1st Oxyfuel Combustion Conference

September 10, 2009

Oxyfuel retrofit to coal power plant (Part1)
- FS of 500MW class plant

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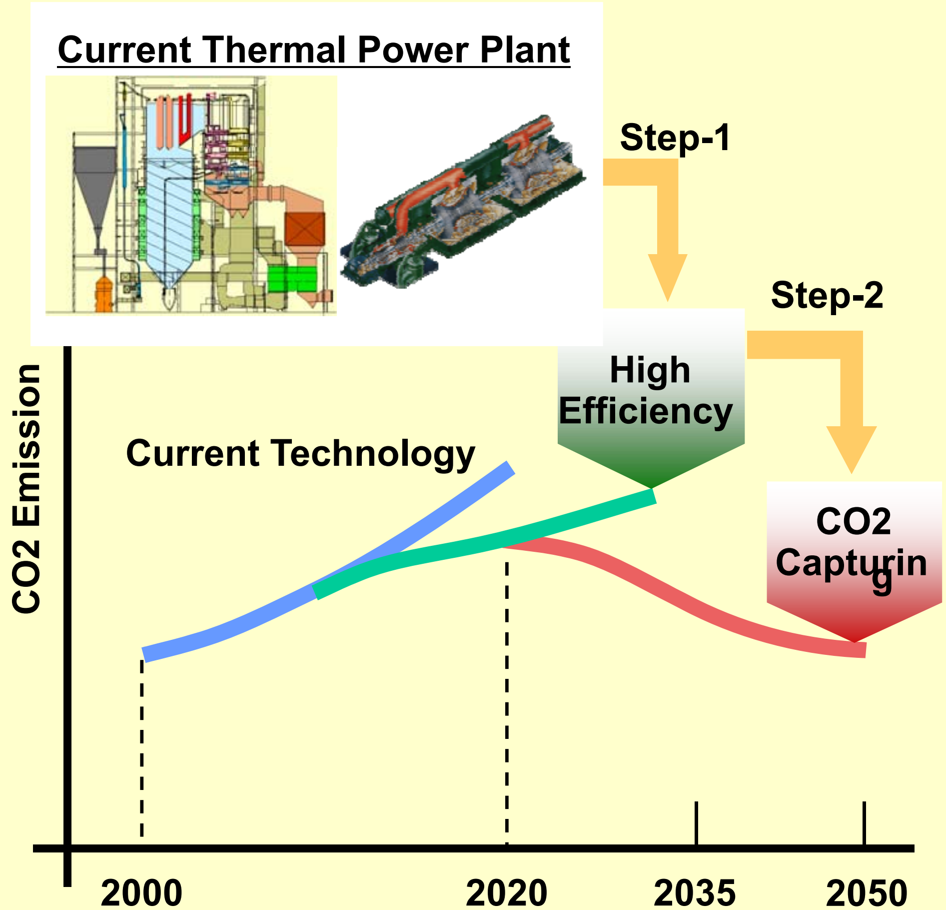
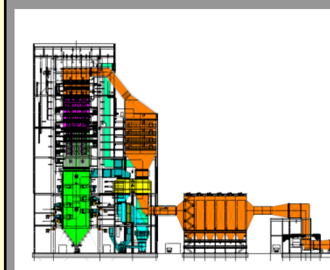
Contents

1. Introduction

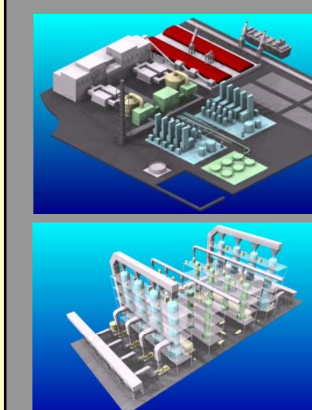
- Hitachi has been developing CO_2 capturing technologies;oxy-fuel combustion, scrubbing, IGCC
-For Oxy-fuel combustion, Hitachi and Fortum are carrying out feasibility studies for retrofit of 500MW class coal fired boiler and combustion tests using 4MWth furnace.





High Efficiency

-700C A-USC
-IGCC



CO_2 Capturing

- OxyfuelCombustion
- Scrubbing
- IGCC-CO_2

CCS approach of Hitachi

2.1 Development Subjects in Oxyfuel Combustion

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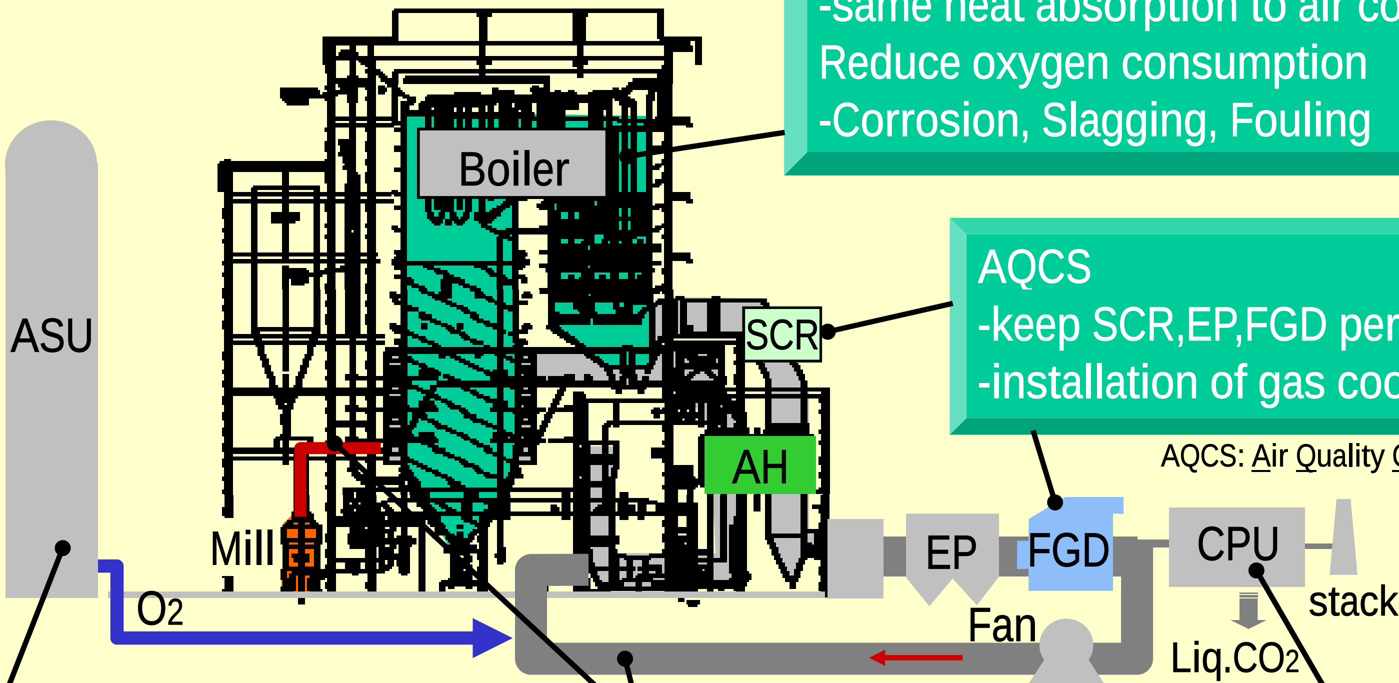
This Study

Boiler
High radiation intensity: CO_2, H_2O
-same heat absorption to air combustion
Reduce oxygen consumption
-Corrosion, Slagging, Fouling



AQCS
-keep SCR,EP,FGD performance
-installation of gas cooler

AQCS: Air Quality Control System

ASU
-reduce initial cost
-reduce power consumption
compact & low power

Mill outlet pipe
-keep temperature 70 – 90 C
Re-circulation line
-reduce corrosive gas: SO_3

CPU
-reduce corrosion potential (SO_3, Cl etc)
-reduce power consumption
compact & low power

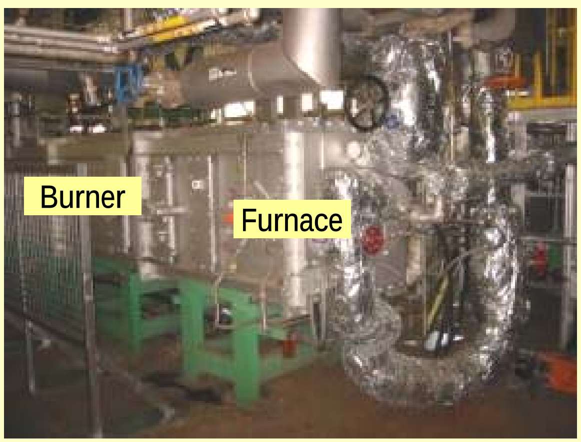
ASU: Air Separation Unit

CPU: CO_2 Compression and Purification Unit

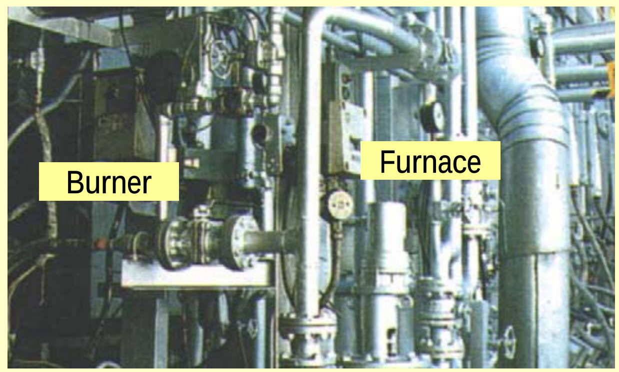
Fundamental study
- Laboratory test
- Basic combustion test
  (0.4MWth test facility)

Verification study
- Large scale combustion test
  (4MWth test facility)
- Total system check
  (1.5MWth test facility)

Feasibility study
- Trial design of actual plant
  Retrofit, New
- Cost evaluation



0.4MWth test facility



4MWth test facility

1.5MWth test facility

1) Trial design
- System flow
  (Process analysis)
- Equipments design
  (Numerical analysis)
- Control system
  (Dynamic analysis)

2) Cost evaluation
- Initial cost
  (Construction, Equipment)
- Running cost
  (Utility check)

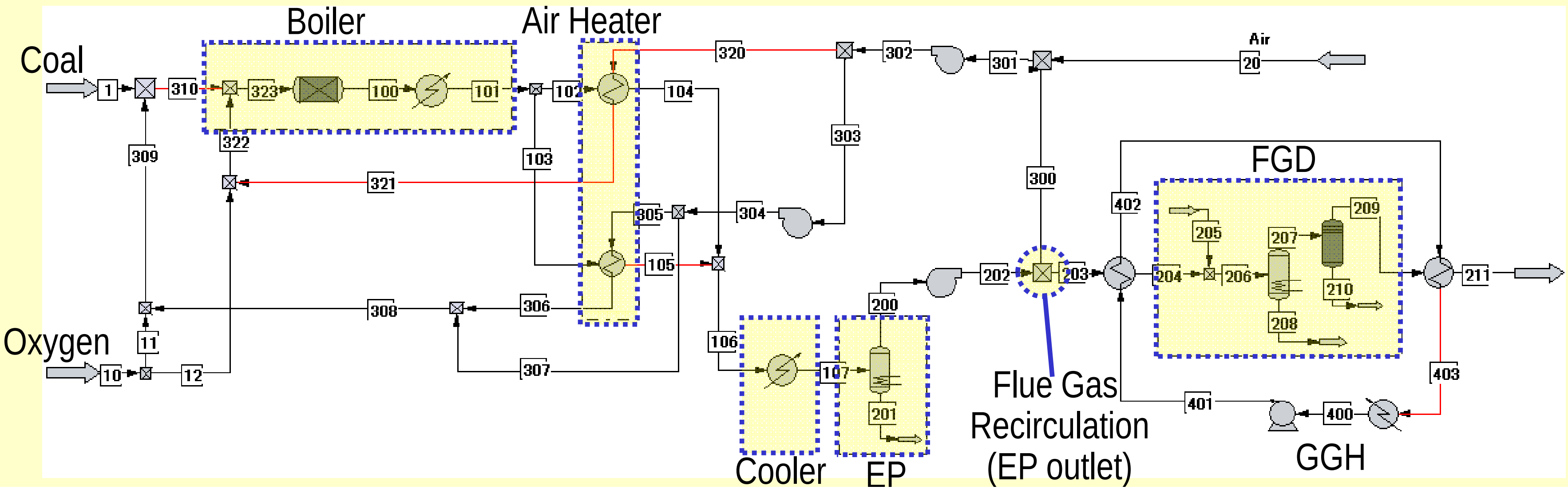
2.3 Subjects and measures in Oxyfuel Combustion

Fortum

HITACHI
Inspire the Next

No.	Item	Subjects	Measures	Method
1	Total system	Safety operation	Alert and protection system	Dynamic control analysis(MATLAB)
		Heat loss reduction	Optimization of gas re-circulation point	Process Simulator (CHEMCAD)
2	Boiler (Combustion, Heat transfer)	Adapt to a current (air comb.) boiler to oxyfuel comb.	Same heat absorption to air combustion	Combustion test (0.4MWth,4MWth) Numerical analysis (CRAFT)
		Burner stability	Burner development	Combustion test (4MWth)
		Mill stability	Reduction of mill line O_2	bench scale mill test
3	AQCS	Adapt to a current (air comb.) AQCS to oxyfuel comb.	-Keep SCR, EP, FGD performance -installation of gas cooler	Combustion test (0.4MWth,1.5MWth)
4	Gas re-circulation System	Anticorrosion	Reduce corrosive gas: SO_3	Process Simulator (CHEMCAD) Combustion test (4MWth,1.5MWth)
5	ASU, CPU	Compact and low power	Capacity up	Feasibility study

Material and Heat Balance Evaluation by Modeling Oxy-fuel Combustion System



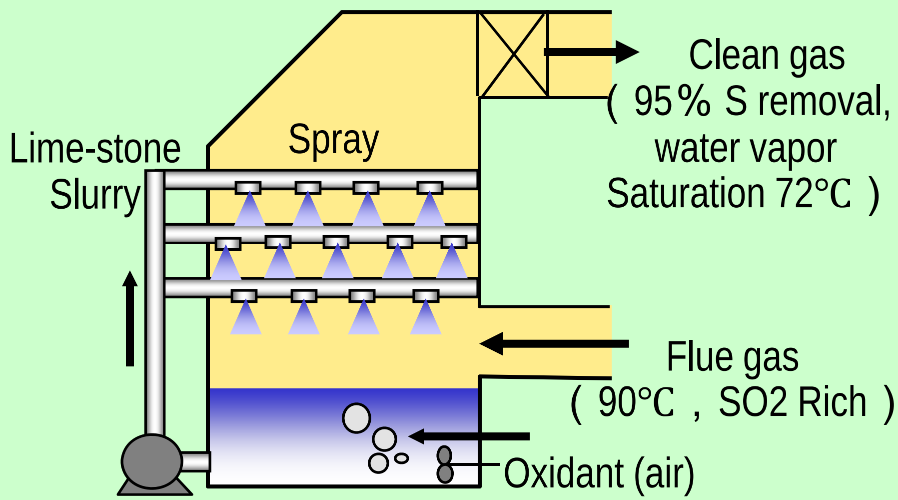
Utility	unit operation	Approach to modeling
Boiler	Gibbs reactor, Heat exchanger	SPEC. : Eco outlet gas temperature (364deg-C) CALC. : Adiabatic flame temperature, Boiler heat input
Air Heater	Heat Exchanger	SPEC. : Heat transfer area, Overall heat transfer coefficient.
Cooler	Heat Exchanger	SPEC. : Outlet gas temperature CALC. : Heat exchanger duty
EP	Component Separator	Dust removal (99%)
FGD	Mixer, Component Separator, Flash	Desulfurization rate (95%), Evaporation, Vapor-Liquid separation

-in view point of boiler output, SO3 content, ash, gas cooler power and FGD handling gas amount

3.1 System Analysis Method (FGD modeling)

- Essential unit operations were chosen from CHEMCAD defaults
- FGD model is configured by connecting them

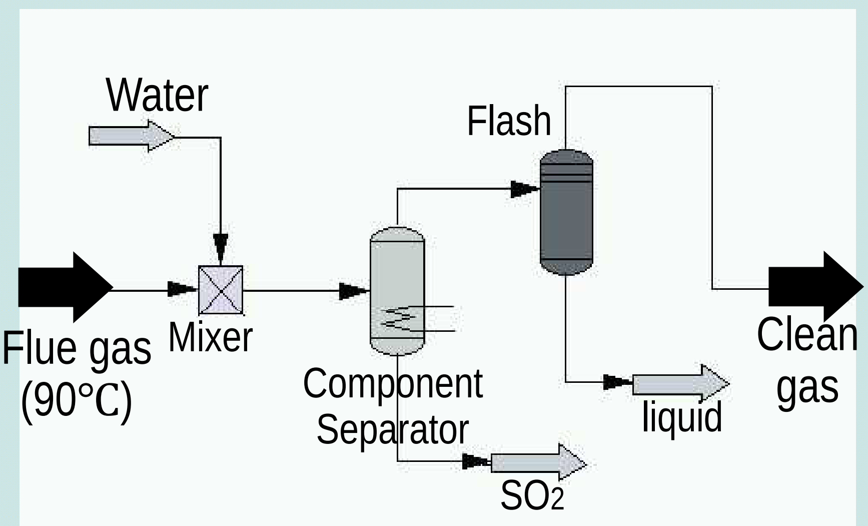
FGD (limestone-gypsum process)



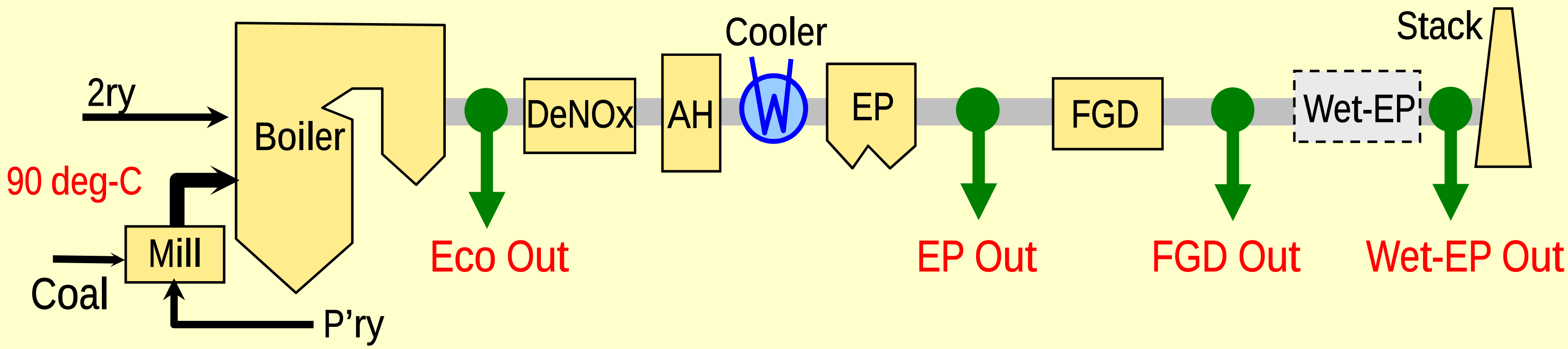
FGD

SO_2 absorbed by spraying slurry, oxidized, neutralized and fixed as gypsum

FGD Model on CHEMCAD



Mixer	Saturated by water
Component Separator	95% (partition coefficient) SO_2 removal
Flash	liquid-vapor separation



No.	Oxidant	GR point (@exit)		+Cooler
		2ry(Combustion Air)	P'ry(Mill Air)	Temp. deg-C
A-1	Air	N	N	N
O-1	Oxygen	EP	EP	N
O-2	↓	EP	EP	140
O-3	↓	EP	FGD	↓
O-4	↓	FGD	FGD	↓
O-5	↓	Eco	FGD	↓
O-6	↓	Eco	Wet-EP	↓
O-7	↓	EP	EP	90
O-8	↓	EP	FGD	↓
O-9	↓	Eco	EP	↓
O-10	↓	Eco	FGD	↓

*GR:Gas recirculation

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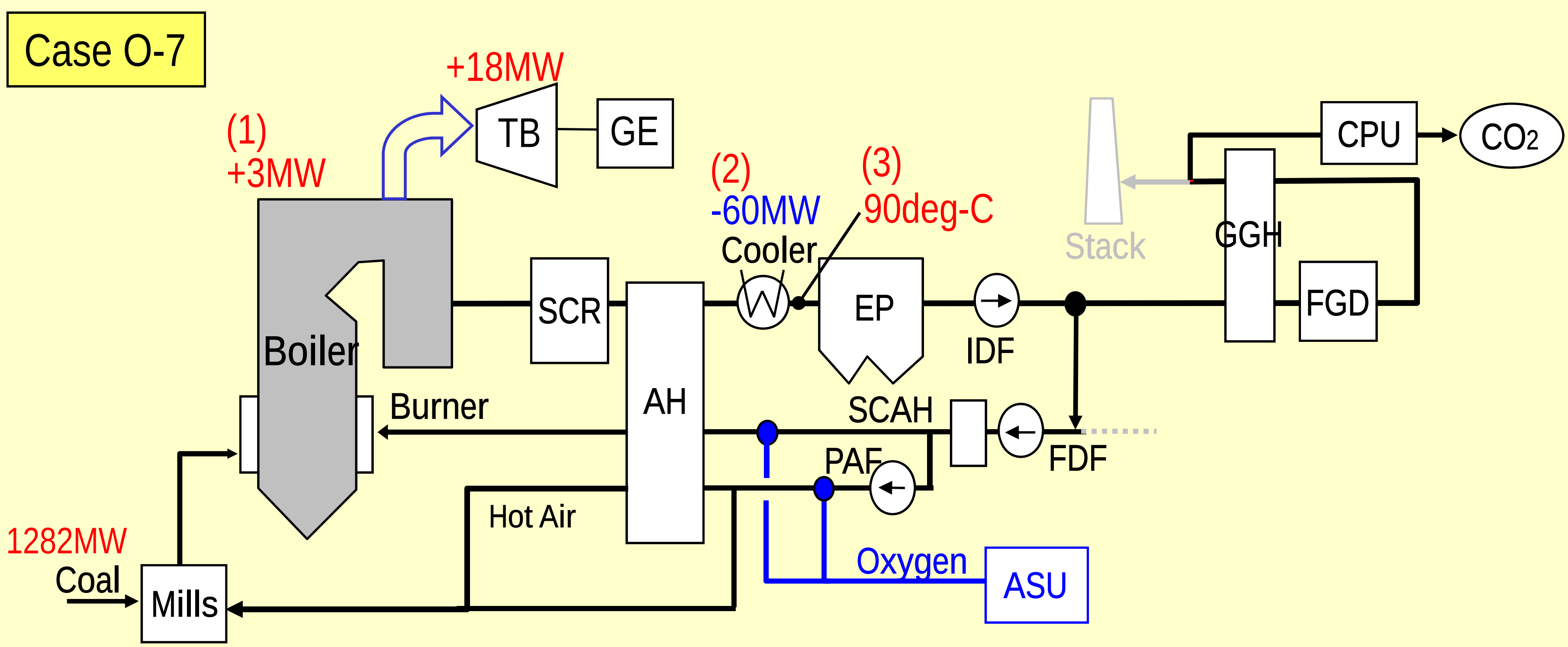
(1) Same boiler output to air combustion
(2) LP turbine power increases because cooler preheats feed water
(3) SO_3 removal with 90 deg-C cooler



3.2 Result of FS(2) ; SO_3 Removal

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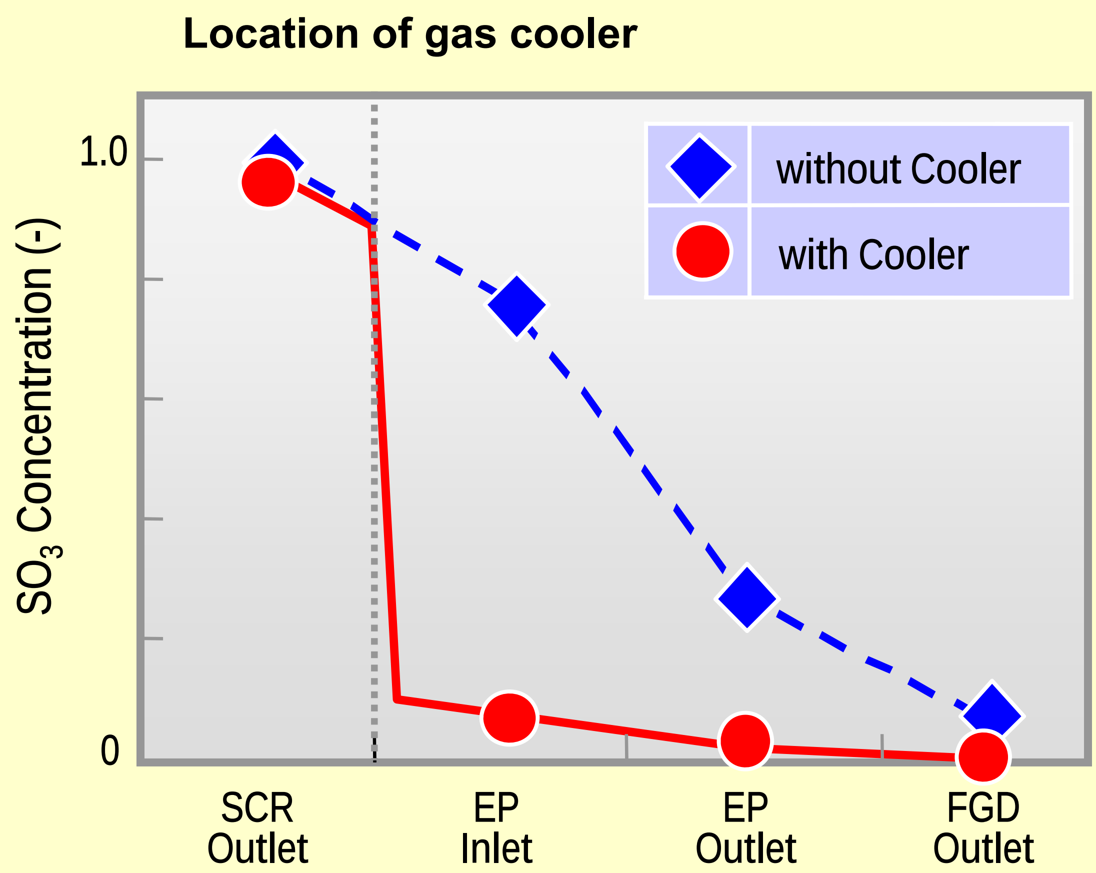
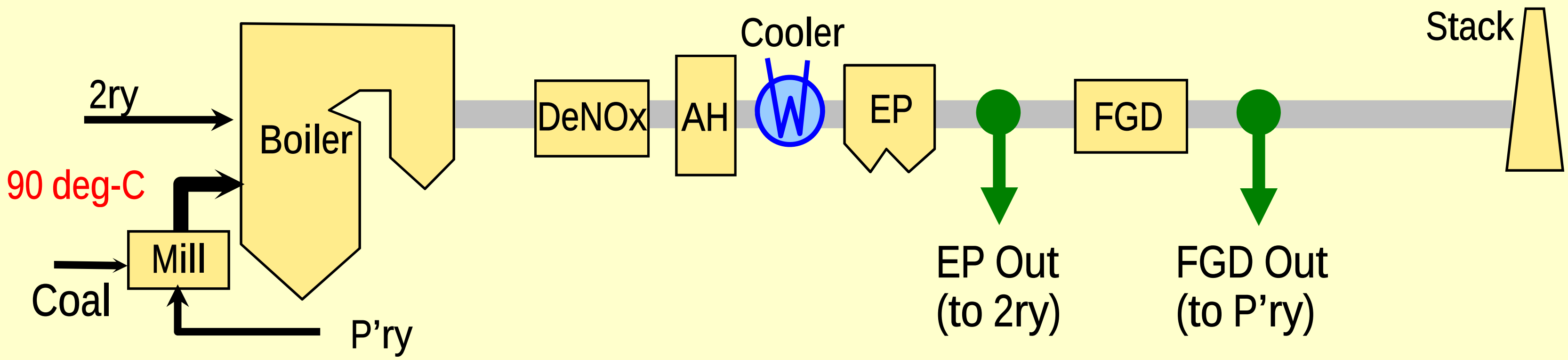
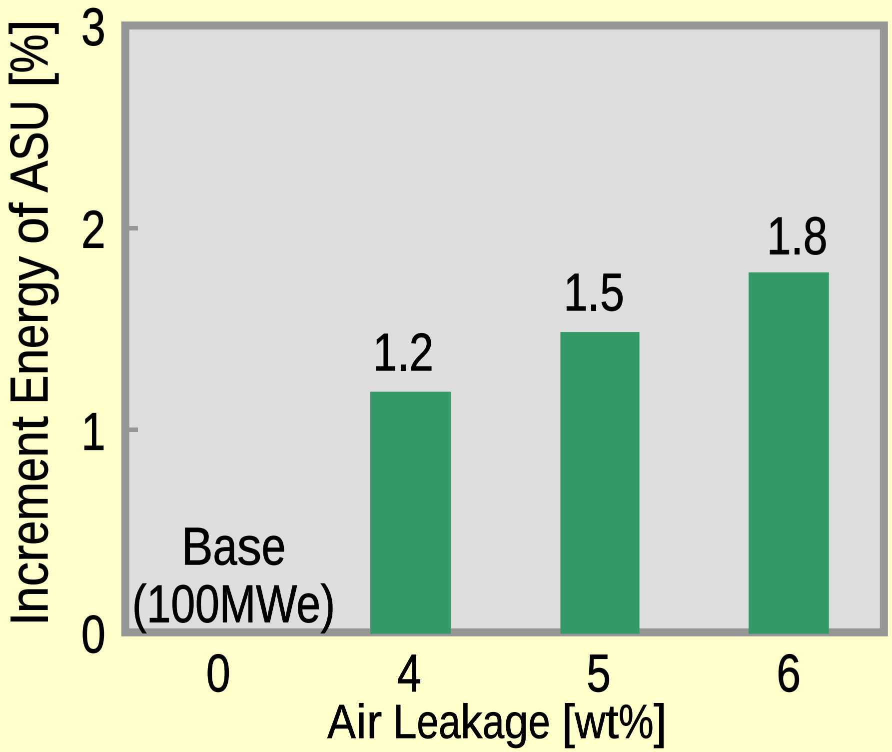
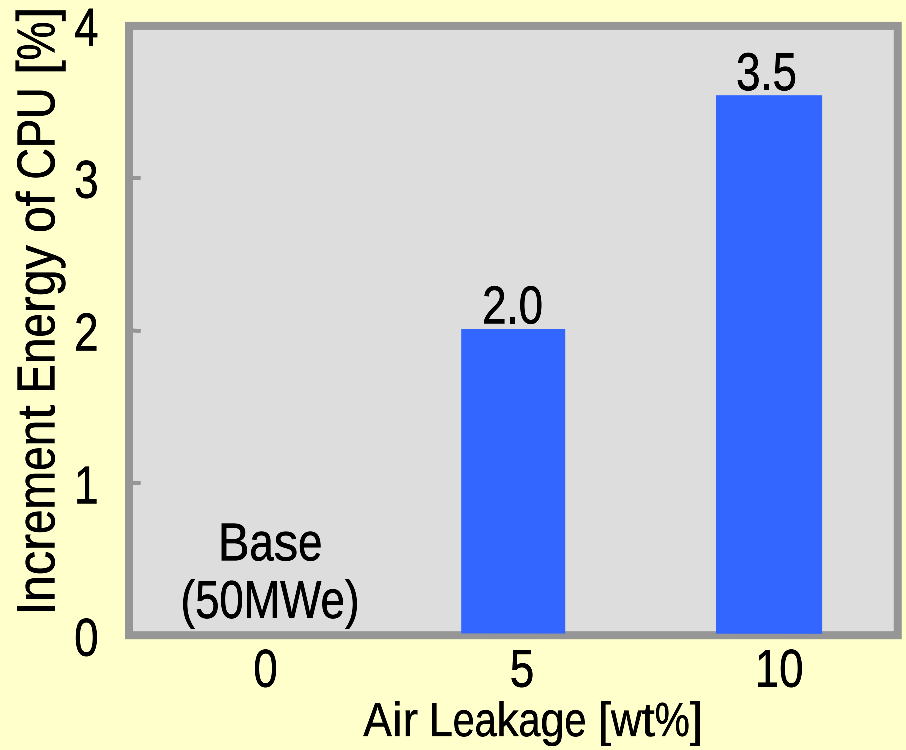
- Below acid dew point (<160C) ,SO_3 in flue gas change to mist
- Mist stick to ash and are neutralized by alkali contained in ash
- Ash are caught with EP



3.2 Result of FS(3) ; Air Leakage

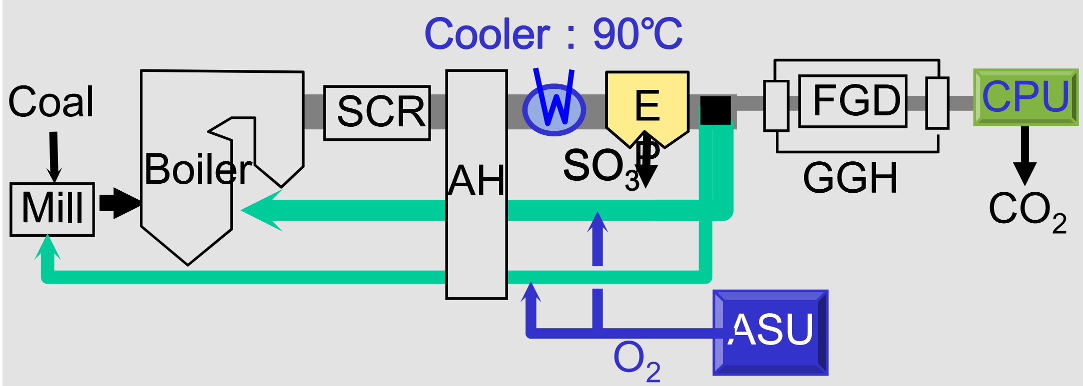
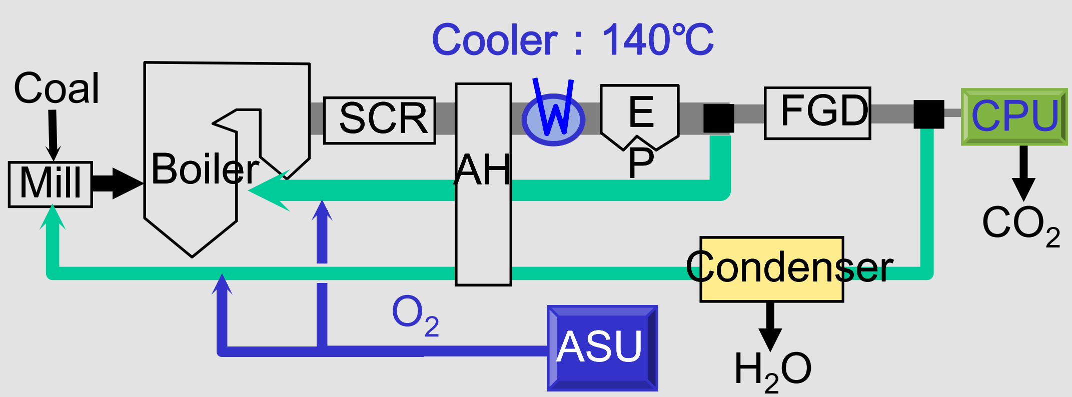






ASU : Specific energy of production=0.35kWh/Nm^3-O_2 [@0℃,1atm] , CPU : CO_2 recovery 90%

3.2 Result of FS(4) ; Efficiency

<table>
<tr><th rowspan="2">Co.</th><th rowspan="2">System Flow</th><th>Heat Transfer</th><th>SO_3</th><th>Water</th></tr>
<tr><th>MWth</th><th>ppm</th><th>%</th></tr>
<tr><td>BHK
(O-7R)</td><td>
</td><td>1183</td><td>< 5</td><td>30</td></tr>
<tr><td>Others
(O-3)</td><td>
</td><td>1163</td><td>< 5</td><td>10</td></tr>
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3.3 Numerical simulation(1); Tool (CRAFT)

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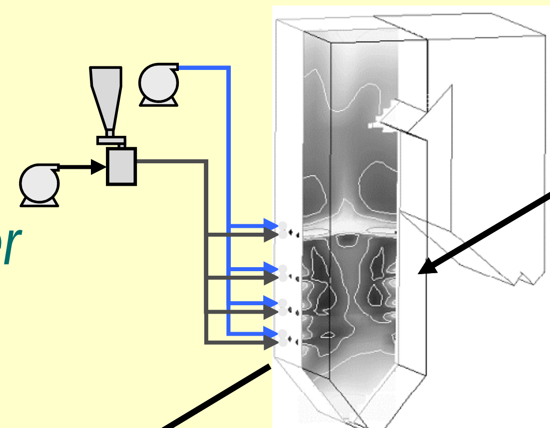
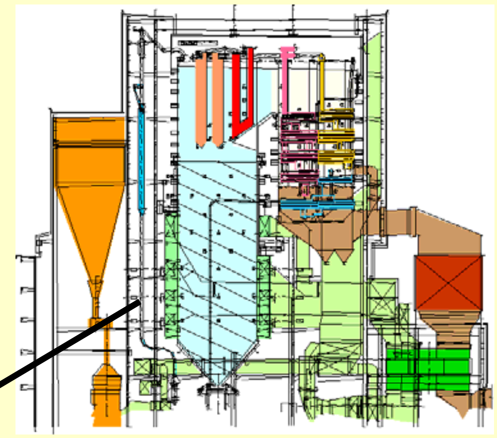
Original simulation models

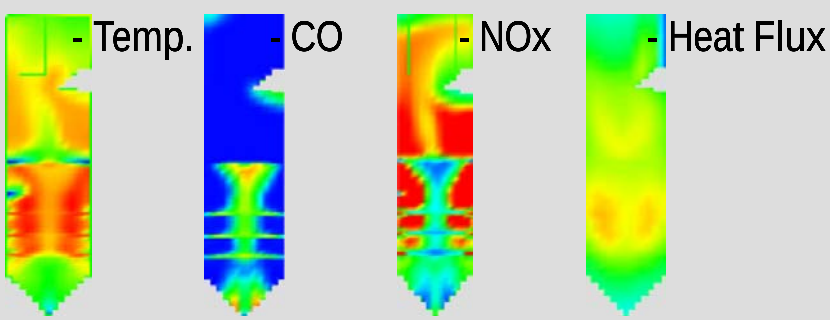
1. Char gasification model
2. Hydrocarbon NOx reduction model
3. Multi-grid discrete transfer radiation model

CRAFT;
Combustion,
RAdiation and water
Flow simulation
Tool



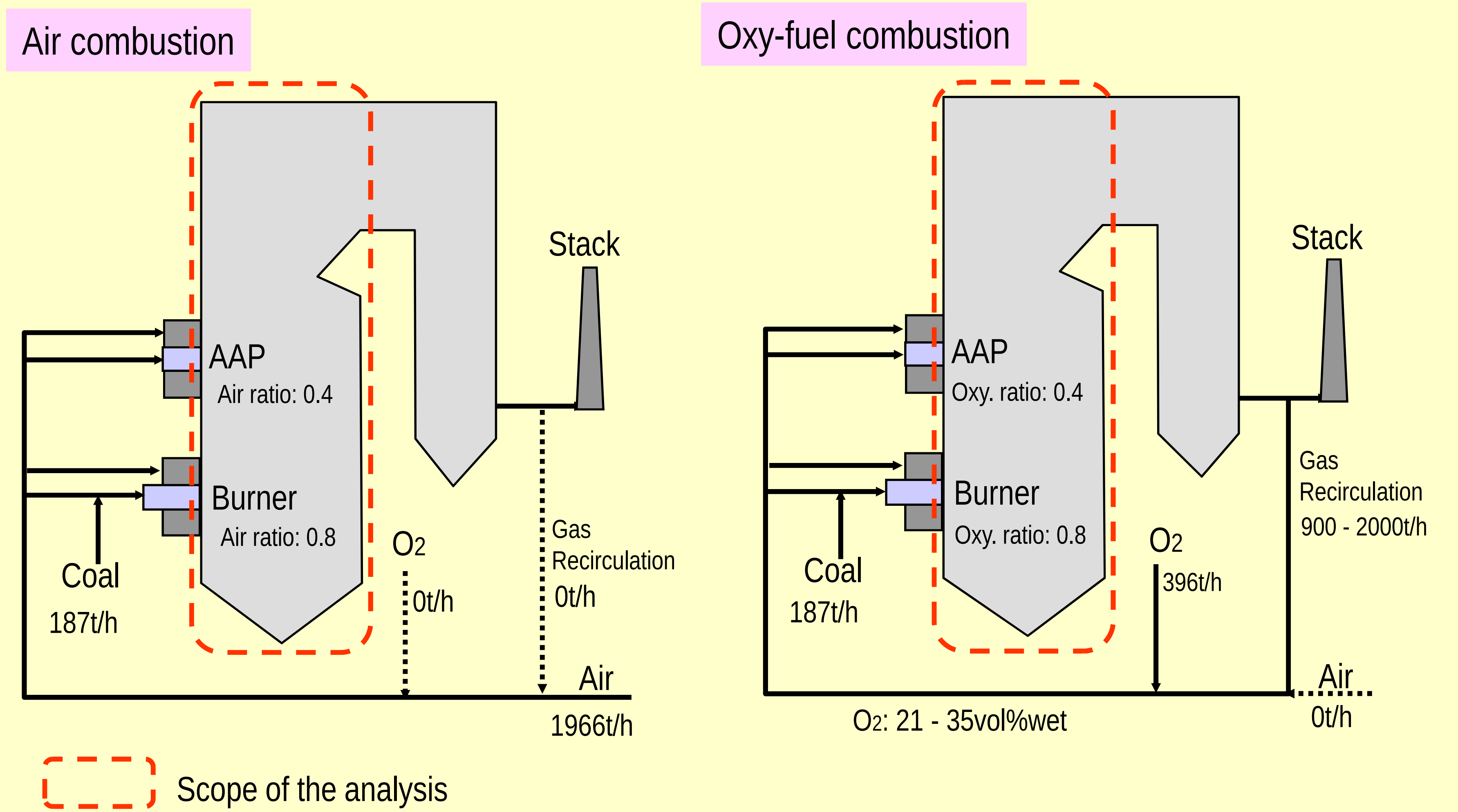


Predicted performances lead to technical solutions

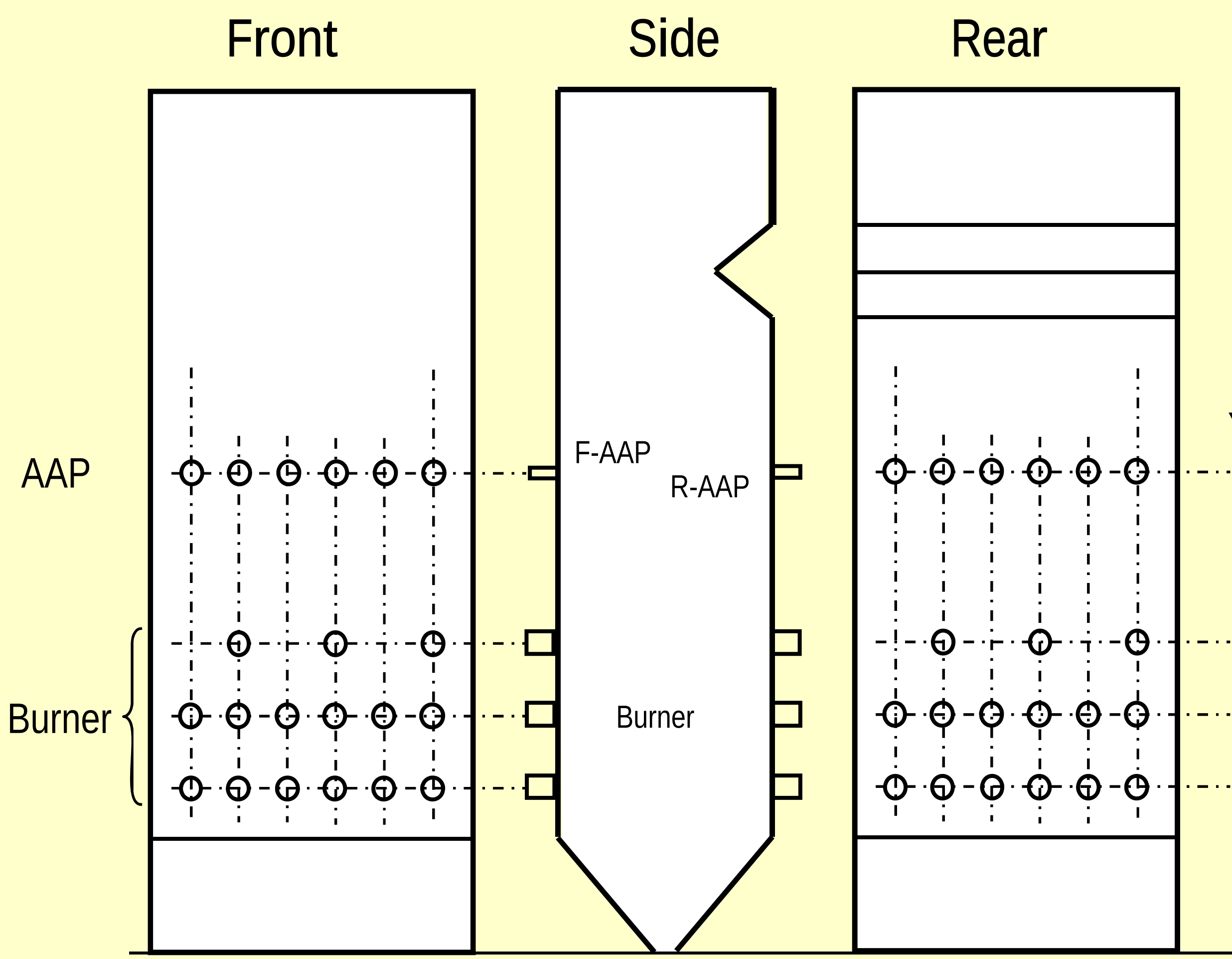


- VOC emission
- Unburned carbon
- Burner blowing off
- Furnace exit gas temperature
- Slagging
- H_2S and SO_2 corrosion

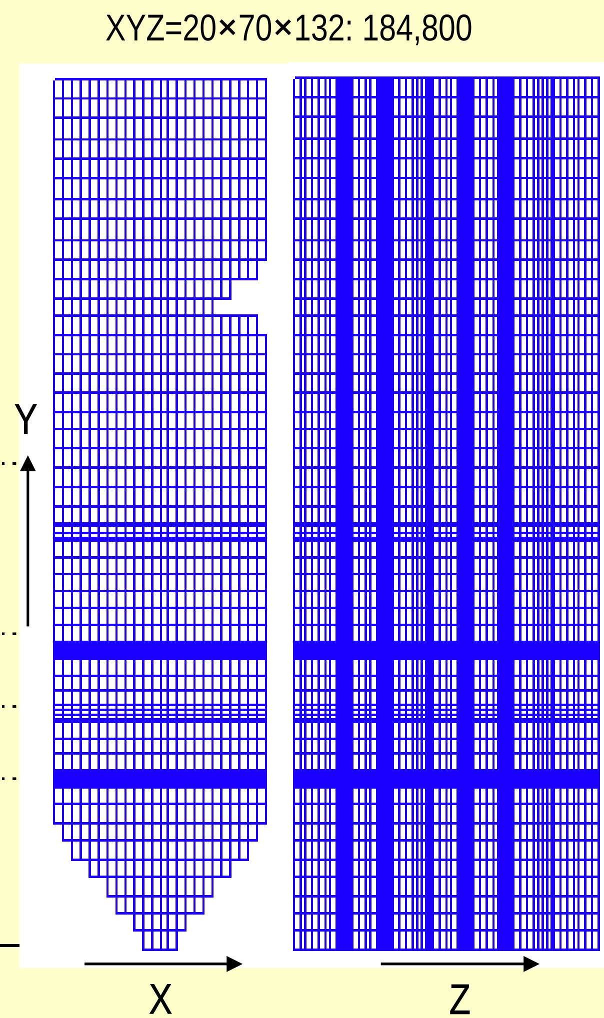
Comparison between air combustion and oxy-fuel combustion.
Parameter: O_2 concentration 21-35vol%wet



3.3 Numerical simulation(3);



Structure



Grid of the analysis

(1) HHV	kJ/kg	26,691
(2) Proximate analysis		
Total moisture	WT%wet	11.80
Fixed carbon	WT%wet	46.80
Volatiles	WT%wet	32.50
Ash	WT%wet	8.90
(3) Ultimate analysis		
C	W T %dry	81.99
H	W T %dry	5.62
O	W T %dry	9.94
N	W T %dry	0.87
S	W T %dry	1.58

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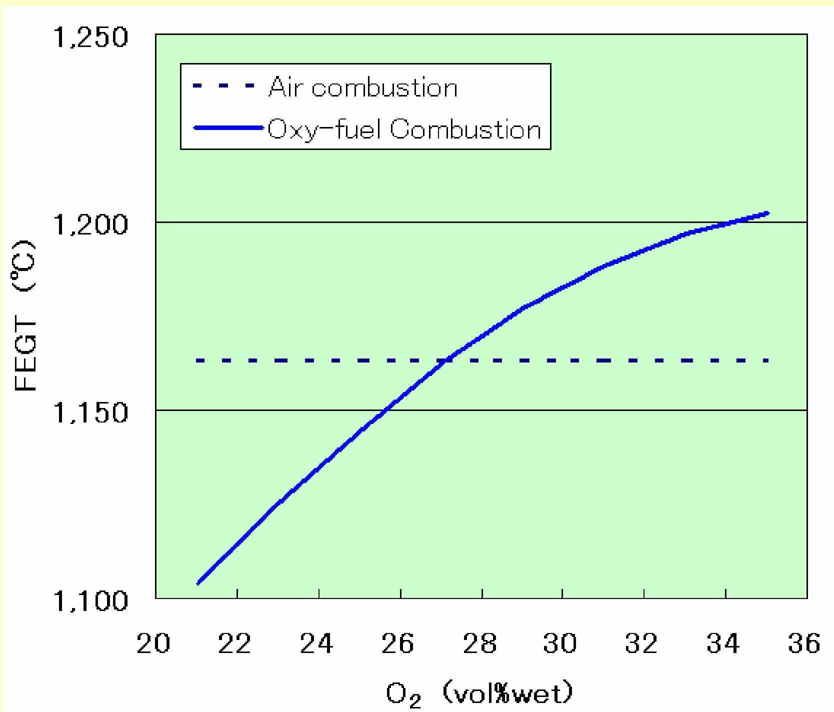
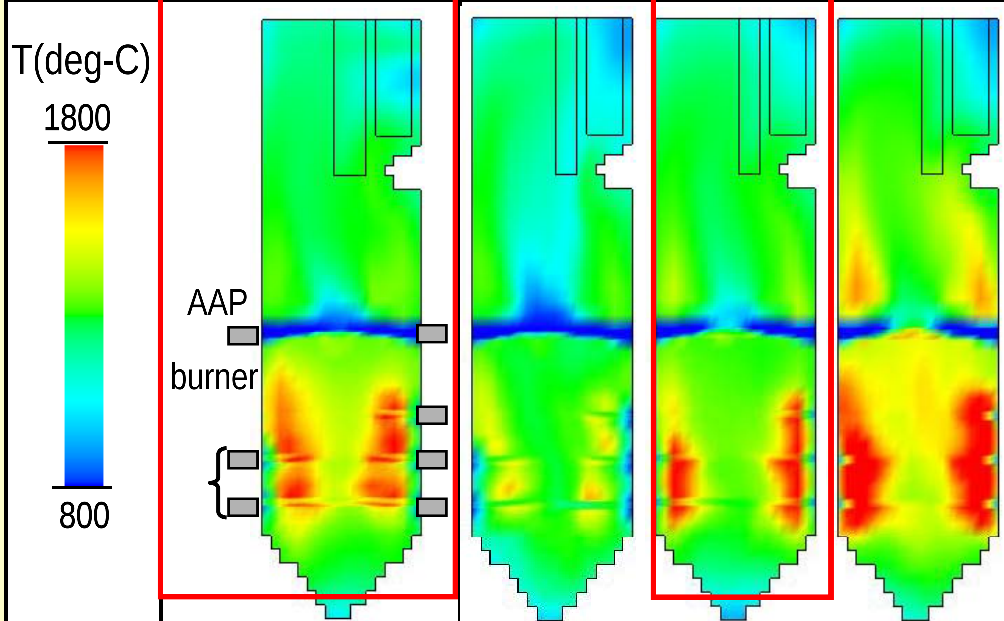
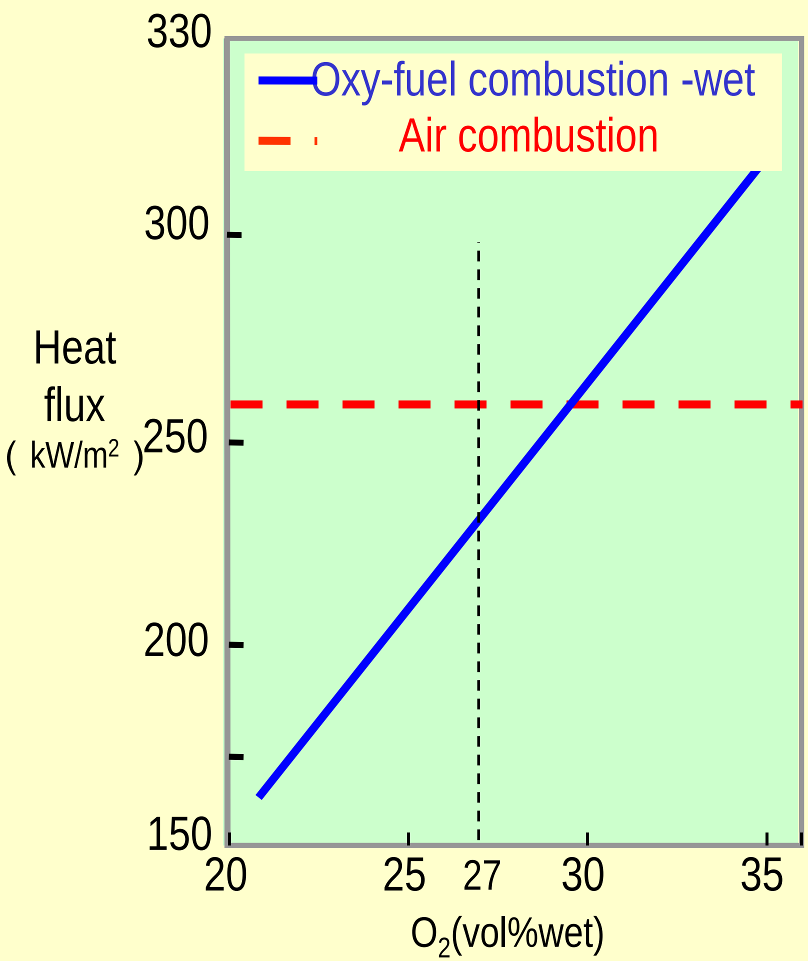
Oxyfuel combustion at O_2=27 ~ 30 vol%-wet take same heat absorption as Air.

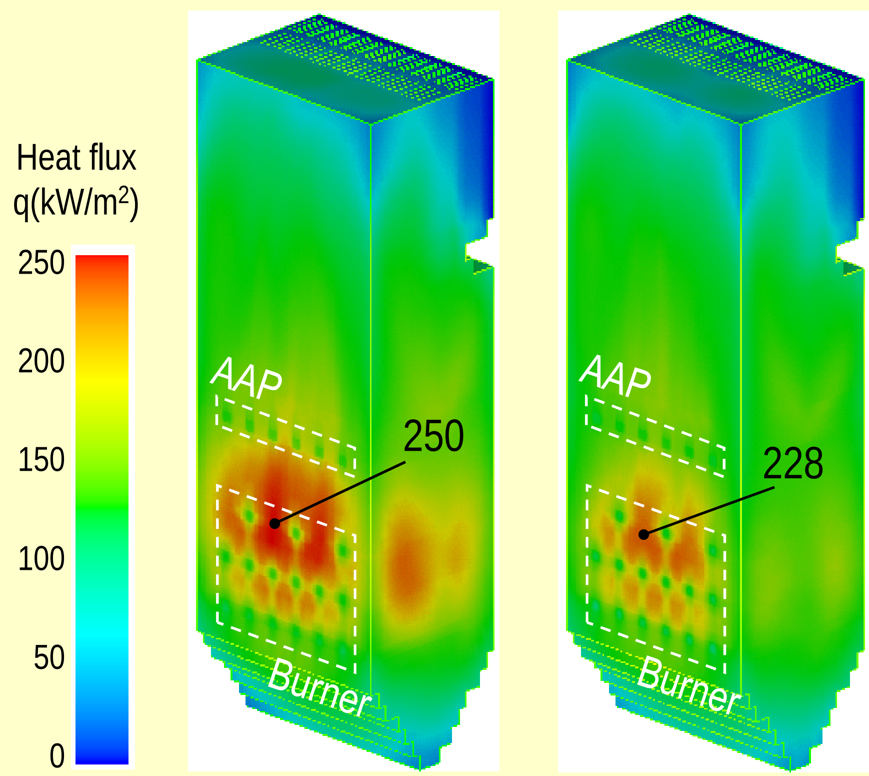


	Air combustion	Oxyfuel combustion (wet GR)		
O_2(vol%)	21	21	27	35
FEGT (deg-C)	1163	1104	1163	1202



Air combustion > Oxy-fuel combustion at O_2:27vol%wet

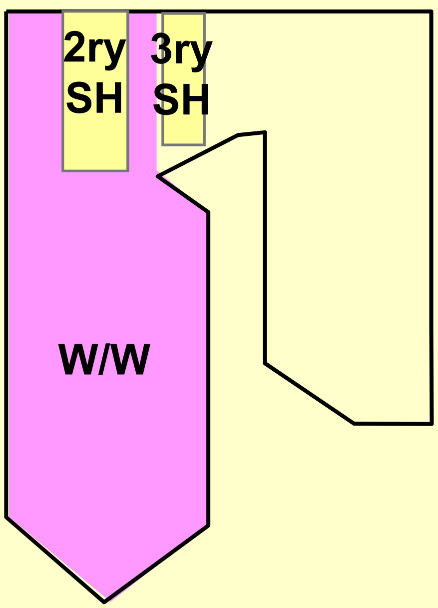




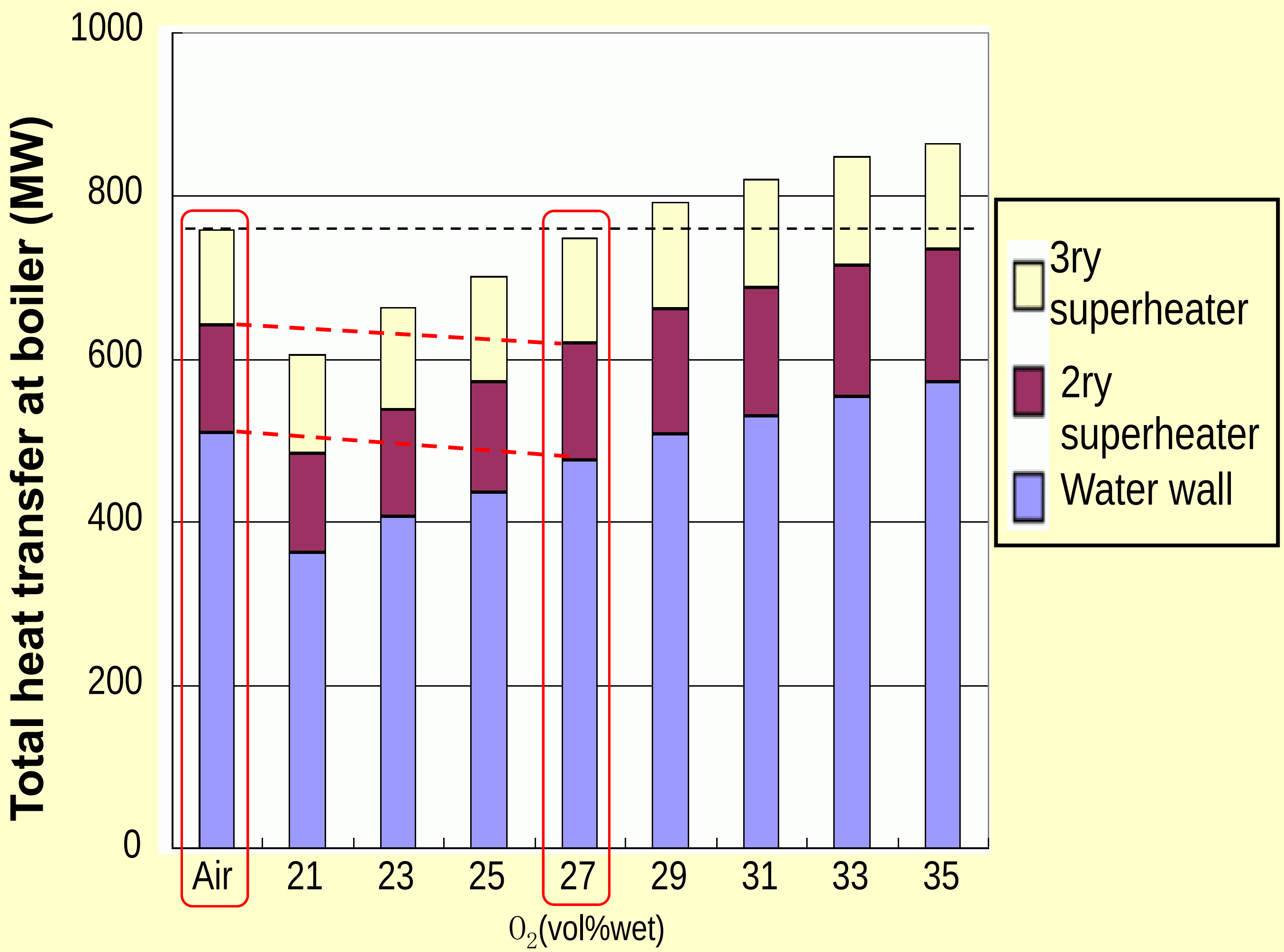
Air combustion

Oxy-fuel combustion
(O_2: 27vol%wet)

Air combustion ≒ Oxy-fuel combustion at O_2:27vol%wet



Structure of calculated boiler (500MW class)



3.4 Safety Operation at Oxy-Fuel Combustion

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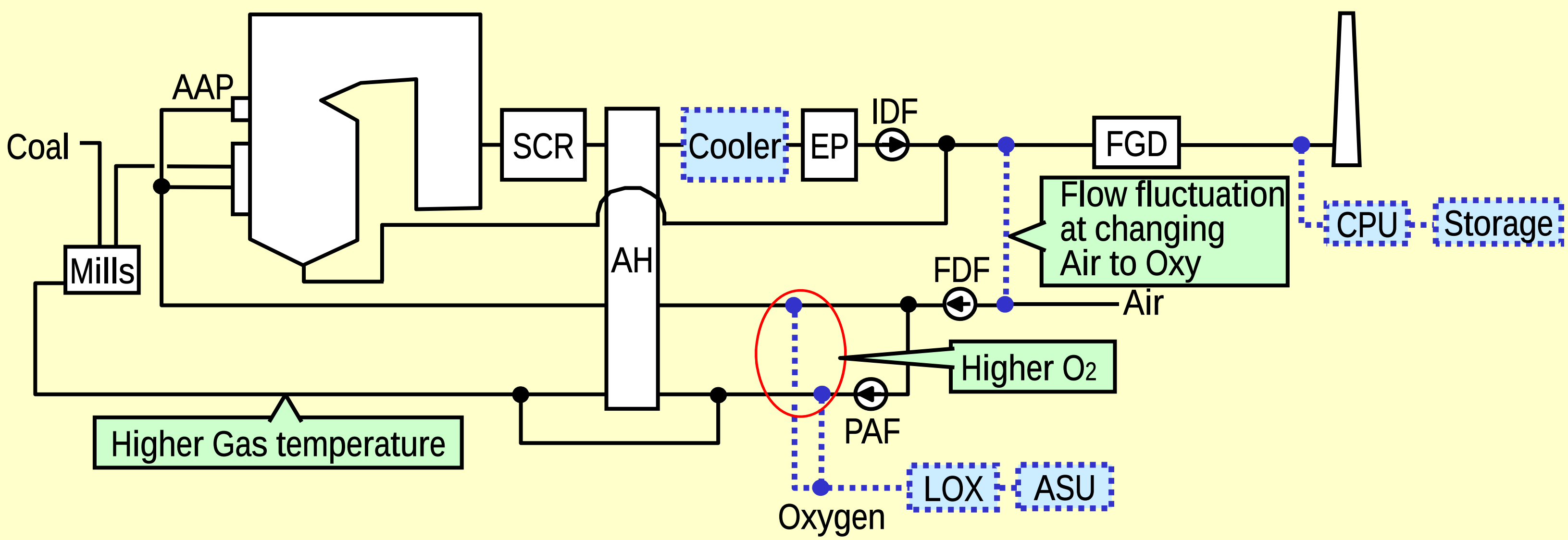
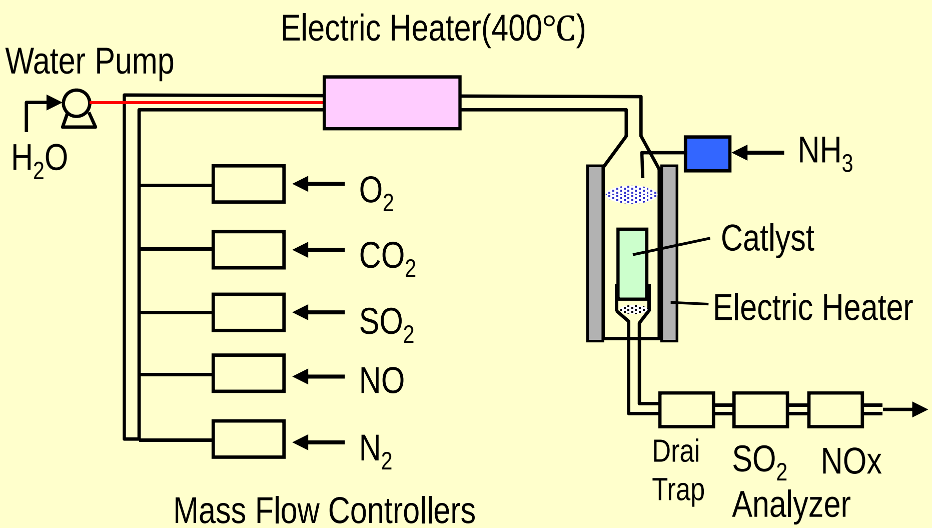
No.	Item	Malfunction	Problem	Protection
1	O_2 / Primary gas ratio (O_2 concentration)	Too high	Fire in mill	According to deviation from set value, alert and protection actions will be initiated 1. Alert 2. Interlock action (Trimming O_2 flow or recirculation gas flow) 3. MFT (Shut down of fuel and O_2 supply)
		Too low	Flame instability	
2	O_2 / Comb. gas ratio (O_2 concentration)	Too high	Undesired combustion	
		Too low	Flame instability	
3	FDF	Trip	High O_2 concentration in primary gas and combustion gas consequently fire in mill and undesired combustion	MFT (Shut down of fuel and O_2 supply)
4	PAF			
5	IDF			

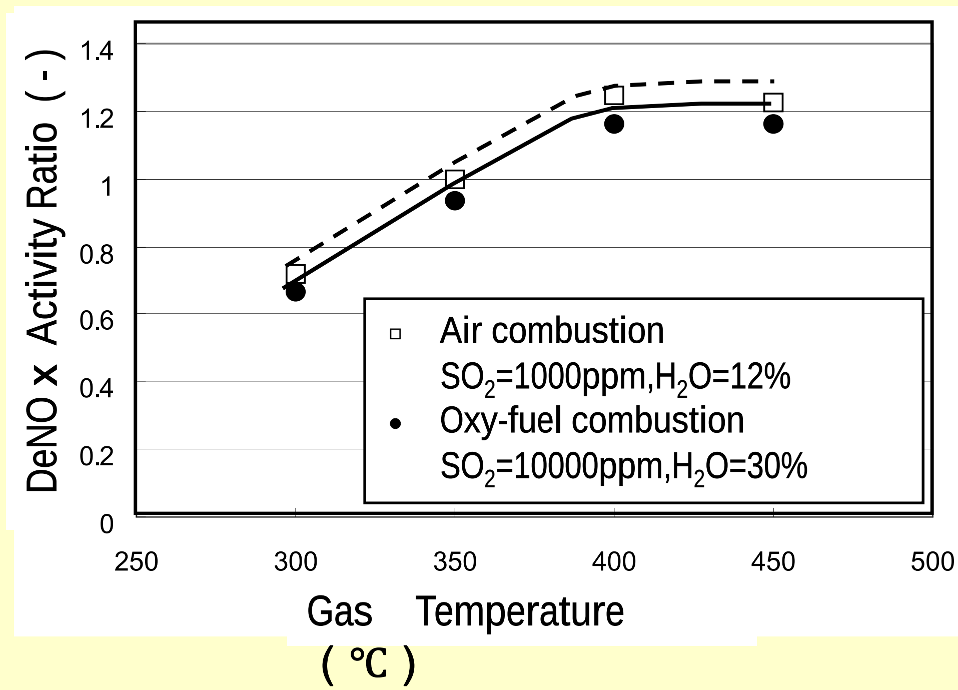
MFT: Master fuel trip



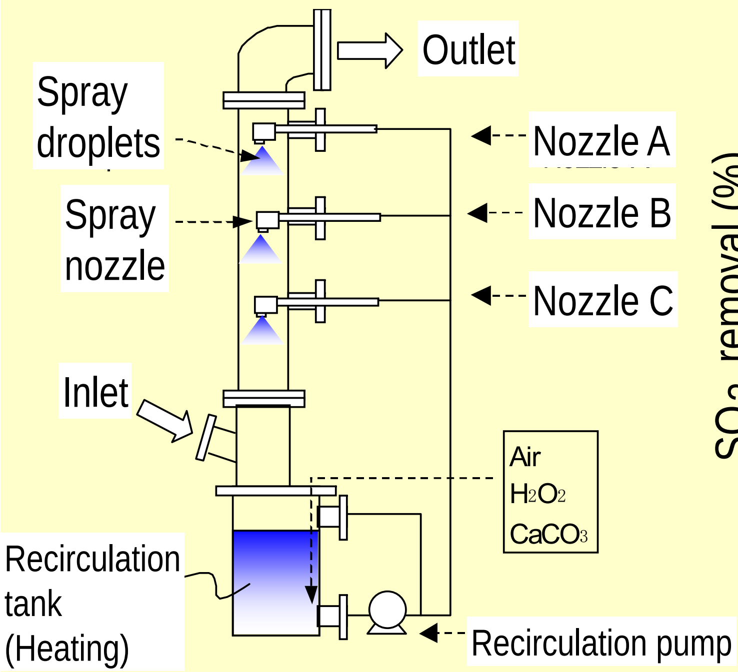
3.5 AQCS system(1) ; SCR

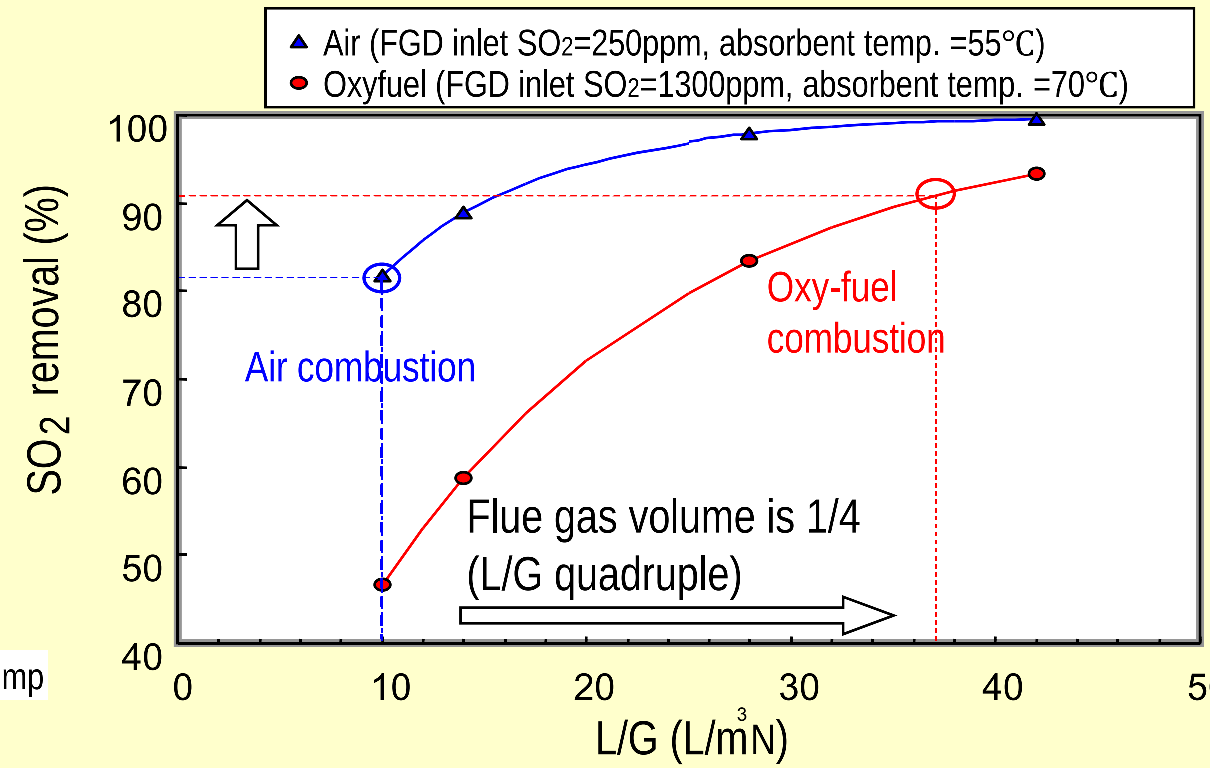
NOx removal efficiency under oxy-fuel combustion was slightly lower than that under air combustion.



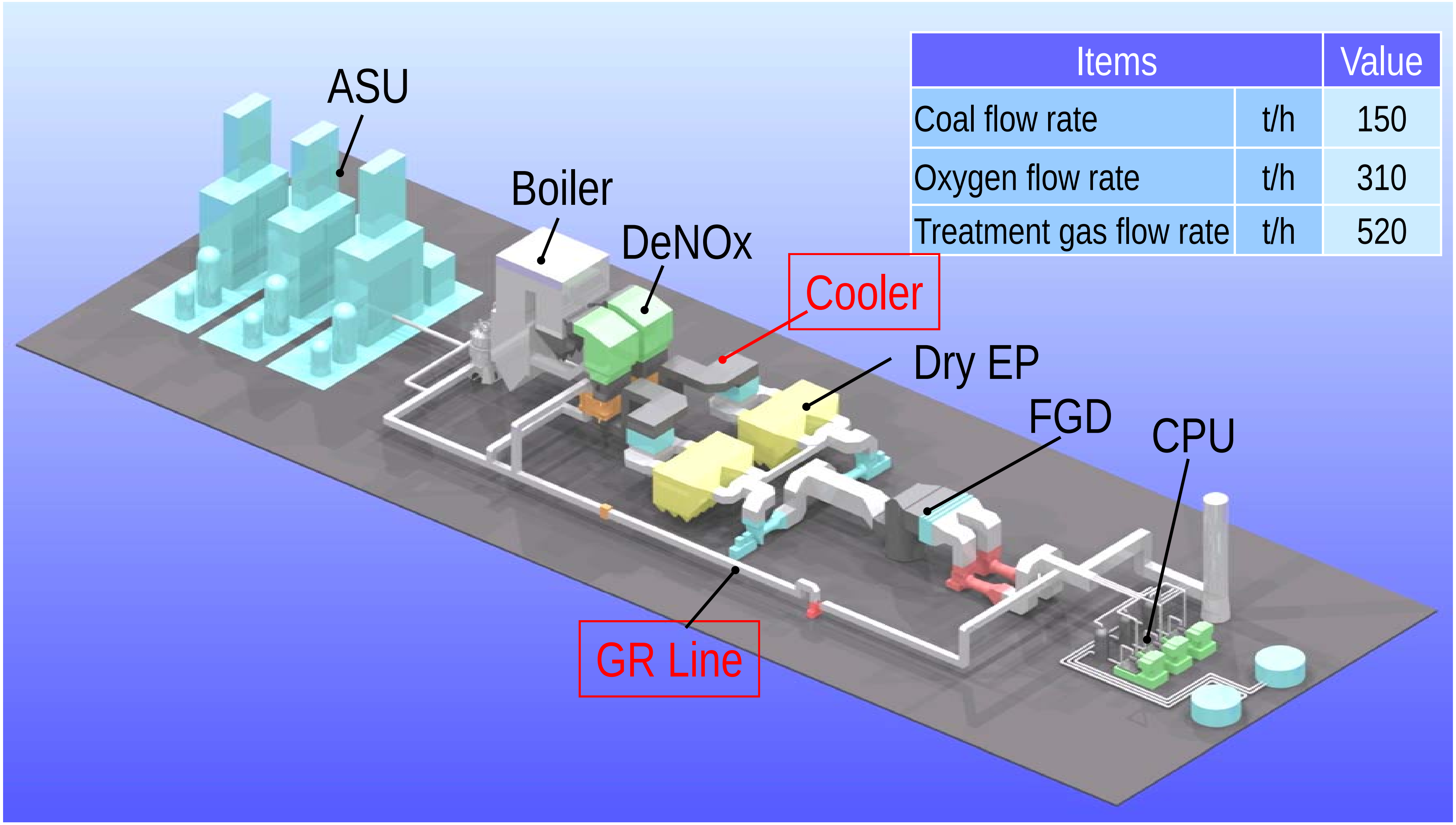


SO_2 removal efficiency at a given L/G decreased under oxy-fuel combustion because of the higher slurry temperature and SO_2 concentration. However, higher removal efficiency can be expected at a given coal due to less flue gas volume.





3.6 Plant Layout



Items		Value
Coal flow rate	t/h	150
Oxygen flow rate	t/h	310
Treatment gas flow rate	t/h	520

4. Conclusion

- To establish suitable oxy-fuel combustion system for existing 500MW class plant, feasibility studies have been conducted.
- Suitable systems were proposed based on heat balance calculation results using process simulation software CHEMCAD.
- Key points of case studies are that checking system performance in view point of boiler output, SO_3 content, ash, gas cooler power and FGD handling gas amount.
- Among studied cases, recommended system is as follows;
  - Gas extraction point is from 2ry:EP outlet and Pry: FGD outlet, cooler temperature: 90 C.

5. Future Works

-Reliability study of proposed system using 1.5MWth one-through combustion and AQCS test facility.
-Mill performance
-Total heat balance
-Dynamic control simulation

5. Future Work : 1.5MWth Combustion and AQCS Test Facility

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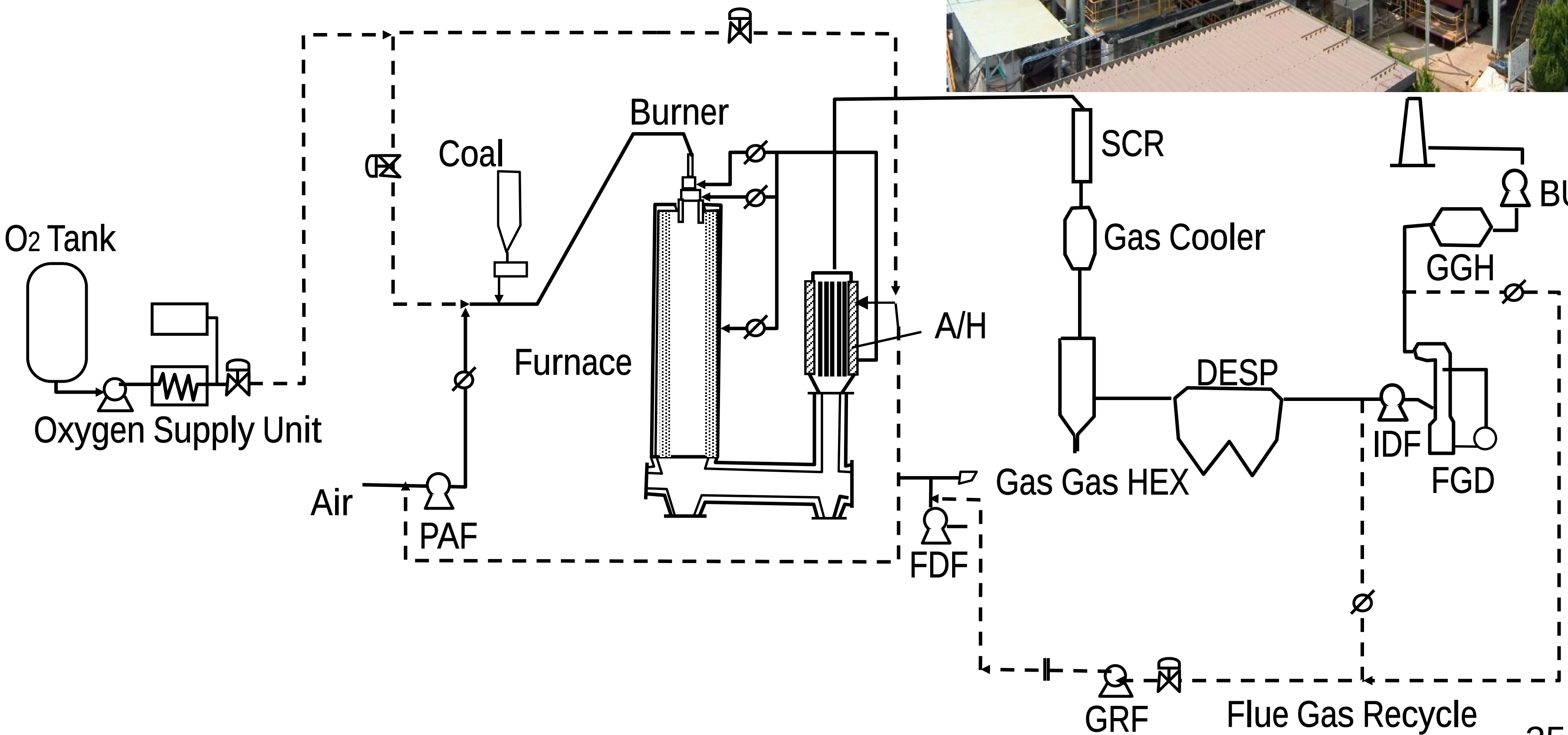
Test items
1. AQCS system check
2. Recycle gas line corrosion potential
3. SOx, NOx and other acid gas control
4. Total system of oxy-fuel combustion



Future Work : Mill Performance

The objective is to evaluate the mill performance represented by the mill power and the pressure drop of mill in CO_2. These values are compared with those of air atmosphere of the primary gas.

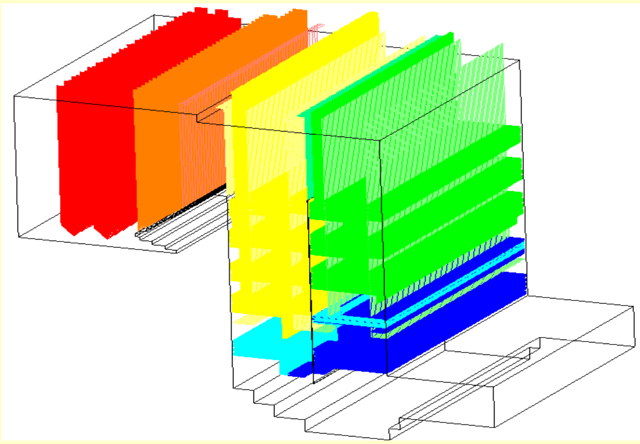
Bench scale mill facility

Mill

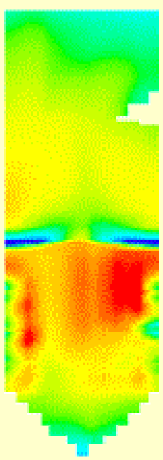
CO_2 supply system
(Max.300kg/h CO_2 gas)

Photos of bench-scale mill facility and CO_2 supply system

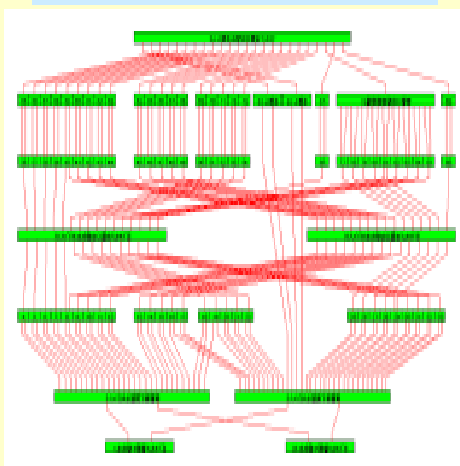
3D-model for heat recovery area



Comb. simulator ‘CRAFT’



Water wall network model



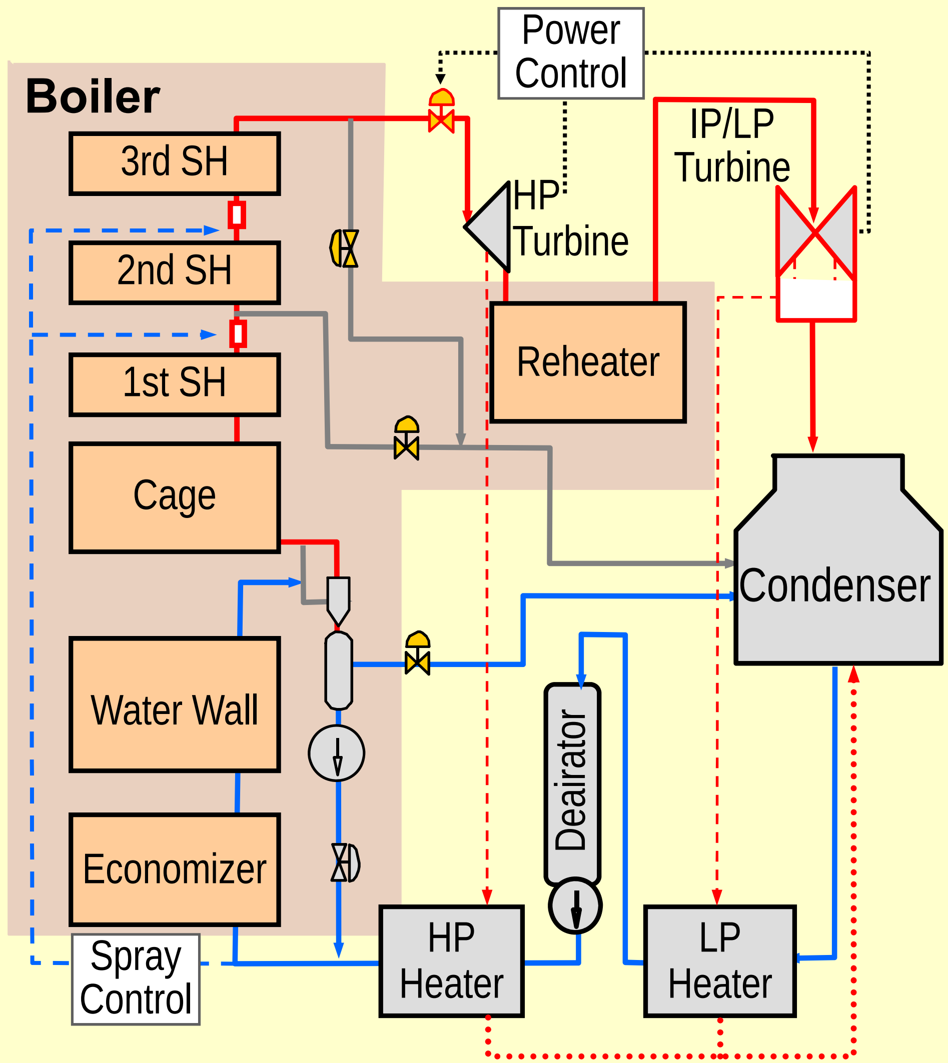
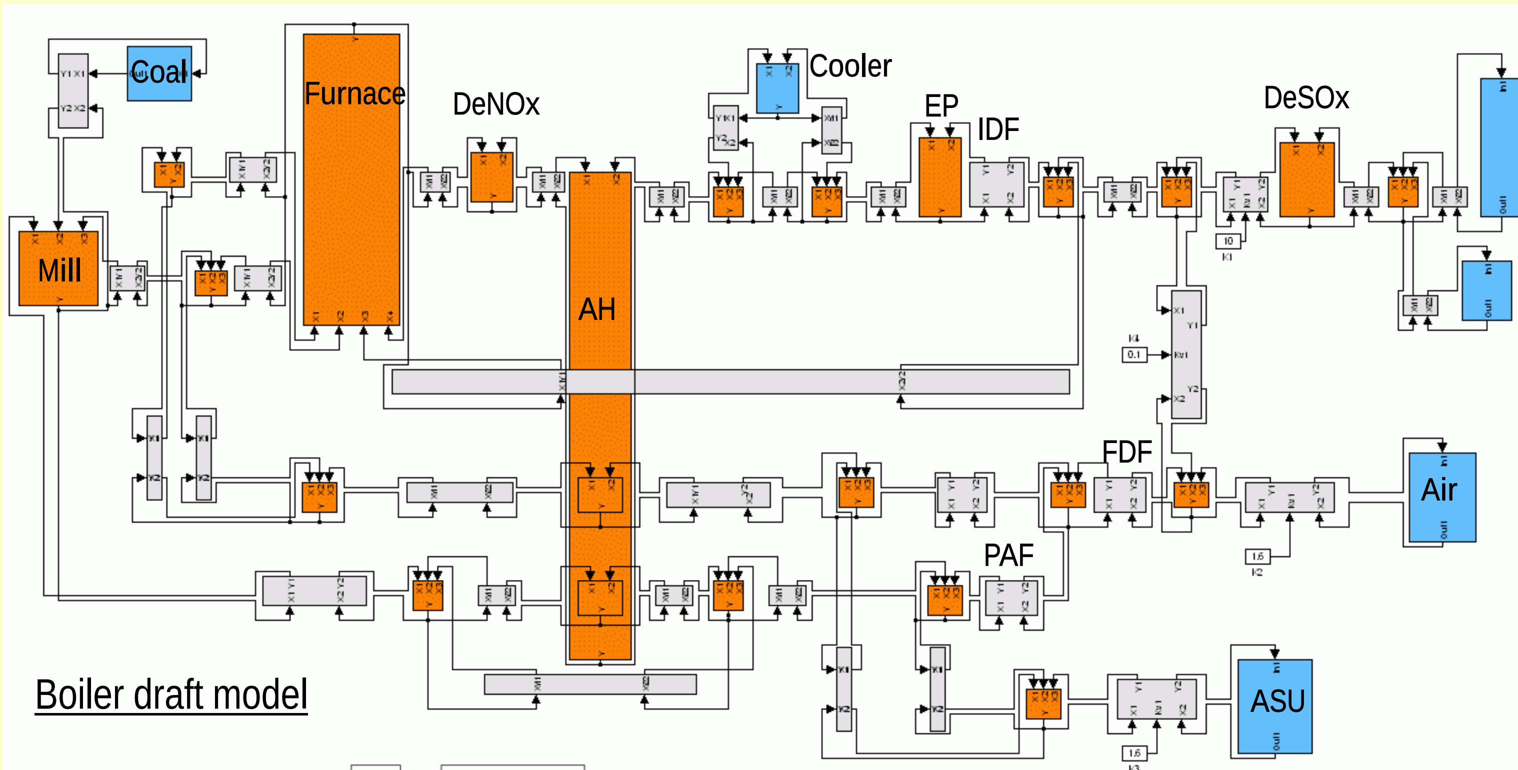
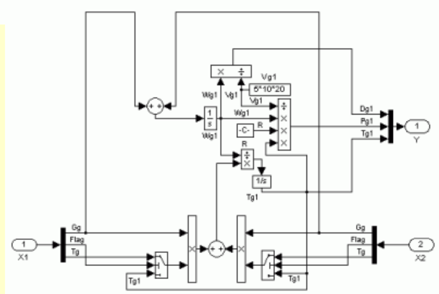


Fig. 2.5.10 Schematic of BTG system calculator ‘Virtual Boiler’

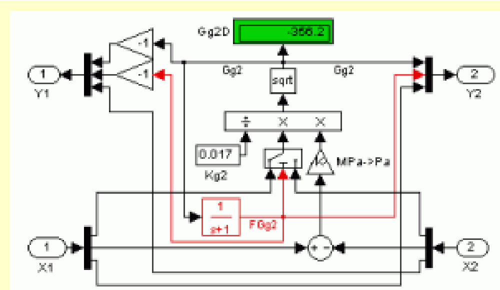


Boiler draft model

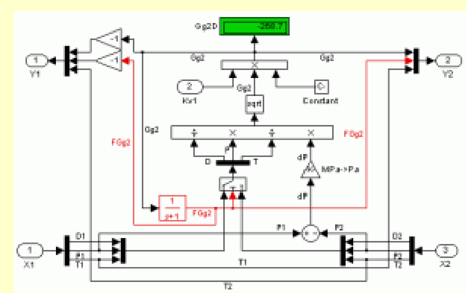
Main elements added or modified



Volume element (Basic)



Pipe element



Valve element

Thank you for your attention

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