have been repaired.
- Actual measurements of gas concentrations due to leaks within affected zone are generally as predicted using the AS/NZS/IEC 60079.10.1:2009 modelling approach.

Oxyfuel boiler - overview



30 MWe (100% Load Factor)

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Oxy-firing mode change sequence

Actual data (at 28 MWe)

Flue Gas Composition		**Air-Firing mode**	**O2 Sequence**	**RFG Mode**	**Oxy-mode**
O_2	vol %, dry	4.5	6.0	6.8	5.4
CO_2	vol %, dry	15.0	16.2	59.9	72.2
CO	ppm, dry	20	20	12	12
SO_2	ppm, dry	220	230	800	890
NO	ppm, dry	550	720	1195	965
NO_2	ppm, dry	9	10	45	46
H_2O	vol %	8	8.5	20.5	21.6

NO_x	ppm, dry @ 7% O_2	474	681	1223	907
NO_x	ppm, dry @ 12% CO_2	447	541	248	168
Flue Gas to Stack	kg/s (wet)	54	59	15.4	14.0
	Nm^3/s (wet)	40.8	44.3	9.77	8.48
NO_x	**g/s**	**43**	**61**	**21**	**15**

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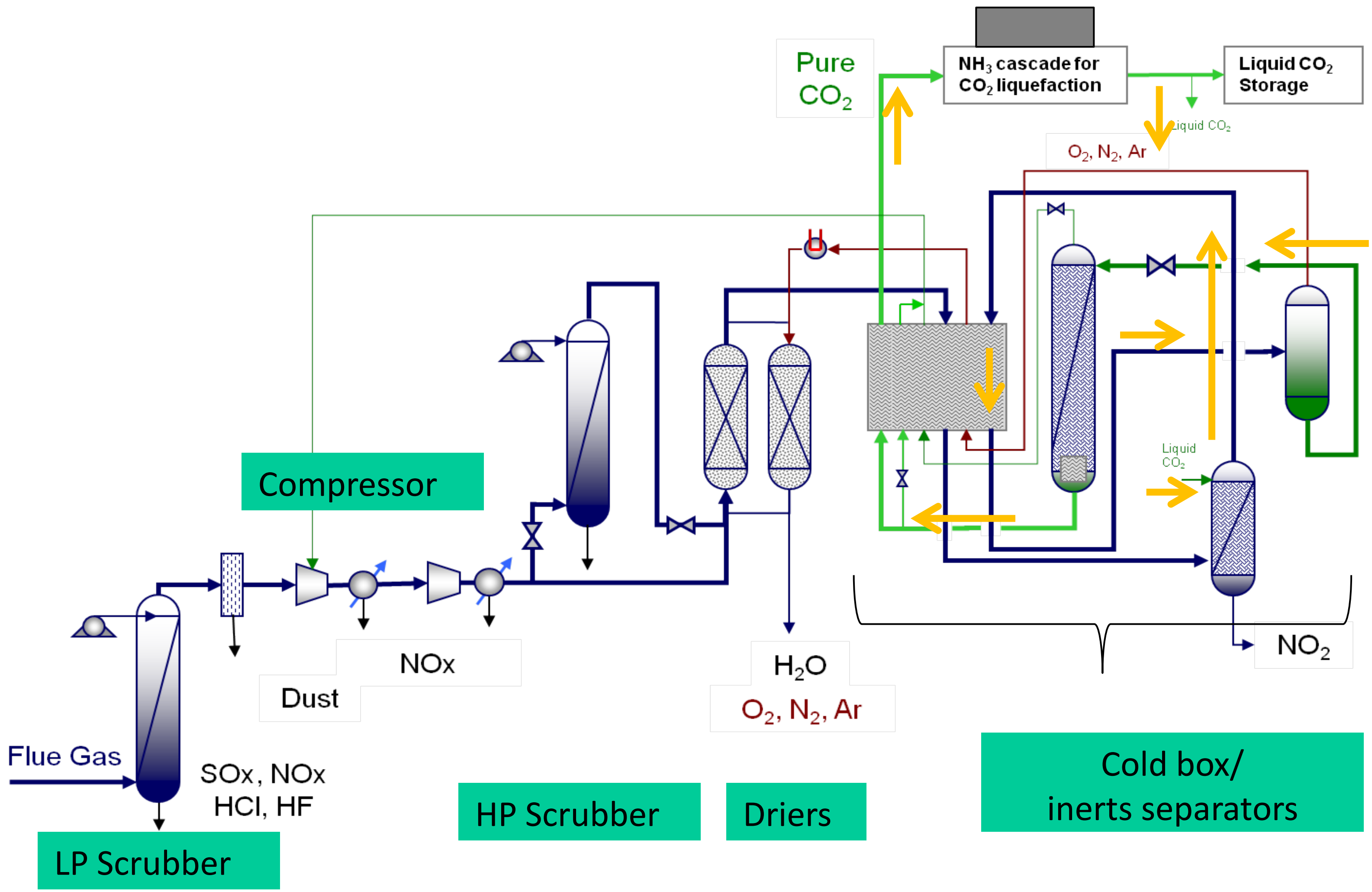
Oxyfuel Boiler – Commissioning issues

- Realigning of Boiler Control settings and new Boiler Protection System settings.
- Optimization of the oxy-firing logic.
- Balance of primary gas and secondary gas pressures to obtain optimal combustion conditions.
- Optimization of logic of the O_2 mixing valve between the ASU O_2 valve skid and the branch point on the O_2 injection line upstream of Secondary (Air) Gas heater.
- Minimizing air-ingress (e.g., improving hatch seals on fabric filters).
- Minimizing unreliability associated with some parts of the old plant (e.g., generator cooling air fans, instrument failures, logic hiccups, Secondary air heater internals).
- Managing coal quality (e.g., rocks in coal jamming coal feeders).

Carbon dioxide capture plant



Courtesy of Air Liquide

CPU – Low Pressure Section

Quencher & LP scrubber

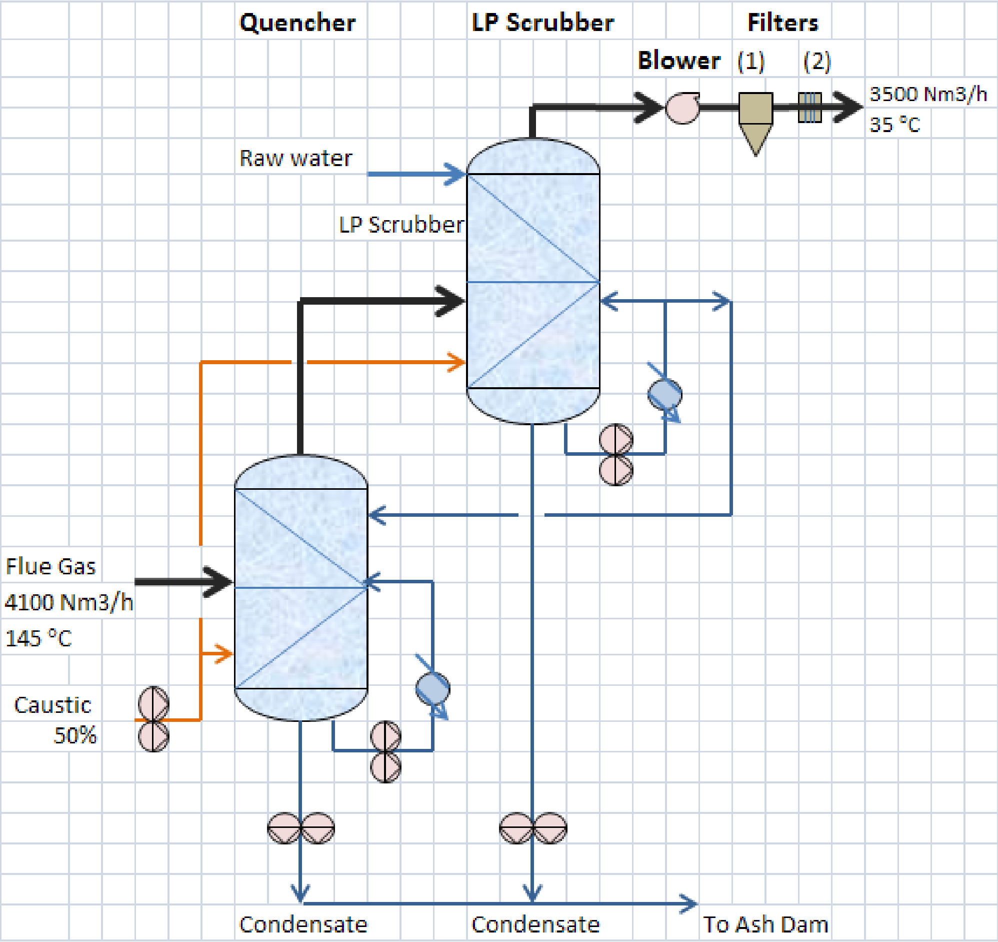
- Cools the gas from up to 145 °C to < 40 °C
- Removes SOx to < 10 ppm in two stages.
- Caustic soda is used to dose the lower sections of neutralise the flue gas.

Blower

- Draws gas from the oxy-fuel boiler ID Fan outlet and compresses the gas to 110 kPa (abs).

Filters

- Dynamic filter is pulsed with CO_2
- Dust level at Static filter outlet is < 0.02 mg/m3



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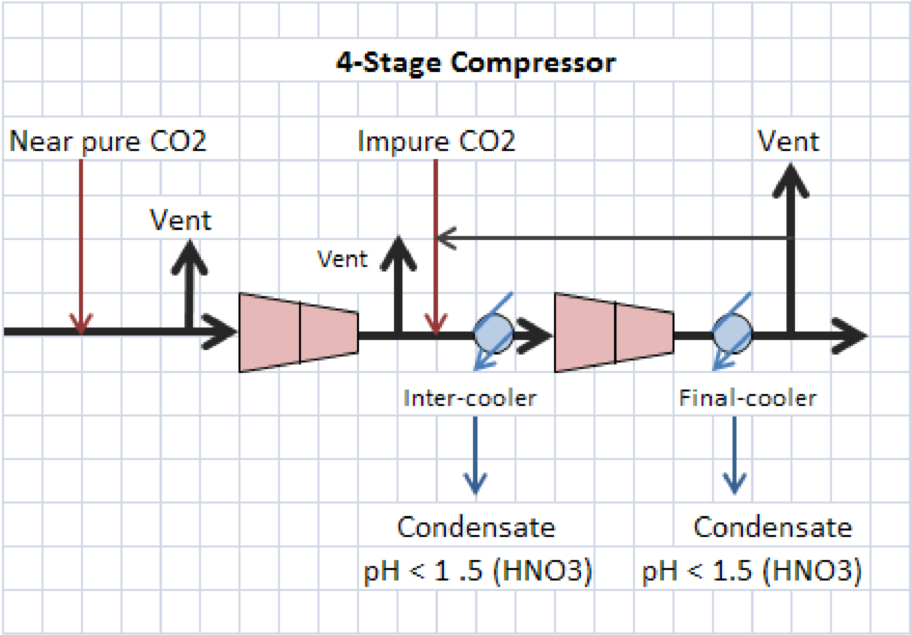
CPU – 4 Stage Centrifugal Compressor

- 4 Stages with coolers after Stage 2 and 4
- Stage 2 ~ 600 kPa (abs)
- Stage 4 ~ 2,500 kPa (abs)
- Acid condensate comprised of Nitric acid with low levels of Nitrous acid.
- Gas can be vented before and after the compressor.
- Commissioning experience is that **Hg is << 0.1 µg/Nm^3** at the compressor outlet.



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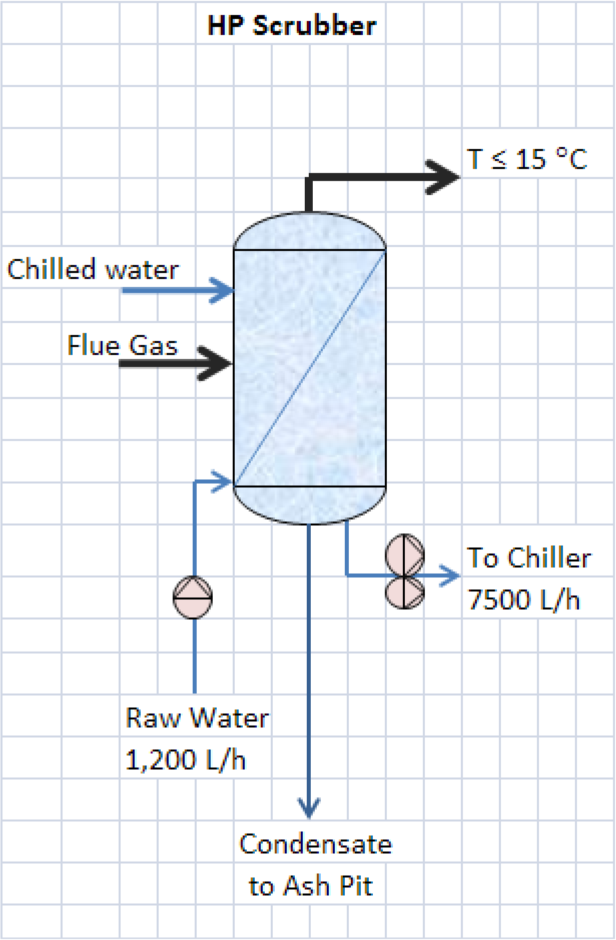
CPU – HP Scrubber (Cooler)

•HP scrubber (cooler) acts as a simple direct cooler to cool the flue gas from the compressor.

•The refrigeration plant provides chilled water at ~ 7 °C to the HP scrubber.

•Condensate (primarily Nitric acid) is neutralised and discharged to the ash pit.



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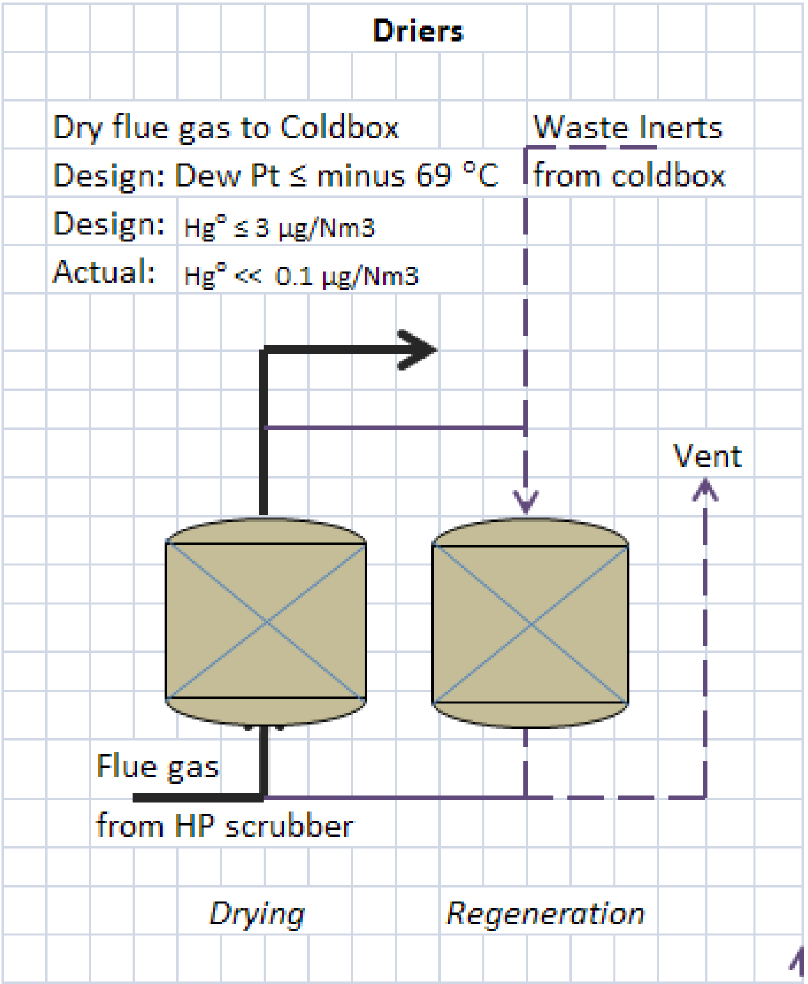
CPU - Dryers

- CPU has two dryers with acid resistant adsorbent.
- Utilises Temperature Swing Absorption principle
- Purpose is to dry the compressed/clean flue gas to very low dew point (typically minus 80 °C), and to remove any final traces of mercury.
- The Dryers are on a 12 hour cycle of adsorption and desorption.
- Desorbed gas, together with other waste gases from the deNOx and DeOx columns are vented from the top of the CPU coldbox.



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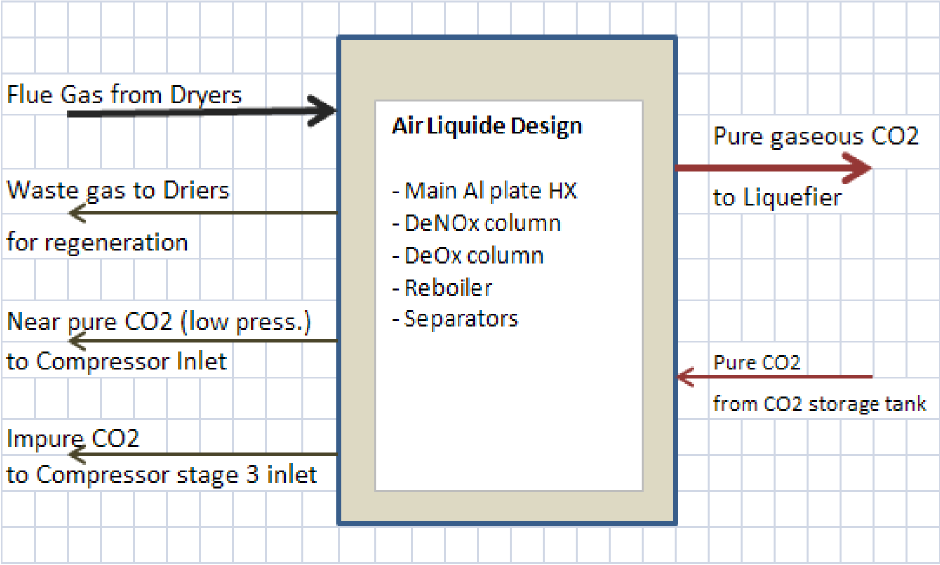
CPU – Coldbox (CO2 purification) & Liquefier

- Within the coldbox there is a large brazed-Al heat exchanger, and an array of columns and vessels that are used to purify the flue gas.
- An O_2 set point limit can be applied to the pure gaseous CO_2 prior to sending this to the Liquefier.
- CO_2 liquefier is coupled with an Ammonia Refrigeration plant and sits above the 100 tonne CO_2 storage tank.
- Analysis of LCO2 product indicates purity exceeding 99.9% CO_2.
- Final CO_2 product is maintained at 1450 to 2300 kPa(abs) and minus 27 °C.



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CPU – Process gas quality (actual)

Gas Composition	Unit of Measure	CPU - LP Inlet	CPU - LP Outlet	Product CO_2
		From Boiler	To compressor	
Boiler Load Factor	%	80 - 100		
H_2O	mol. %	19 - 22	5 - 7	< 20 ppm
O_2	mol. %	3 - 5	3.5 - 6	< 30 ppm
CO_2	mol. %	50 - 57	58 - 67	> 99.95
CO	ppmv	20 - > 200	25 - > 200	< 10
NO	ppmv	500 - 700	580 - 820	< 2.5
NO_2	ppmv	20 - 40	Nil	< 20
SO_2	ppmv	800 - 1000	< 10	< 0.1 ppm
SO_3	ppmv	10 - 15	< 0.1	< 0.1 ppm
N_2 (+ Ar)	mol. %	Balance	Balance	trace
Hg	ppbv	0.3 - 0.5	0.04 - 0.1	< 0.0002
	µg/Nm3	2.7 - 4.9	0.4 - 0.9	< 0.002
Particulates	mg/Nm3 (at 60 - 70% CO_2)	150 - 250	< 0.02	nil
	mg/Nm3 (at 12% CO_2)	20 - 50	< 0.01	nil

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CPU – Process condensates

Data from Dec 2012 trials

Parameter	Unit of Meas.	Raw Water	Quencher	LP Scrubber	Compressor			HP Scrubber
					Intercooler		Final cooler	
pH		~ 7	~ 7	7.5 - 8	< 1.5		< 1.5	0.5 - 1
Total Dissolved Salts	mg/L	100 - 150	5,000 - 6,000	1,000 - 2,000	< 5		< 5	up to 1,000
Tot. Alkalinity	mg/L as CaCO3	< 10	1,500 - 2,000	1,000 - 1,500	< 1		< 1	< 1
Sulfate as SO4	mg/L	10 - 20	3,000 - 4,000	< 100 - 2,000	< 1		< 1	10 - 30
Chloride	mg/L	10	50 - 100	<50	< 1		< 1	10 - 50
Nitrate + Nitrite as N	mg/L	ND	< 5	< 5	up to 25,000		up to 25,000	1,500 - 15,000
Mercury (Hg)	µg/L	ND	up to 15	< 0.1	20 - 50		up to 10	< 2.5

Commissioning data indicates:

- LP area (caustic wet scrubbers and filters) remove particulates, SOX, NO_2 and a major portion of trace elements
- NO is converted to NO_2 in the compressor and a significant portion is removed with the intercooler and final cooler condensates as Nitric Acid.
- Almost all the Hg that has passed through the LP area is removed with the compressor condensates.

Concluding comments

- By the end of August 2013, most issues associated with running-in of new plant had been resolved, and reasonably steady operation is anticipated for the remainder of the demonstration phase to the end 2014.
- The commissioning and operation has provided a great deal of knowledge and experience to inform future oxyfuel technology development. It is very important to have the background from R&D and pilot facilities and carefully considered design; but there will always be unforeseen issues in the plant.
- The Project is supporting a number of R&D initiatives that have received funding support from the Australian National Low Emissions Coal Research & Development, Australian Coal Association, NEDO and METI, and is collaborating with FutureGen 2.

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CS energy

xstrata coal

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Schlumberger

J-POWER EPDC

MITSUI & CO., LTD.

Australian Government

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Supporting Collaborator

JCOAL
Japan Coal Energy Center

Thank you

for more information: www.callideoxyfuel.com

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