

**Contract project-2004
With Ministry of Environment, Japan**



環境省

Ministry of the Environment

Air Pollution Control Technology In Thermal Power Plants

March 2005

Overseas Environmental Cooperation Center, Japan

Air Pollution Control Technology in Thermal Power Plant

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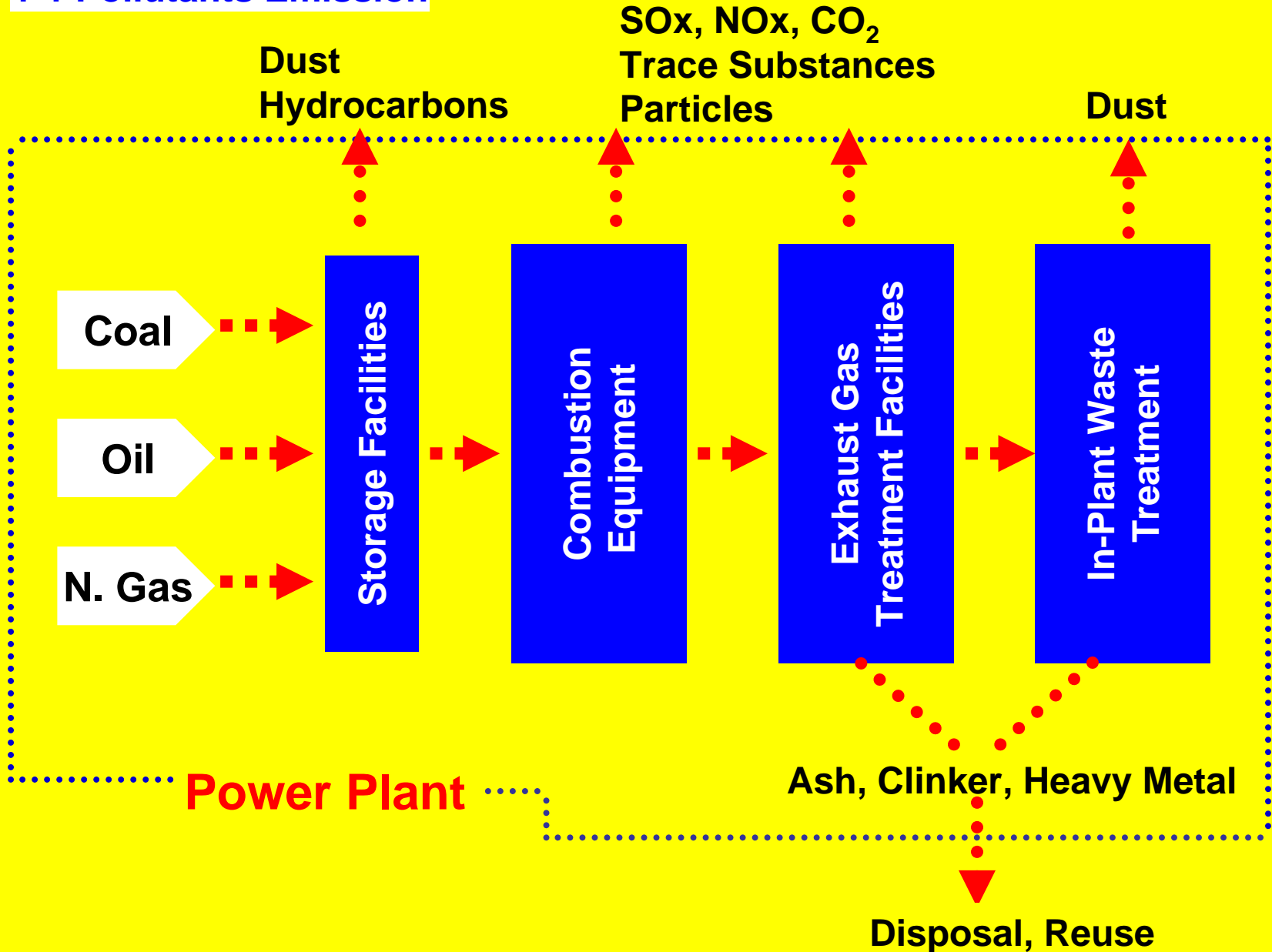
1,000MW, Coal Fire



Generator Building, De-NOx, EP, De-SOx

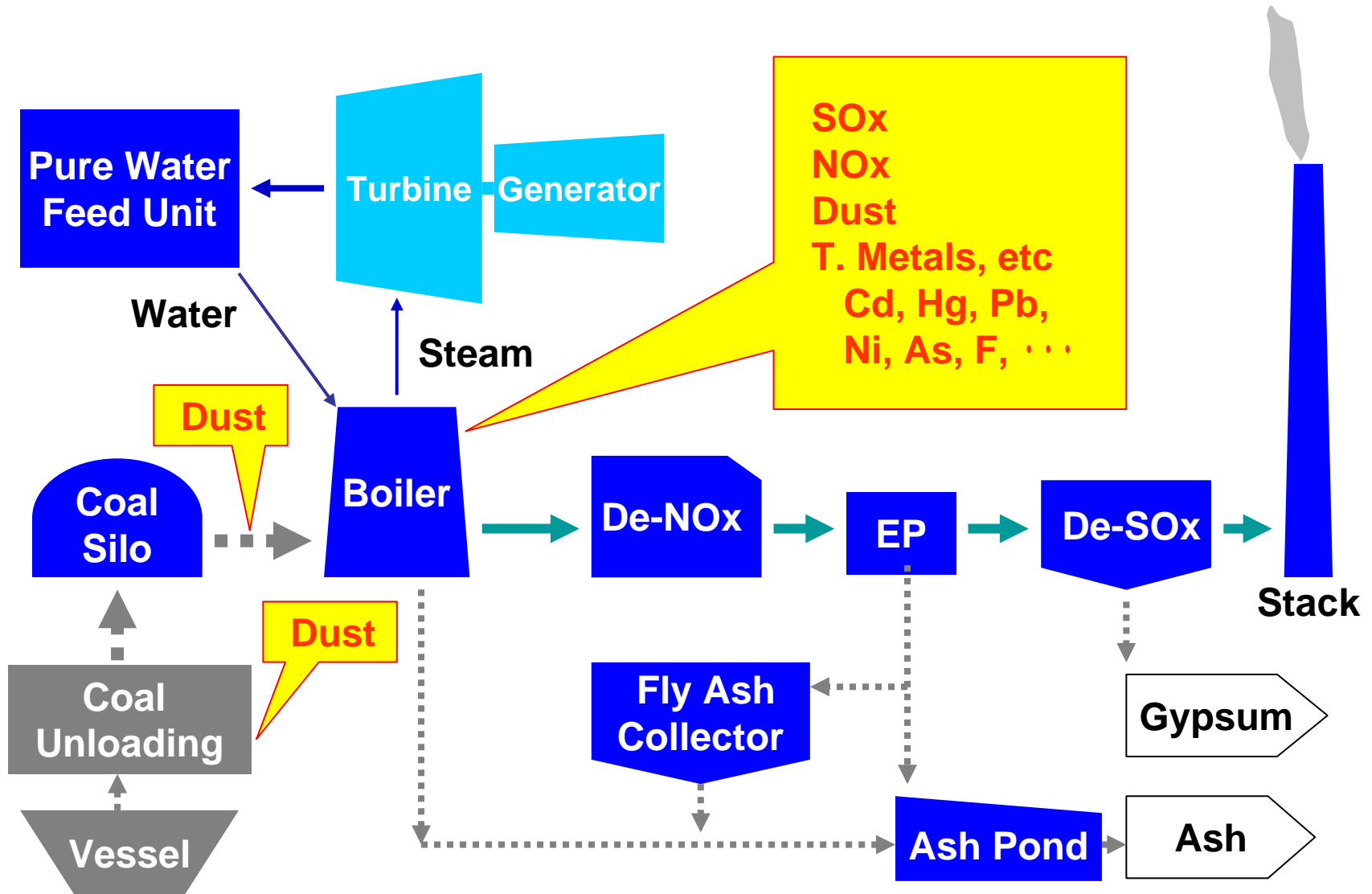
1. Air Pollutions in Thermal Power Plant

1-1 Pollutants Emission



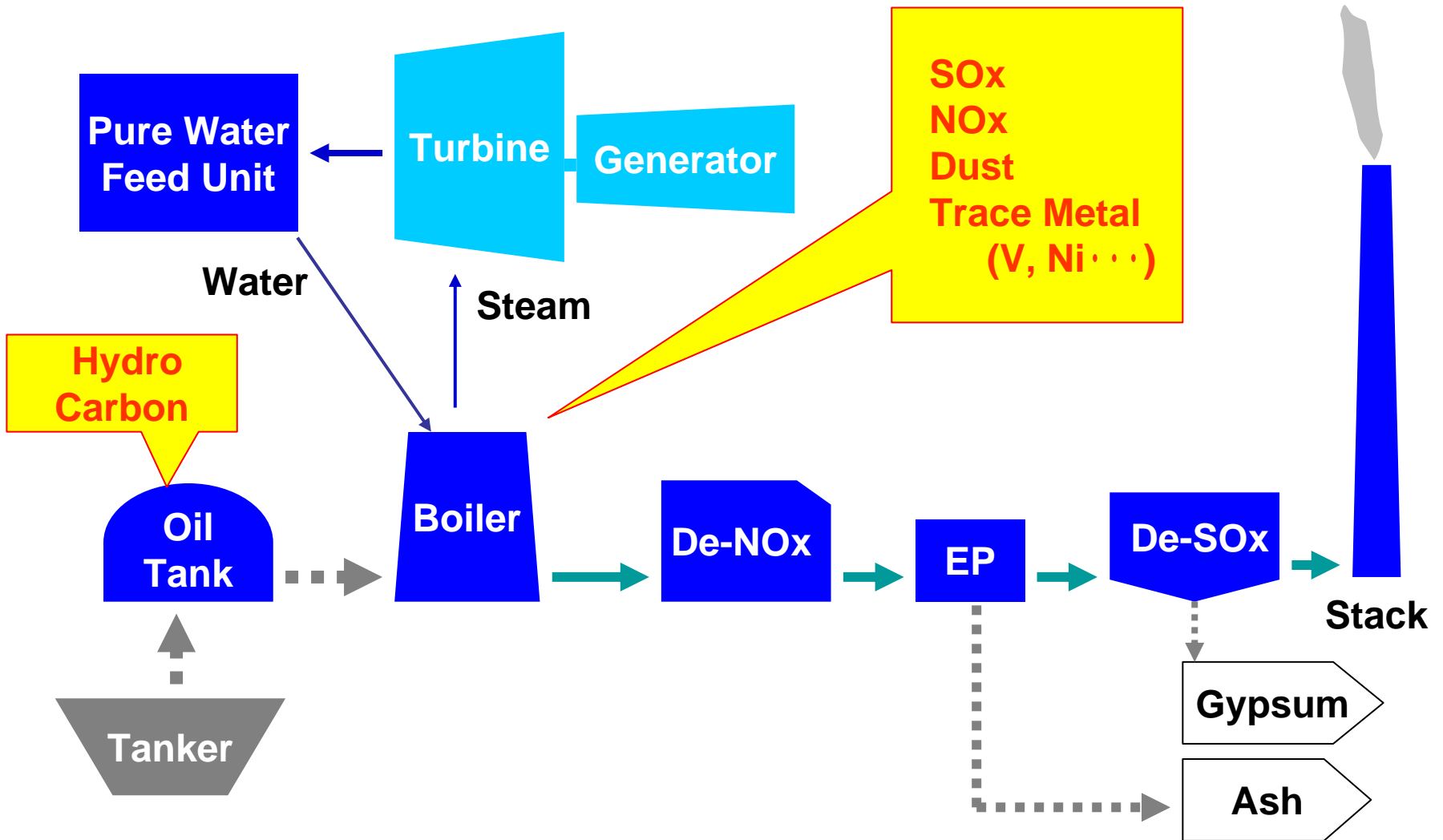
1. Air Pollutions in Thermal Power Plant

1-2 Pollutants and Pollution Control in Coal Fire Power Plant



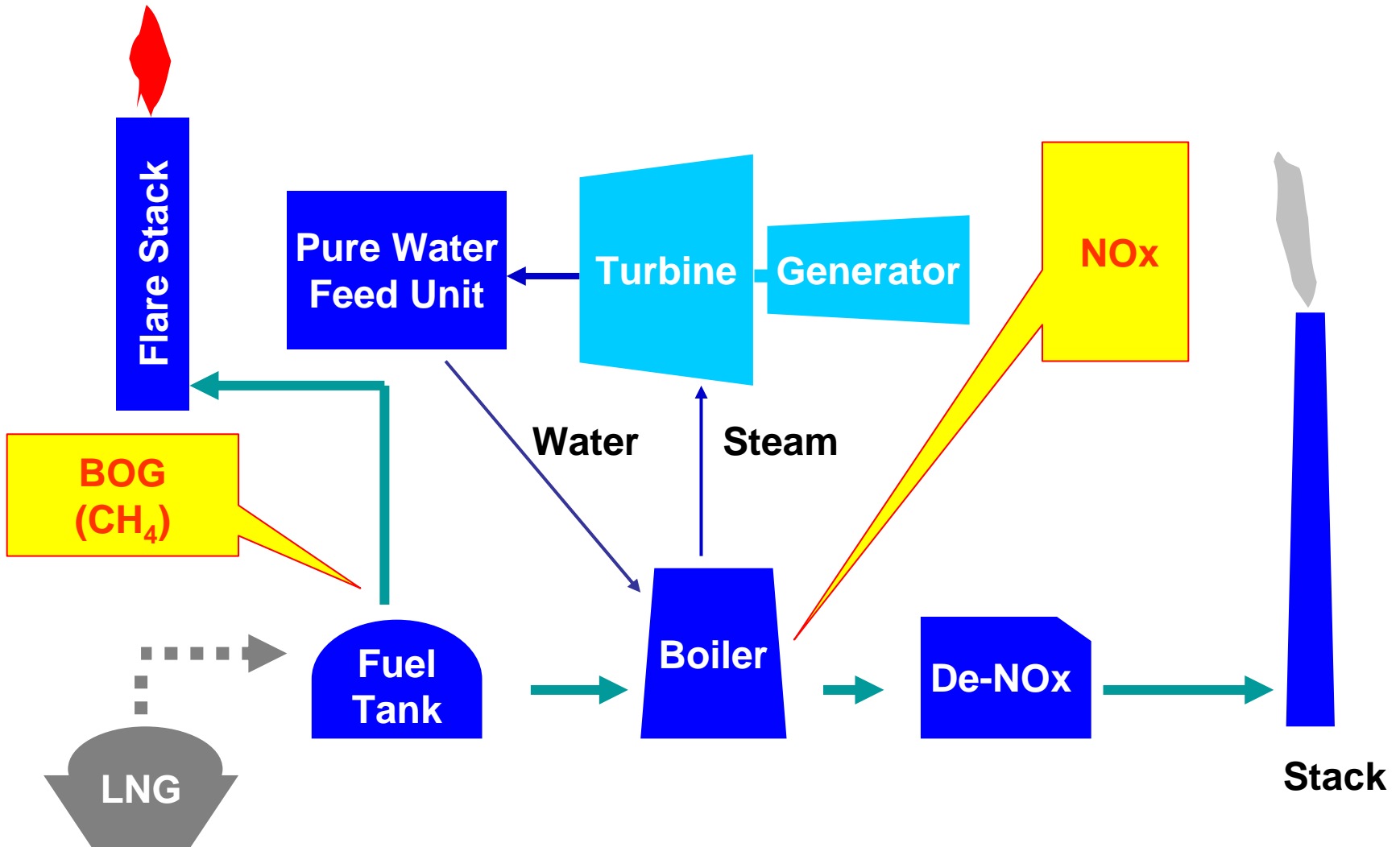
1. Air Pollutions in Thermal Power Plant

1-3 Pollutants and Pollution Control in Oil Fire Power Plant



1. Air Pollutions in Thermal Power Plant

1- 4 Pollutants and Pollution Control in Gas Fire Power Plant

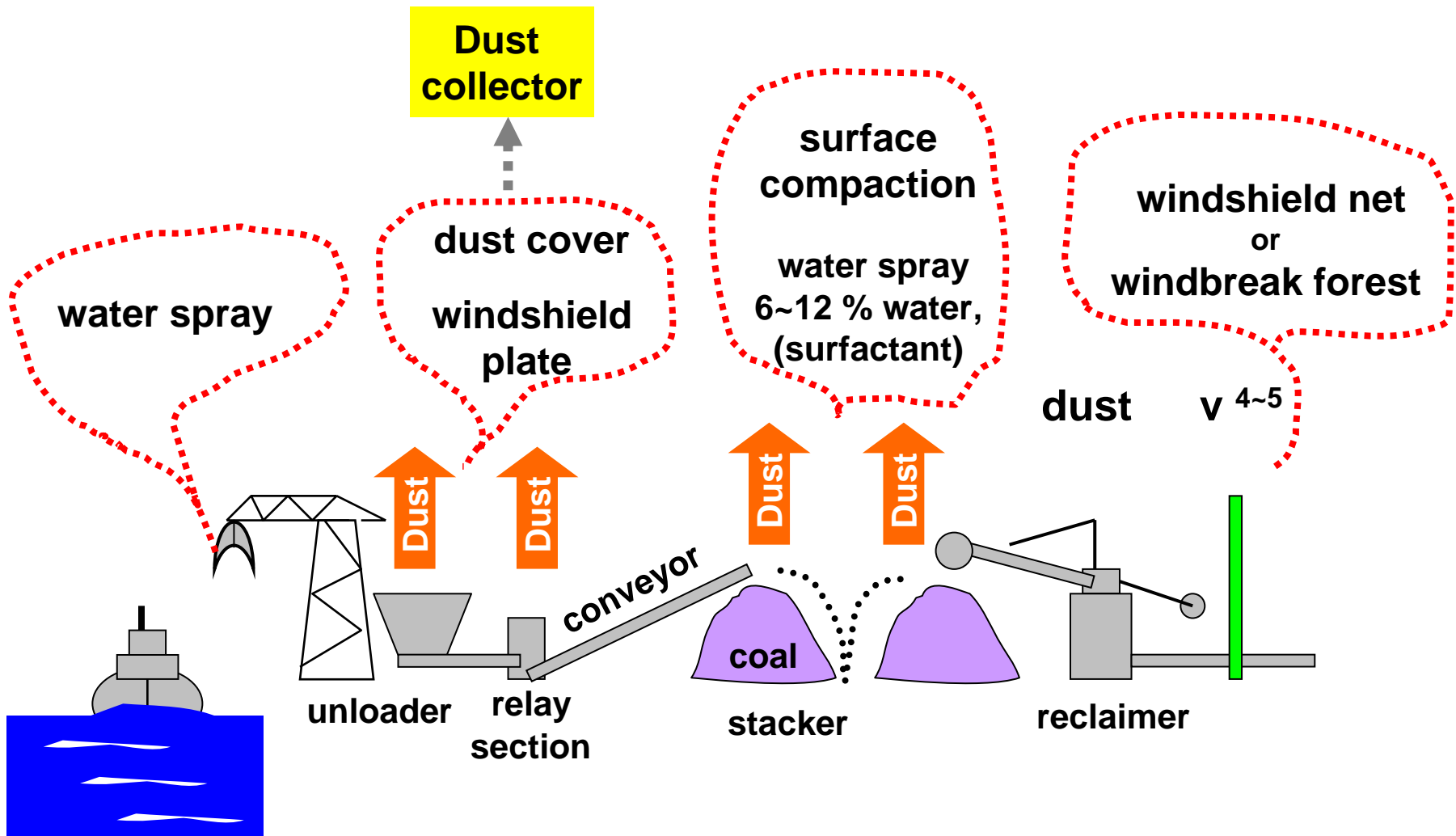


BOG: Boil-off Gas

2. Measures against Fuel

2-1 Coal Fire Power Plant

Dust Control



2. Measures against Fuel

2-2 Oil and Gas Fuel Power Plants

Effect of fuel oil properties on exhaust gas quality

- | | | |
|--------------------|---|------------------|
| 1. Residual Carbon | Soot, Dust | Dust collection |
| 2. Nitrogen | NO _x | Denitrication |
| 3. Sulphur | SO _x | Desulphurization |
| 4. Ash | Pressure drop, Heat transfer broke,
Mechanical Wear, Corrosion | Maintenance |

Effect of fuel gas properties on exhaust gas quality

- | | | |
|------------------------|------------|--|
| 1. Impurity substances | · · · · · | None |
| 2. Nitrogen | · · · None | NO _x (thermal type) Denitrification |
| 3. Sulphur | · · · None | |

3. Combustion Control

3-1-1 Coal Properties

Effect of Coal Properties on Pulverized Coal Combustion

<u>Ignitability & Combustibility</u>	<u>optimum range</u>	<u>effects in case of off-spec.</u>
Fixed-C / volatile content	< 2.5~3.0	increase of non-burn loss
Volatile content	> 20%	unstable ignition
Ignitability Index	> 35	hard ignition
Button Index (viscosity)	< 6 ~ 7	clogging, adhesion

Grindability

Proper size	50 ~ 100 μ m	increase of non-burn loss
Dryness	H ₂ O < 20 %	lowering mill performance

Slagging

Ash Melting Temp.	> 1,300	} slagging
Ash Alkaline Ratio	< 0.5	
Fe ₂ O ₃ / CaO	< 0.3 ~ 3 <	
S / coal	< 2%	

Fouling

basic content; Na ₂ O, K ₂ O, Cl, CaO, S	fouling on inner furnace, radiation heating surface
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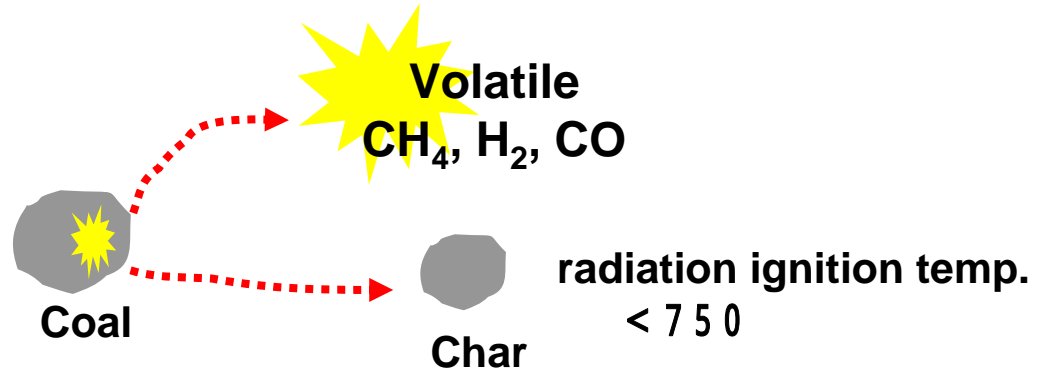
Wear-out Nature

quartz, Fe ₂ O ₃ , S	wear of mill, coal tube, heat transfer surface
--	---

3. Combustion Control

3-1-2 Coal Combustion

Combustion Mechanism of Pulverized Coal



Low NOx Combustion

1. Reduction of surplus air ratio (high volatile coal; 1.2 ~ 1.25)
2. Lowering combustion air temp. (normally 250 ~ 350)
3. Two stage combustion (1st burner + 2nd burner)
4. Recycling exhaust gas (< 20~30%)
5. Inner-furnace denitrification
6. Low NOx burner

slow mixture air & fuel
promotion of unevenness comb.
acceleration of flame heat radiation

1st Process

furnace > 900 HC decomposition
O₂ existing
reductant HC > chemical equivalent O₂

2nd Process

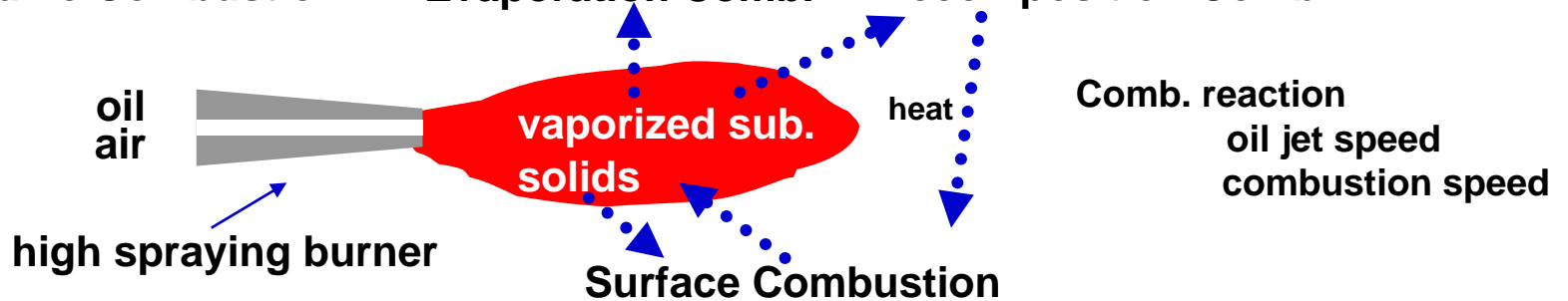
atmosphere temp. > reaction temp. of non-burned portion
sufficient O₂

3. Combustion Control

3-2-1 Oil Combustion

Oil Combustion Mechanism

Flame Combustion ... Evaporation Comb. + Decomposition Comb.



Effect of Fuel Oil Properties on Exhaust Gas Composition

Subs.	Con. wt%	Pollutants	Damages
N	0.01~0.6	NOx	Air pollution
S	0.2~3.0	SO ₂ , SO ₃ SO ₄ (SO _x)	Air pollution, corrosion clogging
Red. C	4.0~11.5	Dust	Dust, carbon adhere
Ash (Na, K, V, ----)	< 0.02	Adherents	Scaling, Vanadium attack, corrosion, mechanical wear, etc.

JIS C-
Heavy Oil

3. Combustion Control

3-2-2 Oil - NO_x Generation

NO_x Generation and its Control in Oil Combustion

Generation

Thermal NO_x (N in Air)

Flame temp.
O₂ concentration
Retention time

Fuel NO_x (N in Fuel)

O₂ concentration
Nitrogen in fuel

Control Measures

- 2-stage combustion
- Exhaust gas recycling
- Low NO_x burner
- Furnace size_expansion

3. Combustion Control

3-3 Gas

Gas Combustion Mechanism

air
gas

Short flame
No-Luminous flame

N = 0
S = 0
Impurity = 0

Thermal NOx

NOx

no
Dust

no
SOx

C/H Ratio

Heat Radiation Rate

7.5

6

3

Heavy crude oil

Naphsa

Natural gas

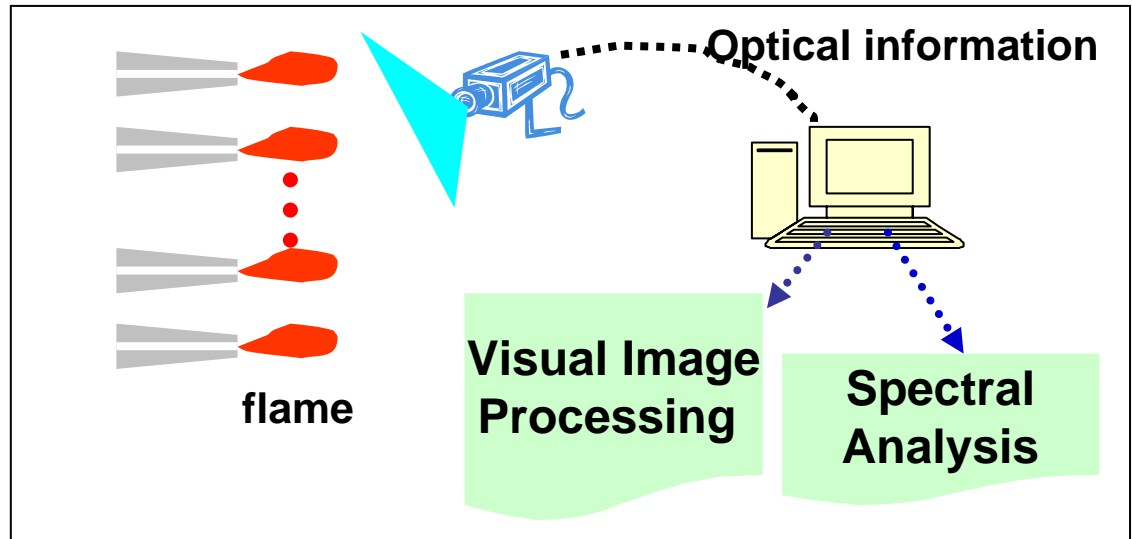
large

small

Control of
NOx Generation

+

Oscillating Combustion
Preventive Measures



4. Dust Collector

d.p.: dew point

S: small M: medium L: large

4-1 Type of Dust Collectors

Type	Applic. Particle (μm)	Operating ()	Cutback Level	Pressure Drop (mm H ₂ O)	Equipment Cost	Running Cost
Gravity	50	d.p. ~ 400	40 ~ 60 %	10 ~ 15	S	S
Inertia	10	d.p. ~ 400	50 ~ 70 %	30 ~ 70	S	S
Centrifuge	3	d.p. ~ 400	10 mg / m ³	50 ~ 150	M	M
Scrubbing	~0.1	no-limit	20 mg / m ³	300 ~ 800	M	L
Filtration	~0.1	no-limit	5 mg / m ³ or less	100 ~ 200	M	M
EP	~0.03	d.p. ~ 400	5 mg / m ³ or less	10 ~ 20	L	S

4. Dust Collector

4-2 Gravitational, Inertial & Centrifugal Dust Collector

Stokes' Law

$$V = \frac{g}{18\mu} (\rho_1 - \rho) D^2 \quad (\text{cm/s})$$

V: settling velocity (cm/sec)

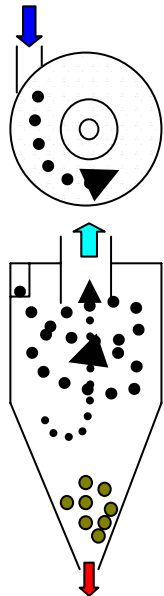
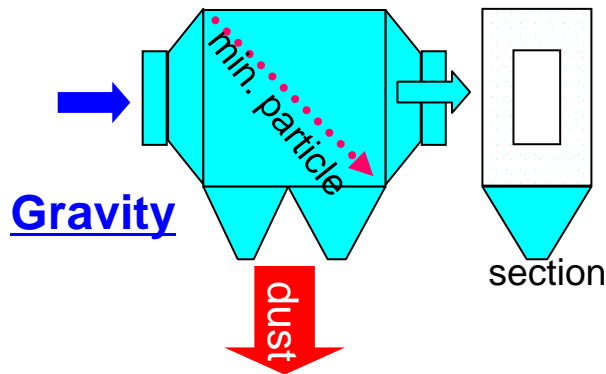
g: gravitational acceleration (cm/s²)

μ : gas viscosity (kg/ms)

ρ₁: particle density (g/cm³)

ρ : gas density (g/cm³)

D: particle diameter (cm)



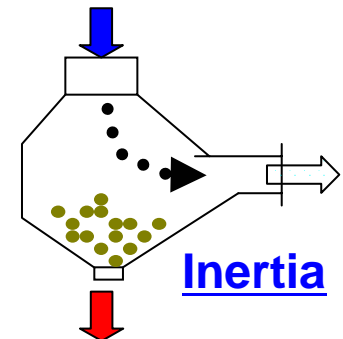
Principle of dust collection ;

$$\text{Centrifugal force (F)} = mv^2/R \quad (\text{N})$$

m: particle mass (kg)

V: particle velocity (m/ s)

R: cyclone radius (m)



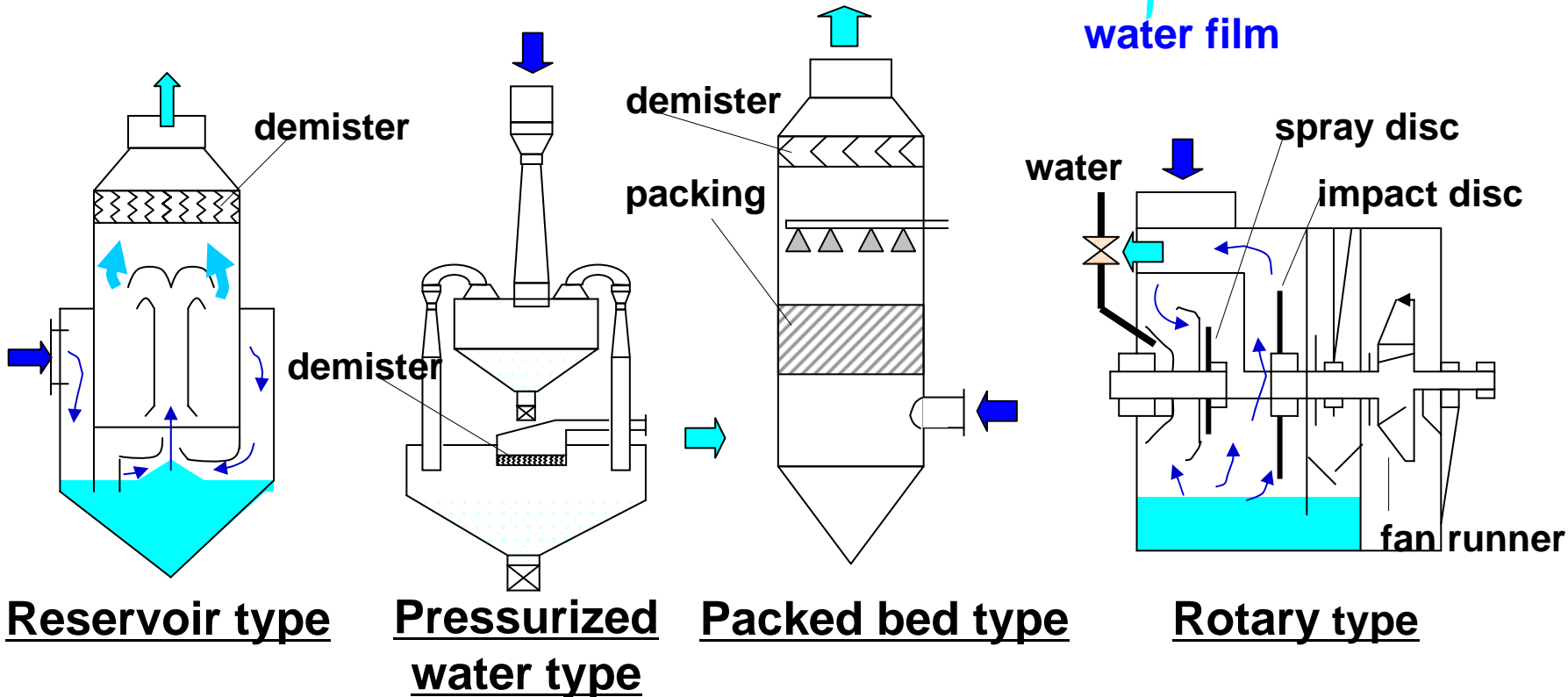
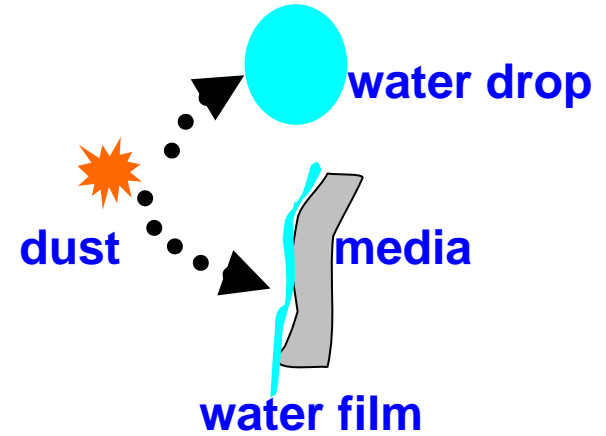
Centrifugal

Inertia

4. Dust Collector

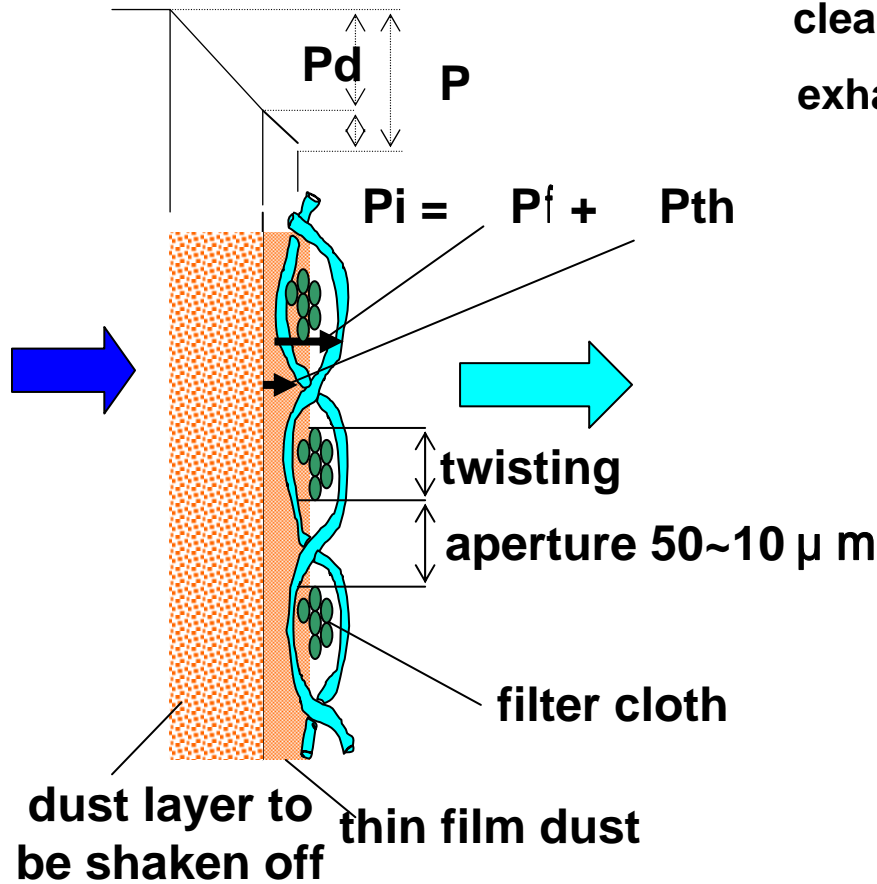
4-3 Scrubbing Dust Collector

Principle of dust collection ;



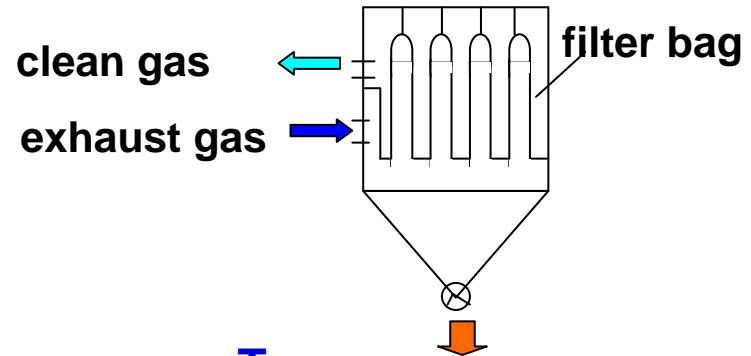
4. Dust Collector

4-4 Filter Type Dust Separator



Filtration Mechanism

Typical bag filter unit



Type:

- (1) bag filter
- (2) cartridge filter

Filter cloth:

- (1) woven fabric
- (2) nonwoven fabric

Dust shake-off:

- (1) intermittent
- (2) continuous

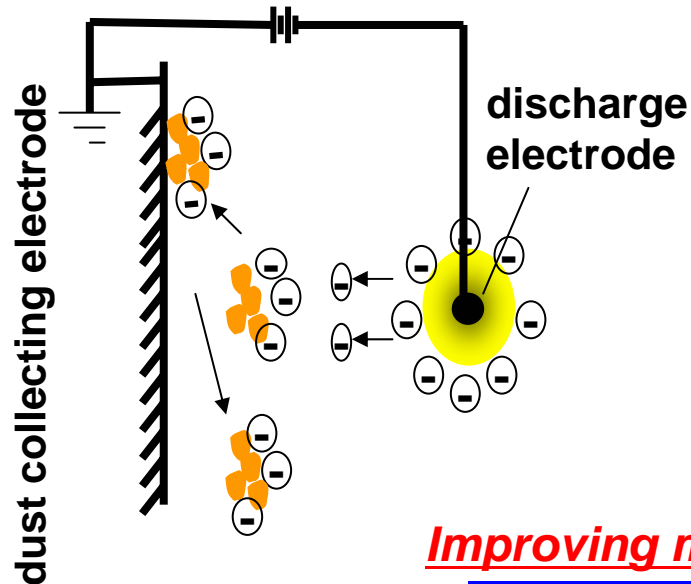
Apparent filtration rate:

0.3~10cm/s

4. Dust Collector

4-5-1 Electrostatic Precipitator (EP)

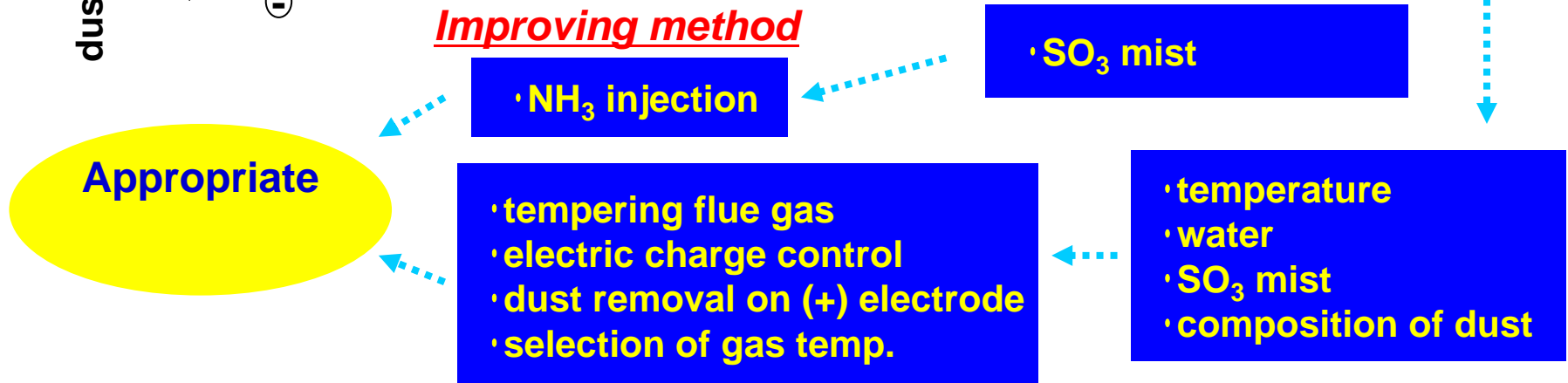
Principle of dust collection



Exhaust gas properties;

		Heavy oil	Coal
inlet soot & dust	g/Nm ³	0.05~0.15	10~20
dust	μ m	1~3	20~30
SiO ₂	Wt %	15~20	60~75
C	Wt %	50~60	0.4~0.8
Rate	·cm	10 ⁴ ~10 ⁶	10 ¹¹ ~10 ¹³
apparent S.G.	g/ml	0.1~0.2	0.6~0.8

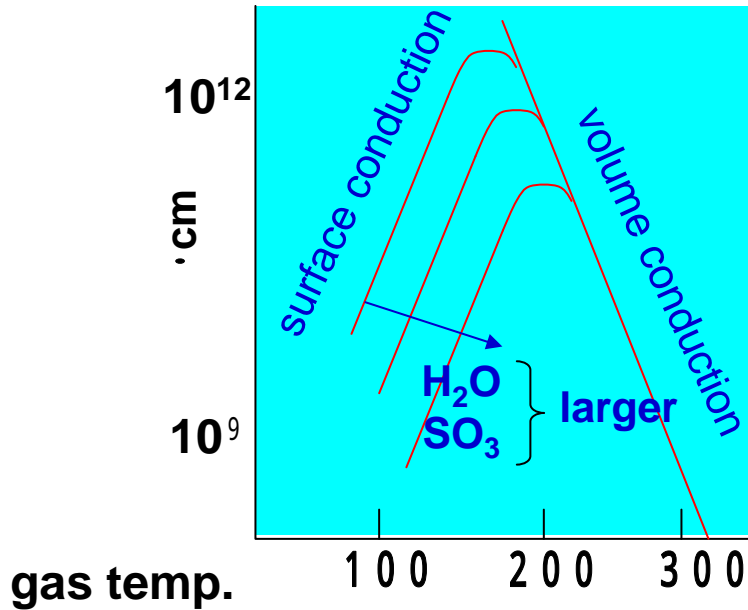
Influence on dust collection



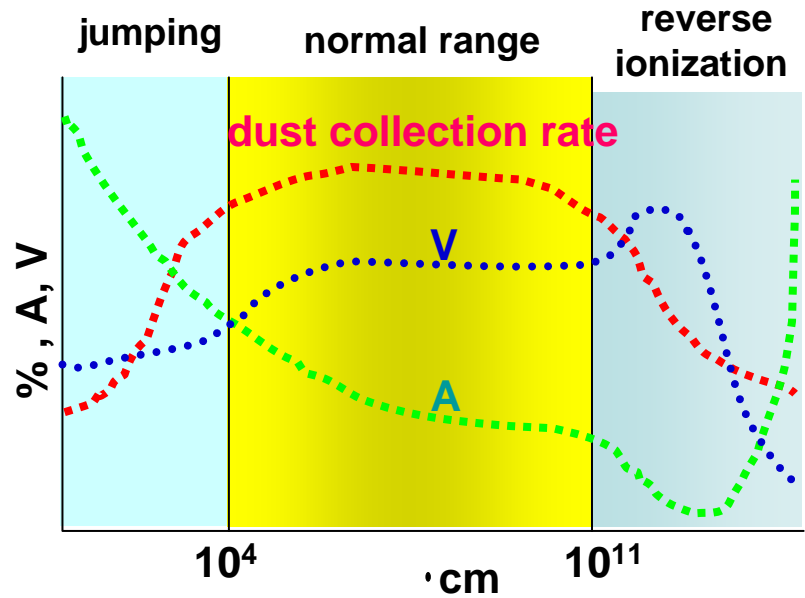
4. Dust Collector

4-5-2 Factors Working on EP

versus gas



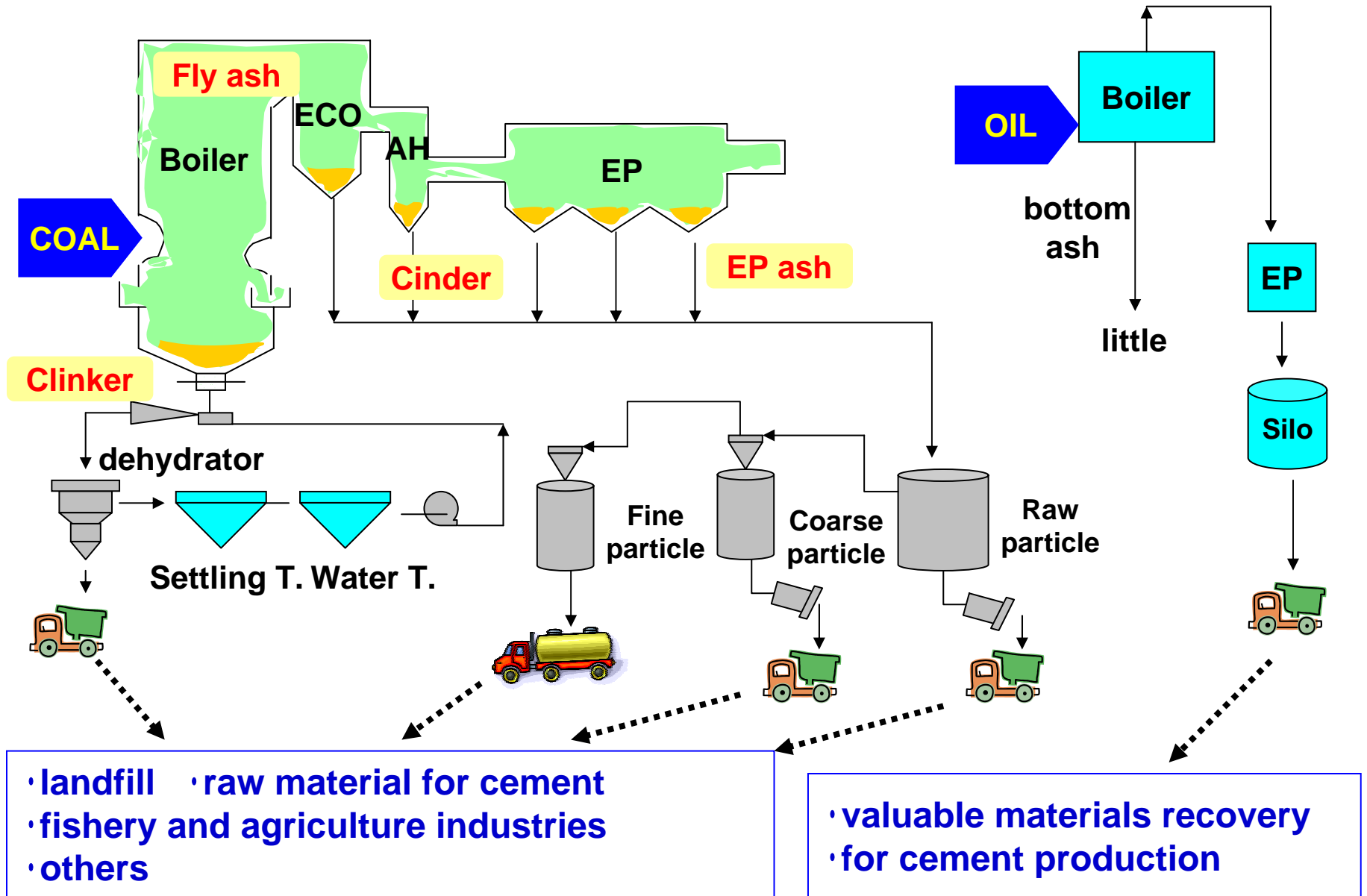
Dust removal versus $\cdot cm$



Advantages and disadvantages of EP

Advantages	Disadvantages
<ul style="list-style-type: none"> large gas volume fine particles of submicron high temperature gas wet type dust collection suitable operation inexpensive maintenance 	<ul style="list-style-type: none"> initial cost – expensive affection of apparent (- Cm) system size- large high level accuracy in manufacturing

4. Dust Collector 4-6 Ash Treatment



- landfill
- raw material for cement
- fishery and agriculture industries
- others

- valuable materials recovery
- for cement production

5. Flue Gas Desulphurization

5-1 Flue Gas Desulphurization Methods (FGD)

Method	Absorbent/ Adsorbent	Byproducts
Wet type	NaOH or Na ₂ SO ₃ solution	Na ₂ SO ₃ , NaNO ₃ , SO ₂ , gypsum
	NH ₃ -water	(NH ₄) ₂ SO ₄ , SO ₂ , gypsum, S
	Slaked lime or limestone slurry	gypsum
	Mg(OH) ₂ -slurry	SO ₂ , gypsum (blended with slaked lime slurry)
	Basic Al ₂ (SO ₄) ₃ -solution	gypsum
	Dilute-H ₂ SO ₄	gypsum
Dry type	Activated carbon	(NH ₄) ₂ SO ₄ , gypsum, S, H ₂ SO ₄

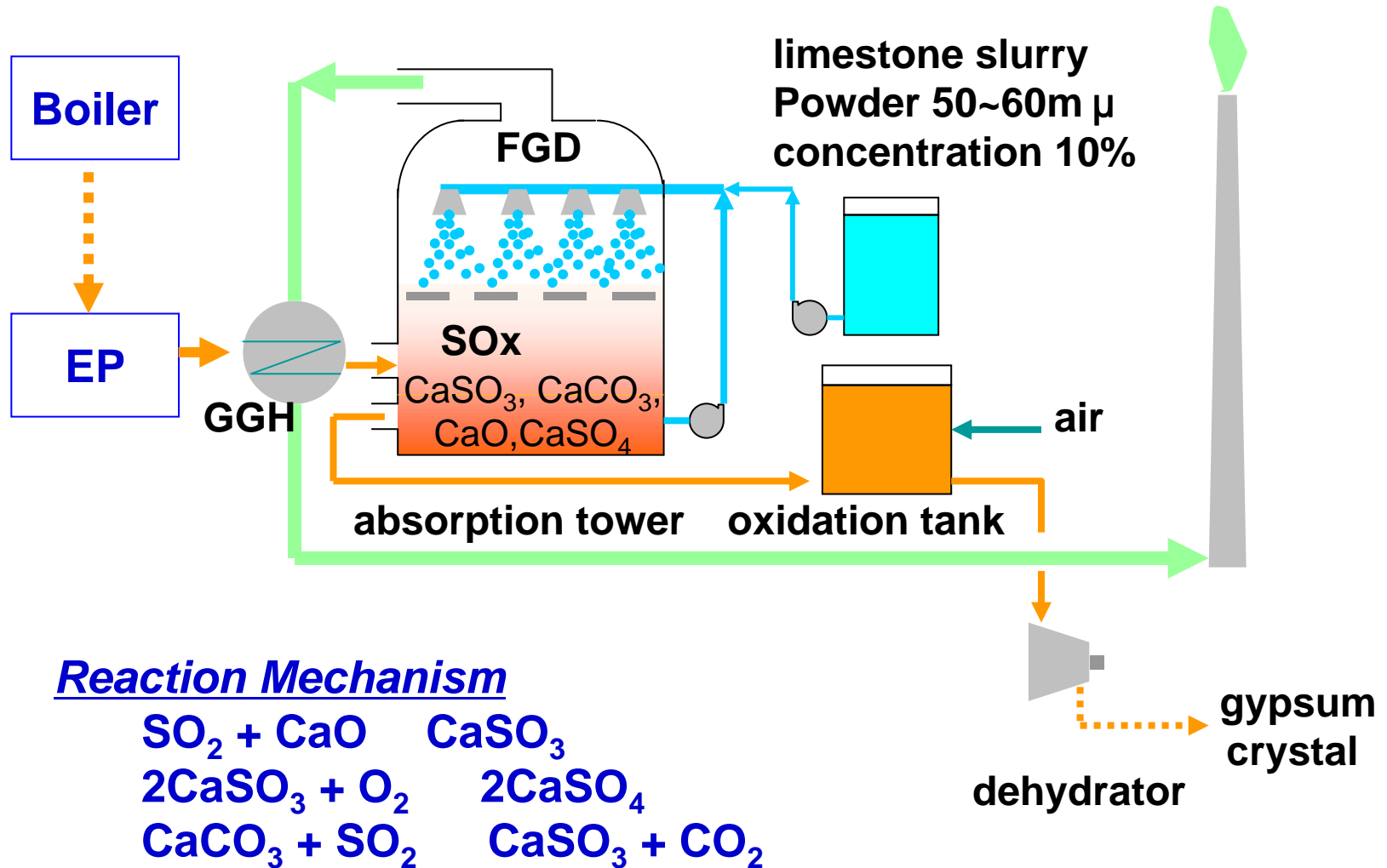
most popularly used method
in Japan

Lime & Gypsum Method

- limestone cheap
- initial & operating cost economics
- system stability & safety
- gypsum stable sales

5. Flue Gas Desulphurization

5-2 Wet Type Lime & Gypsum Method FGD System



5. Flue Gas Desulphurization

5-3 Simplified FGD System

Comparison of Simplified FGD with Conventional FGD

	Lime & Gypsum Method	<u>Simplified FGD</u> Semi-dry Method Intrafurnace Desulphurization + Water Spray Method
Alkali	Ca CO ₃ powder	CaCO ₃ powder
Reaction	$\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ $\text{H}_2\text{SO}_3 + 1/2\text{O}_2 \rightarrow \text{H}_2\text{SO}_4$ $\text{CaCO}_3 + \text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightarrow \text{CaSO}_4 + 2\text{H}_2\text{O} + \text{CO}_2$	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ $\text{SO}_2 + \text{CaO} + 1/2\text{O}_2 \rightarrow \text{CaSO}_4$ $\text{SO}_2 + \text{CaO} + 1/2\text{H}_2\text{O} \rightarrow \text{CaSO}_3 + 1/2\text{H}_2\text{O}$
Advantages	<ul style="list-style-type: none"> useful gypsum large flue gas high-level removal 	<ul style="list-style-type: none"> no wastewater compact size, less space simple process, excellent in economics
Disadvantages	<ul style="list-style-type: none"> wastewater treatment anticorrosion material large area high maintenance cost 	<ul style="list-style-type: none"> slagging inside boiler lower removal lower alkali utilization
Cost		
Equipment	100	20~30
Operation	100	75~80

6. Flue Gas Denitrification

6-1 NOx Abatement Method

Reduction of NOx Generation & Denitrification Methods

Method	Applicability	NOx red. (%)
Flue gas recirculation	T-NOx	70~80
Low NOx burner	F-NOx, T-NOx	10~25
Staged burners	F-NOx, T-NOx	40~70
SCR	F-NOx, T-NOx	80~90
SNCR	F-NOx, T-NOx	60~80

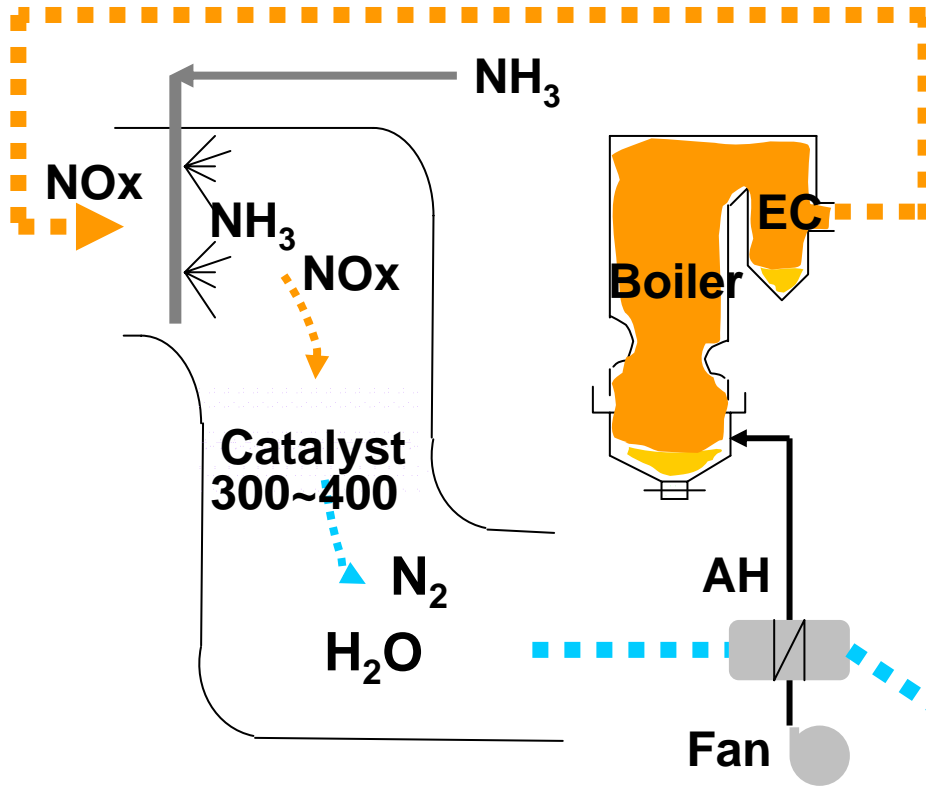
T-NOx: Thermal NOx
F-NOx: Fuel NOx

Denitrification Process

Process	Method
Dry Process	
SCR (Selective catalytic reduction)	NH ₃ , catalyst
SNCR (Selective non-catalytic reduction)	NH ₃ , Gas temp. 800~ 1,000
NSCR (Non-selective catalytic reduction)	catalyst (Pt) + CH ₄ , or CO, or H ₂
Catalytic cracking	catalyst (Pt, ...)
Wet Process	
	NOx + SOx removal
	complicate process
	wastewater treatment

6. Flue Gas Denitrification

6-2 NH₃ Catalytic Reduction Process



SCR Process

Ammonia Catalytic Reduction Process

Catalyst

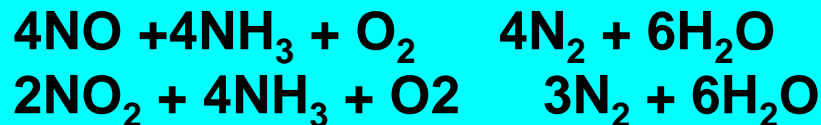
support: ceramic (Ti, Al, ...)

catalyst: metals

shape: granule, grid-form
honeycomb, plate

control: denirification rate
catalyst bed draft loss

Reaction



to EP

7. Stack

Stack height & Draft force

$$(a - g)H_0 + P_{eb} - Vg^2 / 2g \cdot \gamma + \sum h > 0$$

$(a - g)H_0$: theoretical draft force (kg/m^2)

a : air specific weight at atmosphere temp. (kg/m^3)

g : exhaust gas " "

H_0 : stack height from datum level (m)

P_{eb} : effective blower pressure (kg/m^2)

Vg : exhaust gas outlet velocity (m/s)

g : gravitational acceleration (m/s^2)

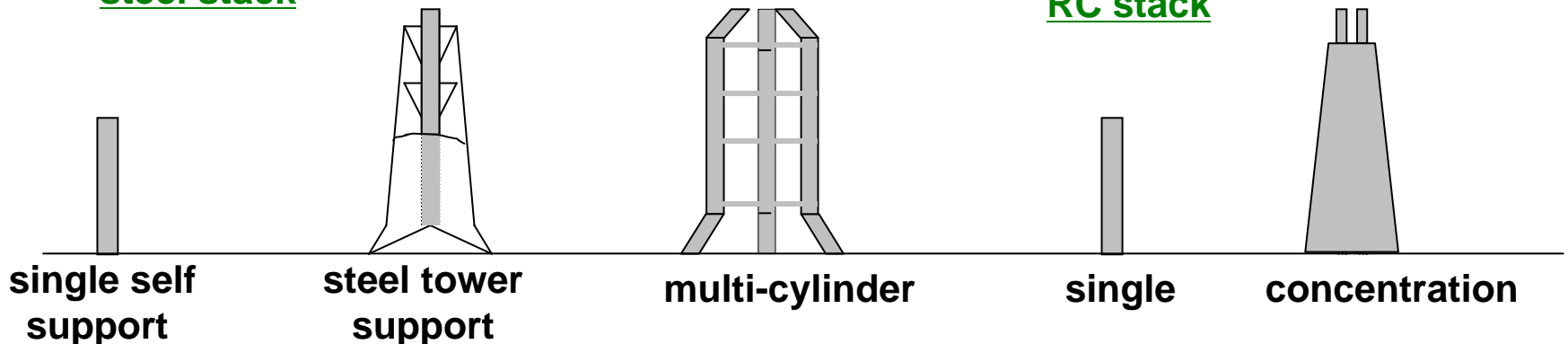
$\sum h$: total pressure loss in exhaust gas route = $\sum \gamma \cdot V^2 / 2g \cdot \sum \gamma$ (kg/m^2)

$\sum \gamma$: resistance coefficient

V : flue gas velocity in route (m/s)

steel stack

RC stack



8. Environmental Management System

1. Environmental Management System EMS
 - Trend of environmental management
 - Organization for env. management & control
 - Mission
 - Pollution control system



ISO 14000

2. Cooperation with Local Government
 - Cooperation in pollution control measures
 - Handling of complaints
 - Env. protection agreement

3. Data disclosing

4. Education and Training of Employees

5. Monitoring

6. Greening of Power Station

7. Measures against Accident and Emergency

- Accident
- Emergency

9. Energy Saving

1990

2000

2010

Steam turbine

Super C

USC

42~44%

Fluidized bed combustion

A- FBC

P- FBC

Advanced A- FBC

44~46%

44~46%

Gas turbine

LNG 1100 Gas Turbine

LNG 1300 Gas Turbine

LNG 1500 Gas Turbine

44%

47%

50%

Coal gasification

Gasification technology

IGCC 1300

IGCC 1500

44~48%

48~50%

Direct power generation

PAFC

MCFC

SOFC

IGFC

35~40%

> 50%

> 50%

> 50%

*Efficiency improvement
= Energy saving
= Pollution decreasing*