Callide Oxyfuel Project

Callide Oxyfuel Project: Boiler Retrofit Design

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IHI Corporation

Research & Development Department
Power Plant Division

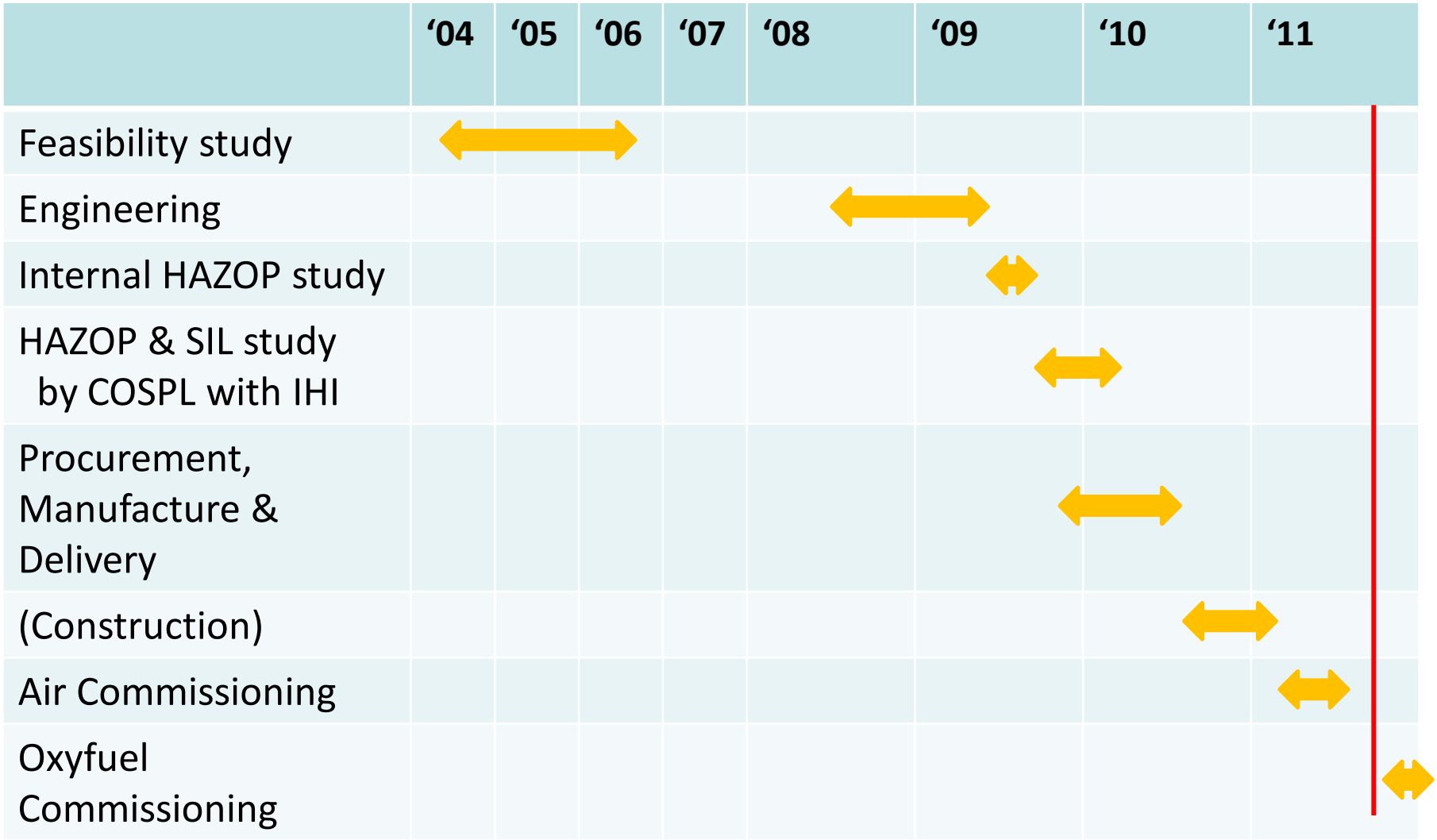
IHI

Contents

1. Existing Boiler specification

Item	Description
Manufacturer	Riley Dodds Australia Limited
Boiler type	2 drum type boiler without reheater
Power output	30MW x 4 unit
Main steam condition	136 t/h, 4.31 MPa (abs), 463 degC
Furnace wall type	Skin casing
Burner	Front wall firing
Draft system	Balanced draft
First commissioned	1966-1968
Refurbished	1982, 1997-1998 (Dry storage from 2002)

2. Schedule of Boiler Retrofit Work



3. Design Condition & Operating Target

< Design Condition >

Item	Description
Coal	Callide coal (High Ash, High Moist., Low S)
Coal consumption	5.4 kg/s
Boiler inlet O2 concentration	27 vol%wet (O2 : RFG ≒ 1 : 3)
Boiler outlet O2 concentration	3 vol%wet
O2 consumption	7.6 kg/s
O2 purity	98%<

< Operating Target in Oxyfuel combustion >

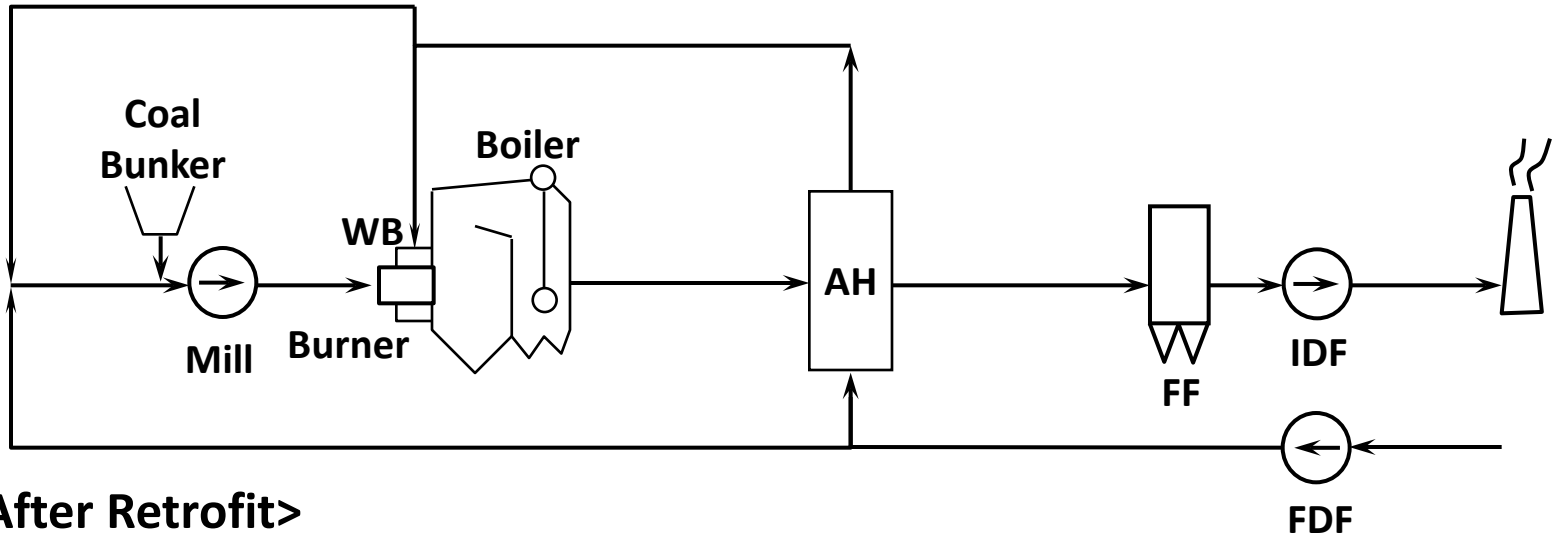
Item	Description
Minimum Load	80%Load
Mode change time (Air => Oxyfuel, Oxyfuel => Air)	Within 60 minutes each
Ramp rate up	5% / hour
Ramp rate down	1% / minutes

4. Consideration for engineering

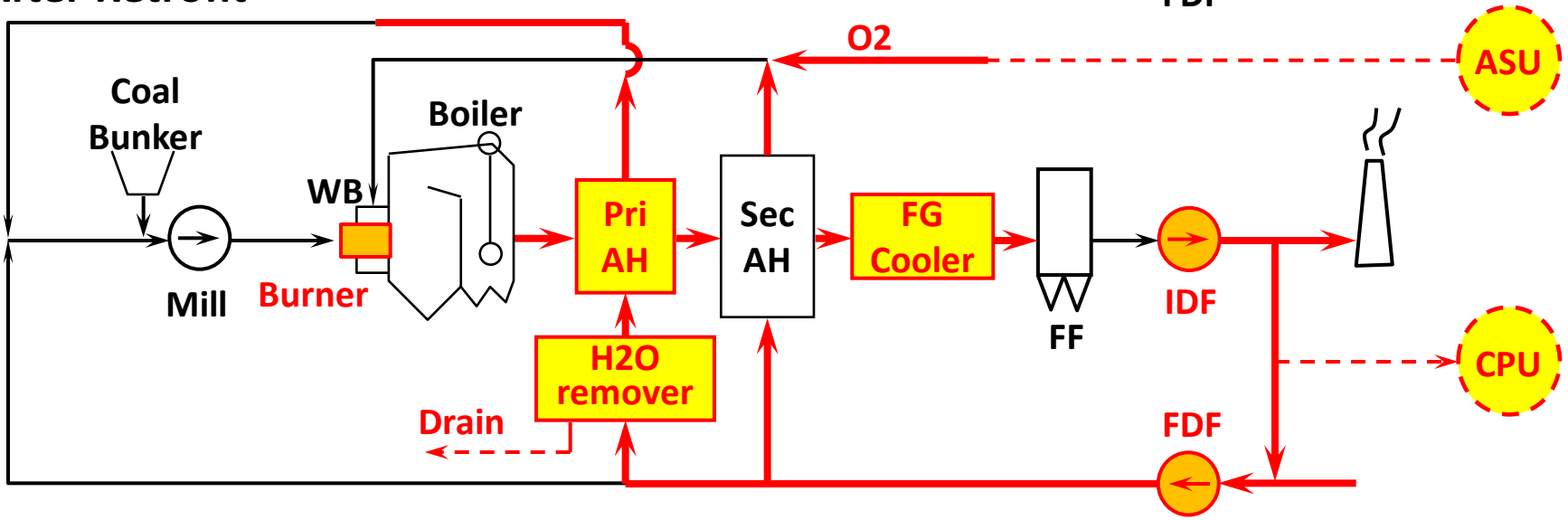
- 100%Load operation in both Air and Oxyfuel combustion
- Re-use the existing equipment as much as possible
- Cooperation with ASU and CPU operation
- Compliance with IGC document for Oxygen system
- No oxygen supply into Primary RFG system for safety reason
- Air ⇔ Oxyfuel mode change with one push button
- Countermeasure for low temperature corrosion
- Installation of measurement considering various tests

5. Callide system before / after Retrofit

<Before Retrofit>



<After Retrofit>



5. Callide system before / after Retrofit

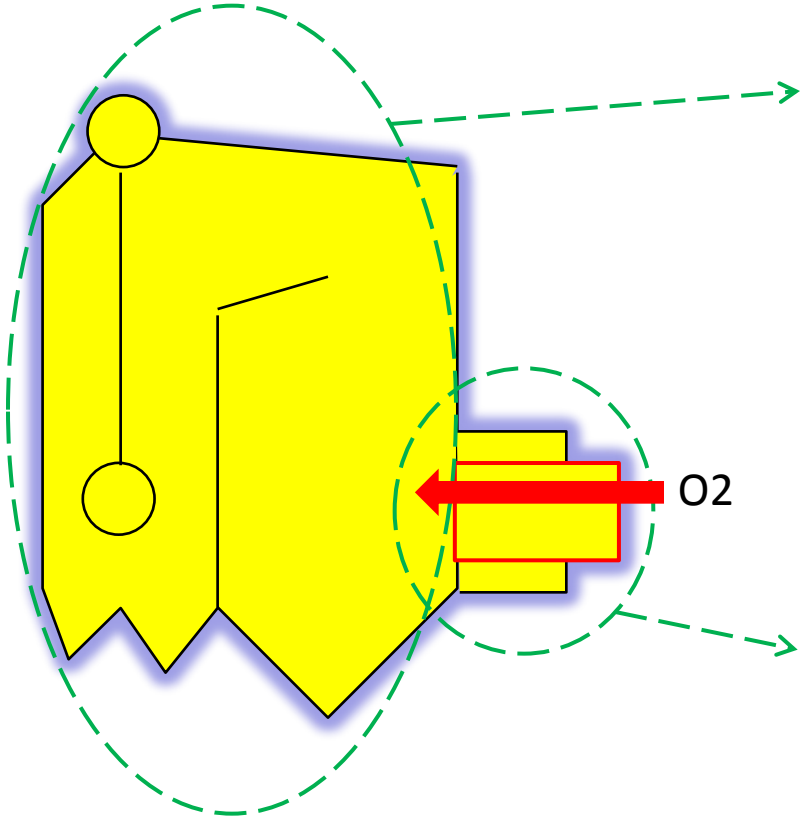
< Flue gas component comparison at 100%Load >

unit : vol% wet

	Air combustion	Oxyfuel combustion
H2O	9	21
O2	3	3
CO2	15	60
N2	73	15
SO2	0.1>	0.1>
Ar	0	1
Total	100	100

6. Outline of Modification design

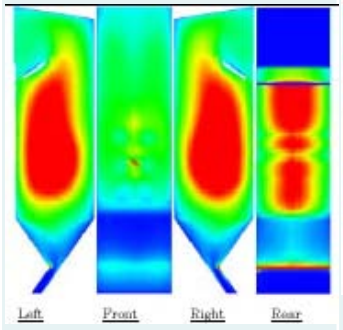
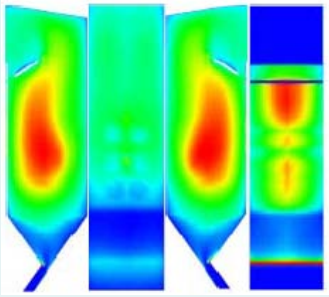
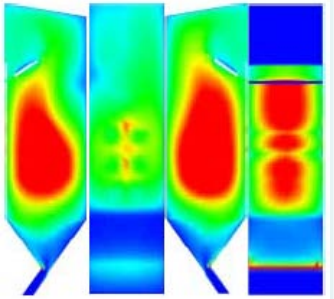
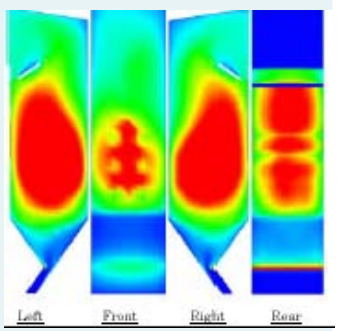
< Furnace & Burner >



- Pressure parts are not modified.
- Observation windows are modified to lessen influx air into furnace.
- 2 burners out of 6 are replaced to IHI-low NOx burner.
- Oxygen line directly to the furnace is installed into all burners

6. Outline of Modification design

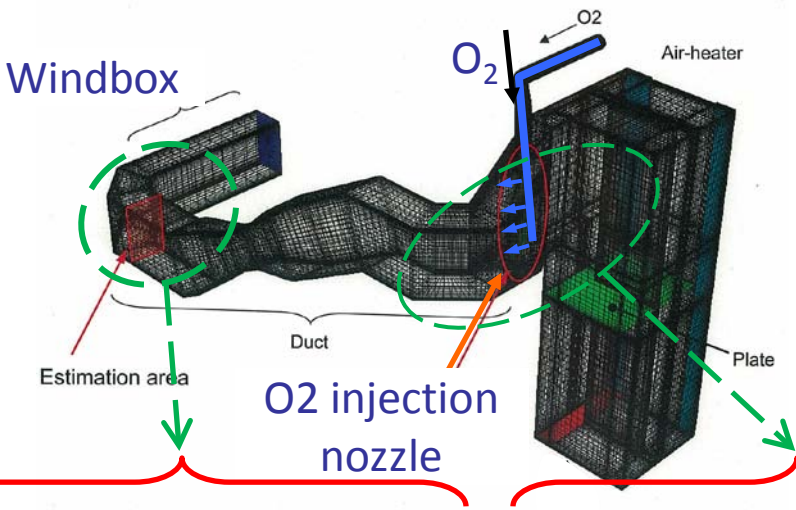
< Design consideration - Heat flux in the boiler >

	Air	Oxyfuel1	Oxyfuel2	Oxyfuel3
Total gas flow	140 t/h	170 t/h	140 t/h	120t/h
Boiler inlet O2	21%	21%	27%	30%
Simulation result				
Heat flux	Base	Lower	Nearly equal	Higher

We set 27% as the design condition of Boiler inlet O2 concentration.

6. Outline of Modification design

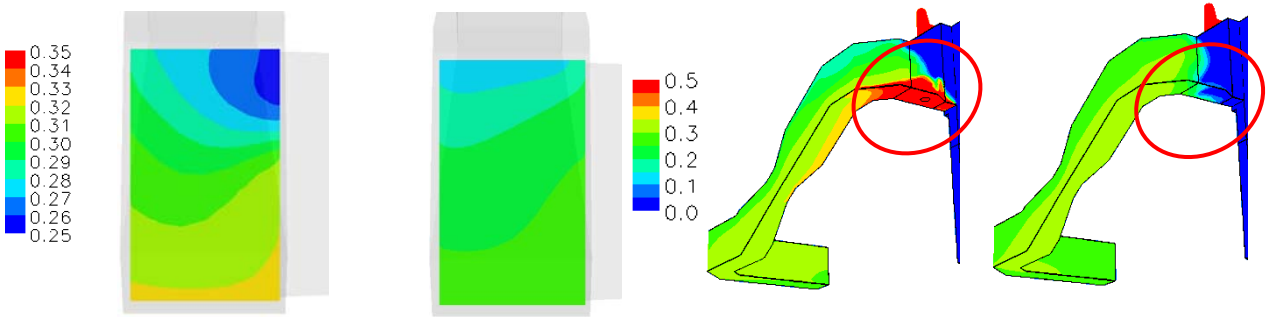
< Mixture of Oxygen with Recycled Flue Gas >



Evaluation of cross-sectional evenness and absence of spot after mixing by modeling.

Nozzle B is adopted

Nozzle A | Nozzle B | Nozzle A | Nozzle B



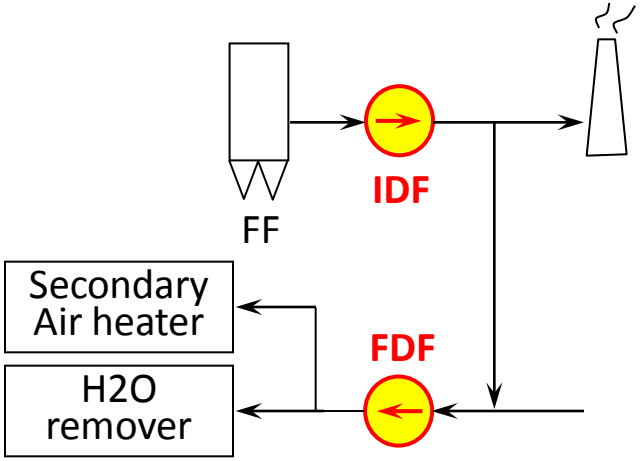
(3%) (1%) (max 98%) (max 34%)

Deviation of O_2 concentration at Windbox inlet [%]

Spot of O2 concentration just after mixing [%]

6. Outline of Modification design

< Forced Draft Fan & Induced Draft Fan >

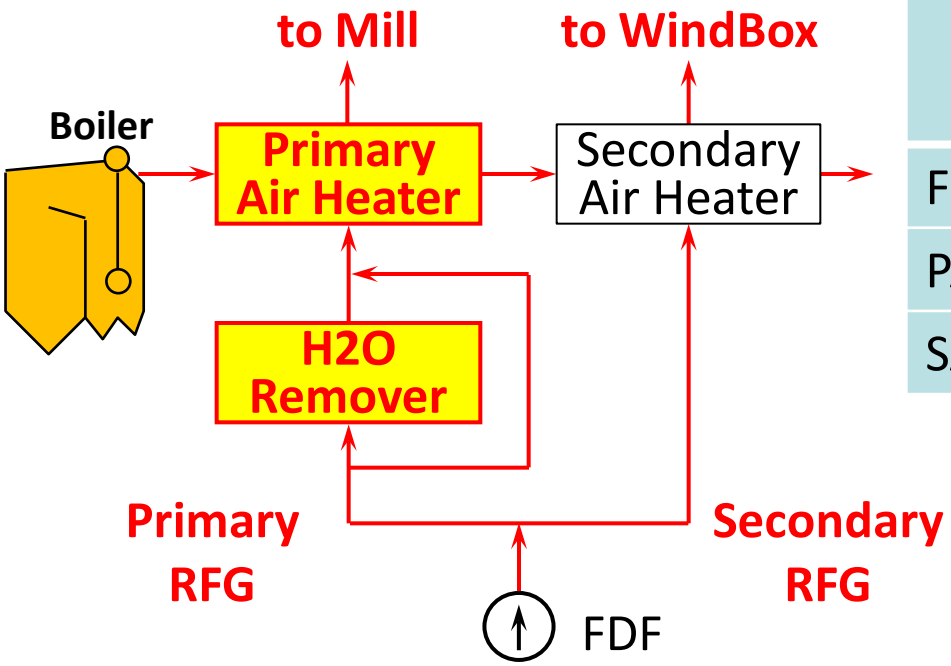


- FDF is replaced due to lack of static head and temperature rising.
- IDF is replaced due to lack of static head.
- FDF is used as Gas recycle fan in Oxyfuel mode.

		Before Retrofit	After Retrofit	
			Air mode	Oxyfuel mode
FDF	Volume flow (m3/min)	2,100	2,100	1,700
	Static head (kPa)	2.0	4.2	5.7
	Gas temperature (degC)	30	30	150
IDF	Volume flow (m3/min)	3,500	3,500	2,700
	Static head (kPa)	2.7	4.2	3.9

6. Outline of Modification design

< H2O Remover & Primary Air Heater >

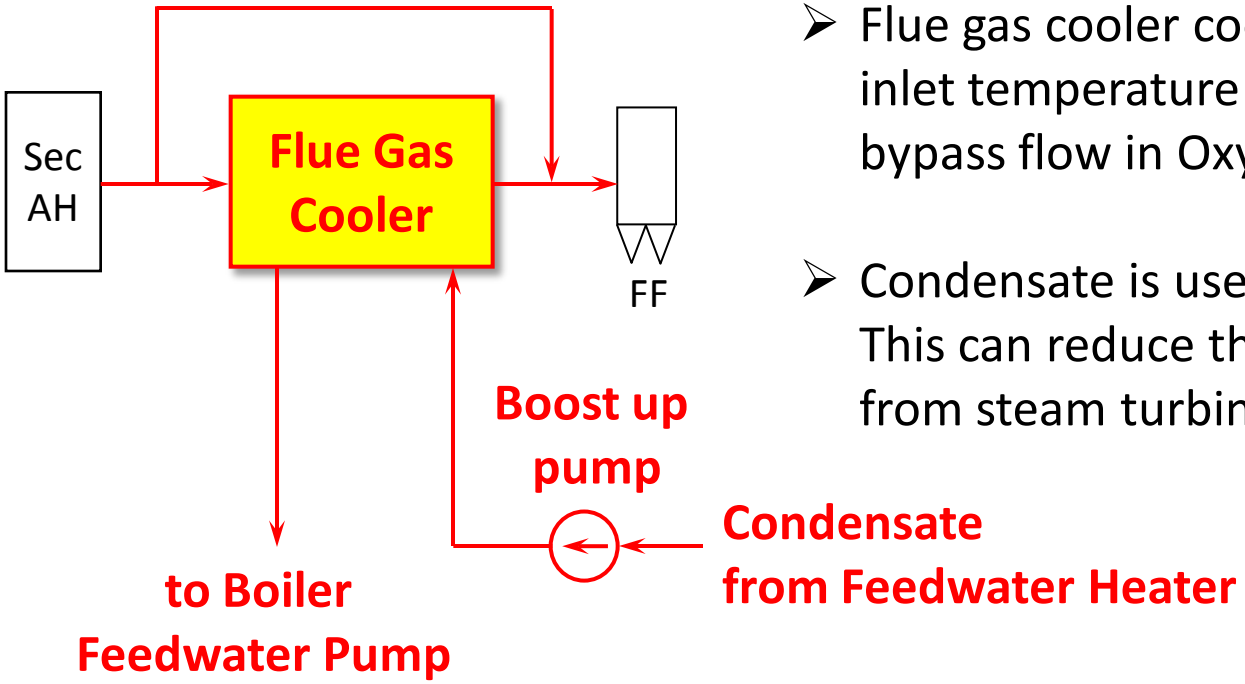


	H2O (vol% wet)	Temperature (degC)
FDF outlet	20	150
PAH outlet	8	350
SAH outlet	20	280

- To use Primary RFG for drying and delivery of pulverized coal and to prevent pulverized coal pipe from low temperature corrosion,
  - H2O remover reduces H2O in only Primary RFG and
  - Primary RFG is firstly heated in Primary Air Heater by flue gas.
- It is possible to conduct H2O remover bypass operation test.

6. Outline of Modification design

< Flue gas cooler and Condensate system >



- Flue gas cooler cools the flue gas to FF inlet temperature SV by regulating the bypass flow in Oxy mode.
- Condensate is used for cooling medium. This can reduce the extraction steam from steam turbine.

	Secondary AH outlet temperature	Flue Gas Cooler	FF inlet temperature
Air mode	150 degC	bypass	150 degC
Oxyfuel mode	230 degC	pass through	150 degC

6. Outline of Modification design

< Combustion control >

Combustion mode	Controlled variable	Manipulated variable
Air mode	Boiler outlet O2 conc.	Air flow rate
Oxyfuel mode	Boiler outlet O2 conc.	O2 flow rate
	Boiler inlet O2 conc.	Recycled flue gas flow rate

Oxyfuel combustion can control the furnace heat flux
by regulating the Boiler inlet O2 concentration.

< Oxygen flow matching with boiler side and ASU side >

	Philosophy
Boiler side	O2 consumption control & O2 demand signal to ASU
ASU side	Matching with O2 consumption and production

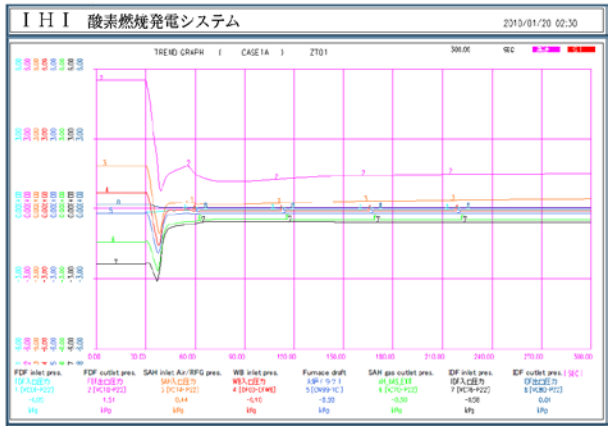
6. Outline of Modification design

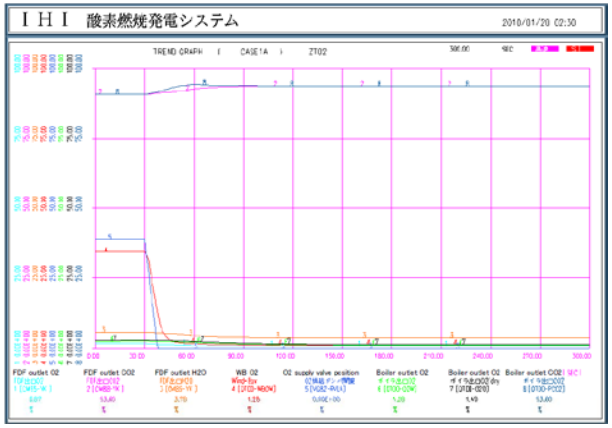
< Interlock >

Special consideration to the MFT event

- Furnace implosion
- Excessive oxygen supply ⇨ Furnace explosion
- CO2 leak to atmosphere

We confirmed the behavior after MFT by dynamic simulation study .

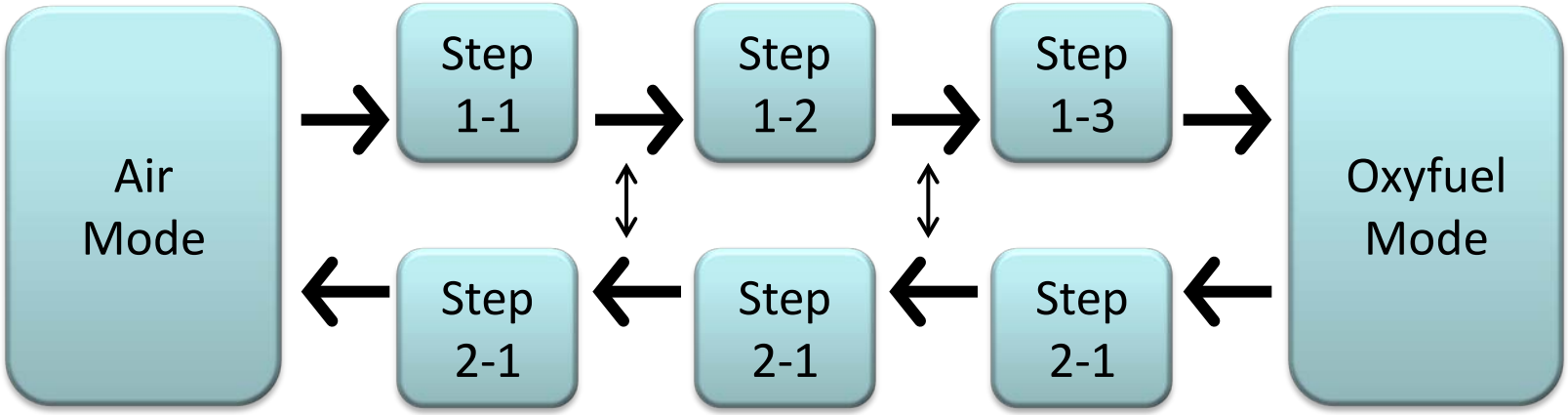




6. Outline of Modification design

< Air ⇔ Oxyfuel mode change >

- Air ⇔ Oxyfuel mode change with one push button
- Sequence run step by step
  - Completion of step kicks commencement of next step
- In case of jam, the step will stop.



6. Outline of Modification design

< Risk assessment by HAZOP study >

- COSPL conducts HAZOP study with IHI and the authorized facilitator.
- IHI conducts internal HAZOP study before COSPL's HAZOP study.

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	S	L	R	REF#	RECOMMENDATIONS	BY
More (cont.)	More Flow (cont.)	201. Secondary Air heater bypass D22 air damper fails open (cont.)	201.2. Decrease in secondary air temp and increase in Secondary Air Heater gas outlet temperature, leading to possible FF damage (cont.)	...design					Same As R-17 (cont.)	
		202. High mill air flow due to mill air flow control fails	202.1. Covered in PF Firing Node							
		203. High "in" leakage - ash hopper doors left open	203.1. Raises back end temp - Air Heater temperatures, loss of efficiency, possible load reduction	Operator surveillance High steam or metal temperature alarms provided	1	D	L			
		204. Loss of dip seal	204.1. Raises back end temp - Air Heater temperatures, loss of efficiency, possible load reduction	Operator surveillance Furnace high pressure alarm provided	1	D	L			

< Risk reduction on the basis of SIL >

- COSPL conducts SIL study with IHI and the authorized facilitator.
- Boiler protection system is designed on the basis of the result of the SIL study.

7. Commissioning in Air mode

23 March 2011	- First fire on fuel oil (diesel)
01 April 2011	- Turbine to 3000rpm
11 April 2011	- First coal fire in the furnace
13 April 2011	- First synchronization
17 May 2011	- Full load (30MWe)
14 July 2011	- Completion of Air commissioning

Major confirmed items in Air combustion commissioning

- Draft balance tuning
- MFT test
- Combustion tuning
- Load swing

Now some modification is conducted considering the result of Air commissioning.
Commissioning in Oxyfuel combustion will commence about the end of this year.

8. Oxyfuel Demonstration

Major Oxyfuel combustion test (assumed)

- ✓ Boiler inlet O2 concentration change test
- ✓ Boiler outlet O2 concentration change test
- ✓ Minimum load
- ✓ Load swing
- ✓ MFT test / Fan trip test
- ✓ Reliability run (Continuous running)
- ✓ Coal change test

Other confirmation item of Control and Measurement

- ✓ Controllability of boiler inlet / outlet O2 concentration
- ✓ Minimization of Air ⇔ Oxyfuel mode change time
- ✓ O2 monitor and CO2 monitor accuracy
- ✓ Flow meter accuracy
- ✓ Flame detector performance

8. Oxyfuel Demonstration

< Major confirmation & verification items>

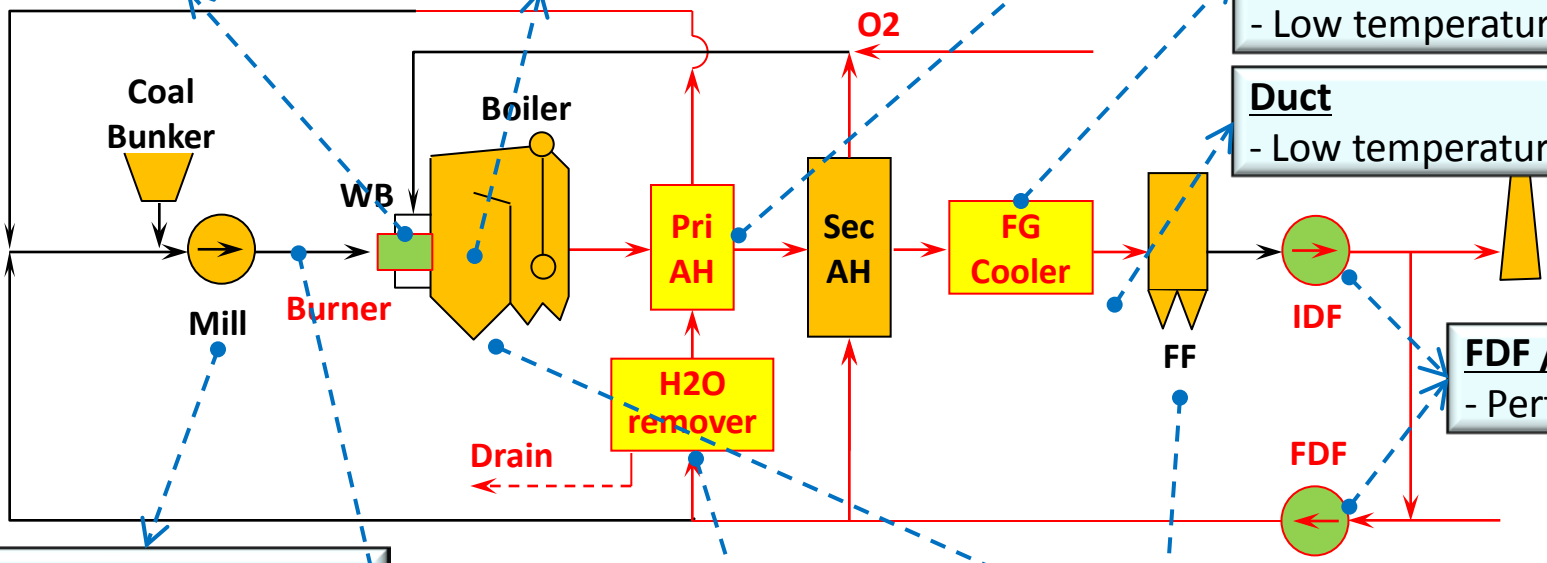
Burner
- Flame stability / Ignitability
- Flame temperature
- Effect of direct O2
- Flame detector

Boiler
- Heat flux
- Slugging / Fouling / Clinker
- Gas temperature / Metal temperature
- Corrosion

Primary air heater
- Performance
- Low temperature corrosion

FG Cooler
- Performance
- Low temperature corrosion

Duct
- Low temperature corrosion



FDF / IDF
- Performance

Mill
- Fineness / Dryness
- Mill exit temperature

Pulverized coal pipe
- Erosion / Low temperature corrosion
- Transport performance

H2O remover
- Dewatering performance

H2O remover outlet duct
- Sulfuric acid corrosion

Bottom ash and Fly ash
- Amount
- Component
- Carbon in ash
- Ash distribution

9. Conclusion

IHI shall conduct the followings in cooperation with COSPL.

- Completion of Oxyfuel combustion commissioning as soon as possible
- Steady implementation of the scheduled Oxyfuel combustion test
- Storage of the knowledge and Feedback to future plants

Thank you for your kind attention!

And special thanks to COSPL

Callide Oxyfuel Project