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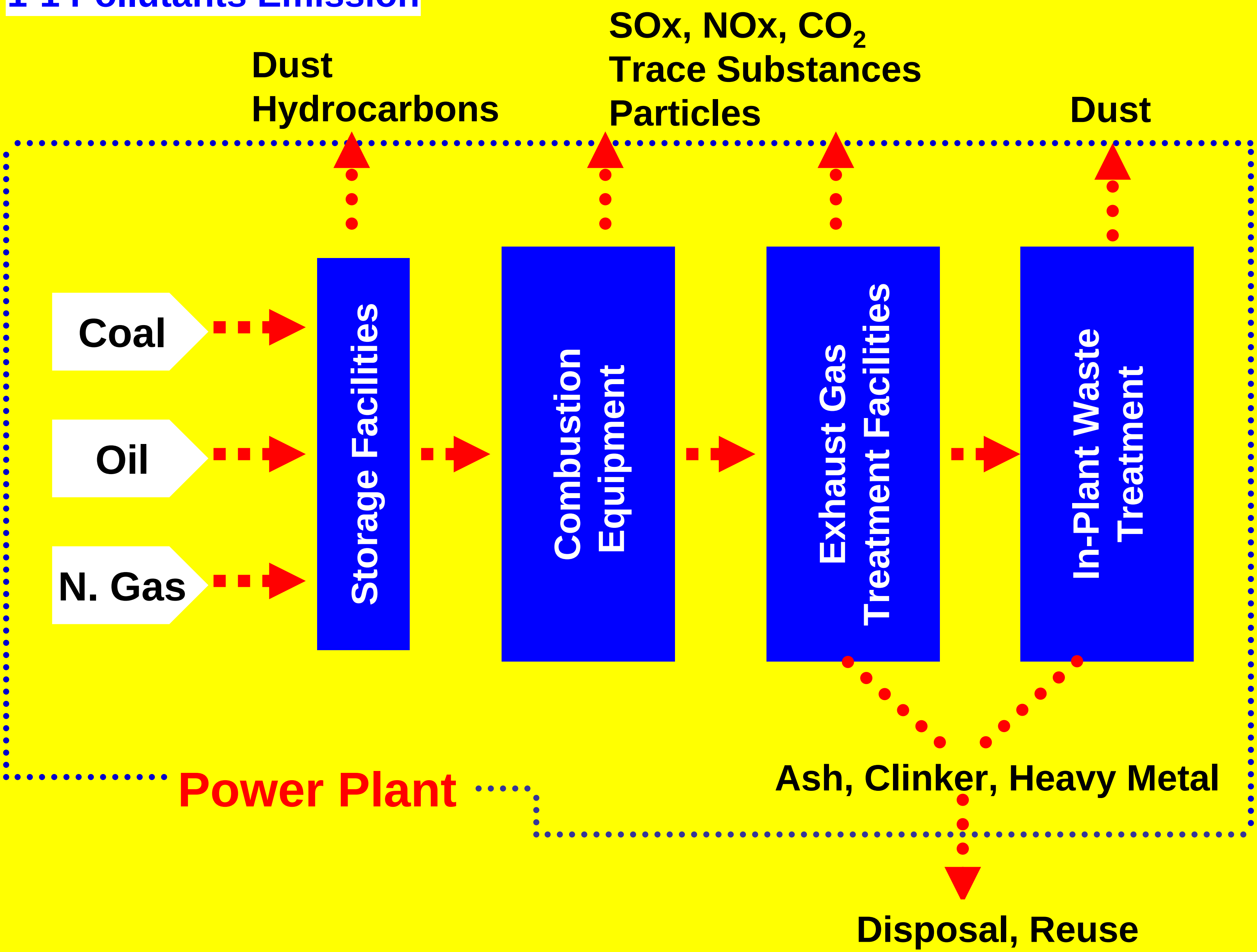
Generator Building, De-NOx, EP, De-SOx

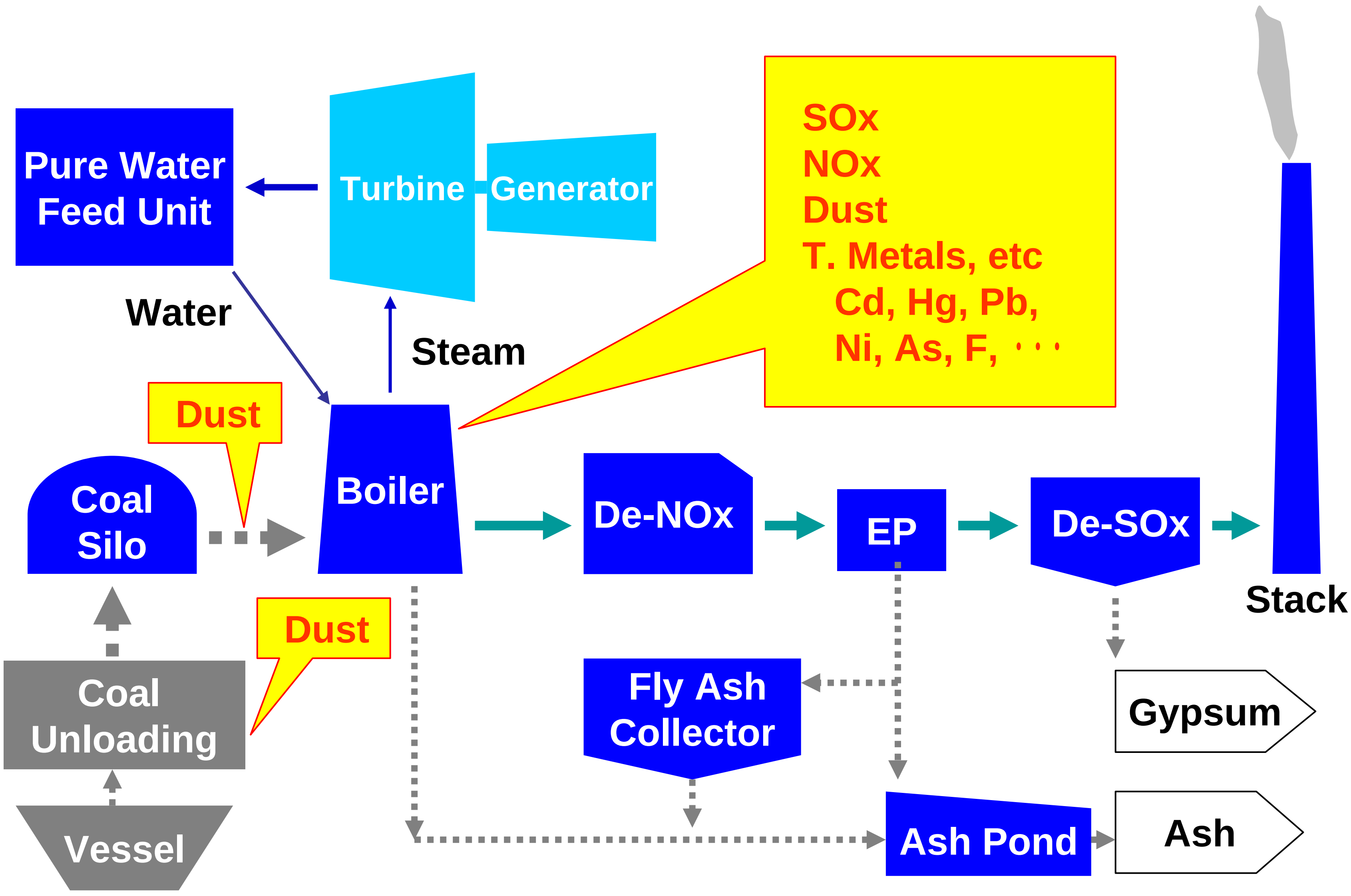
1. Air Pollutions in Thermal Power Plant

1-1 Pollutants Emission



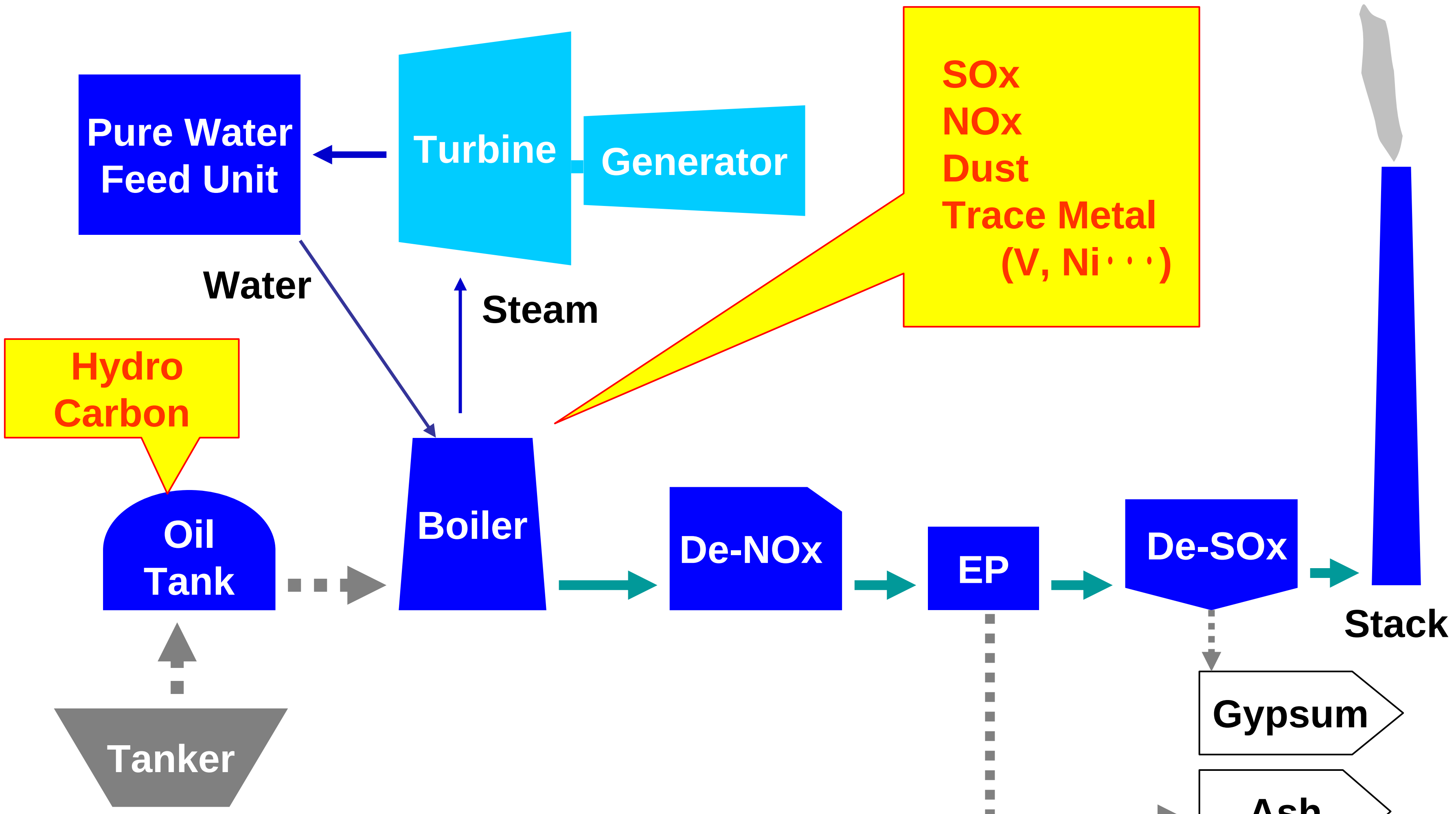
1. Air Pollutions in Thermal Power Plant

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



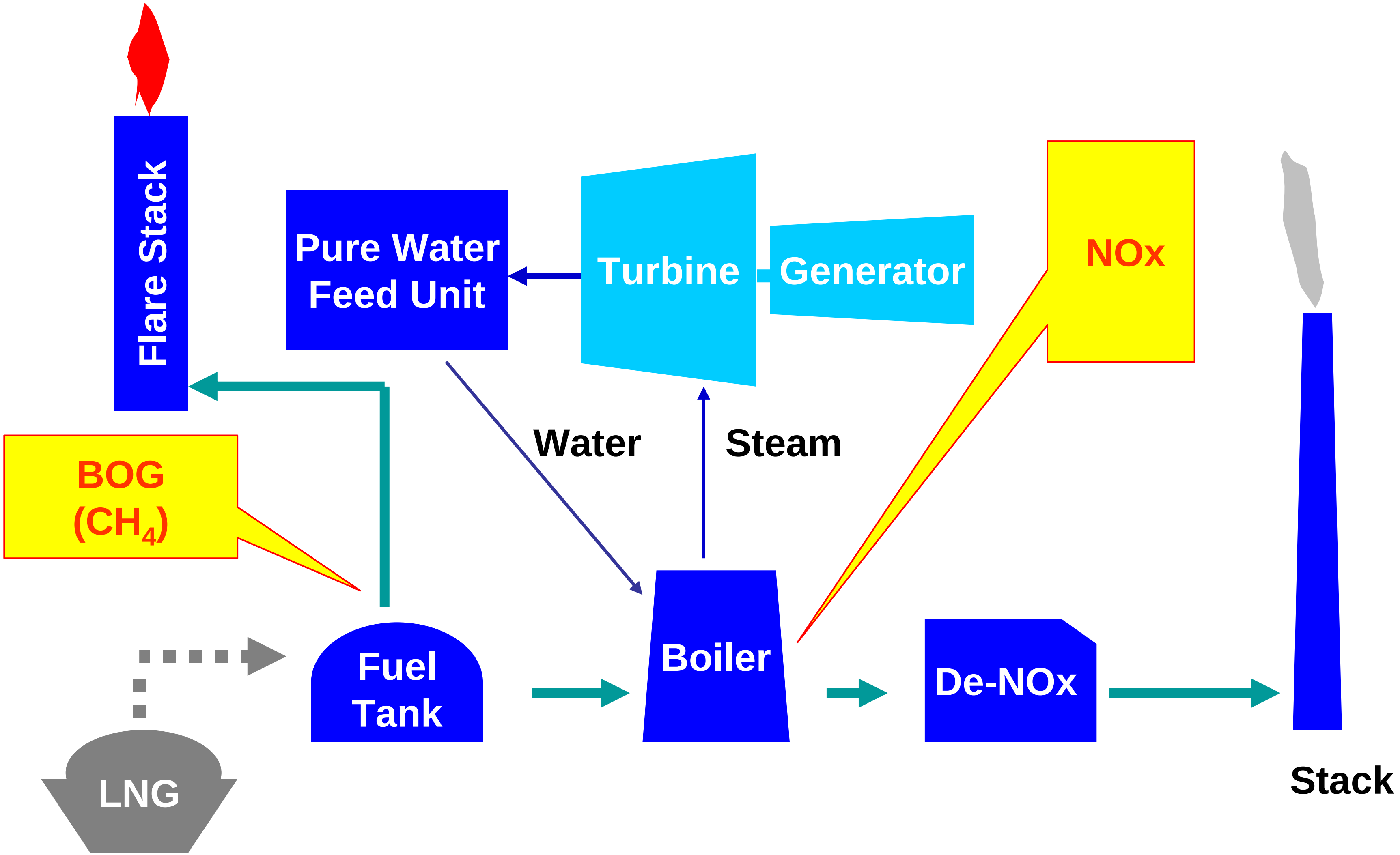
1. Air Pollutions in Thermal Power Plant

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

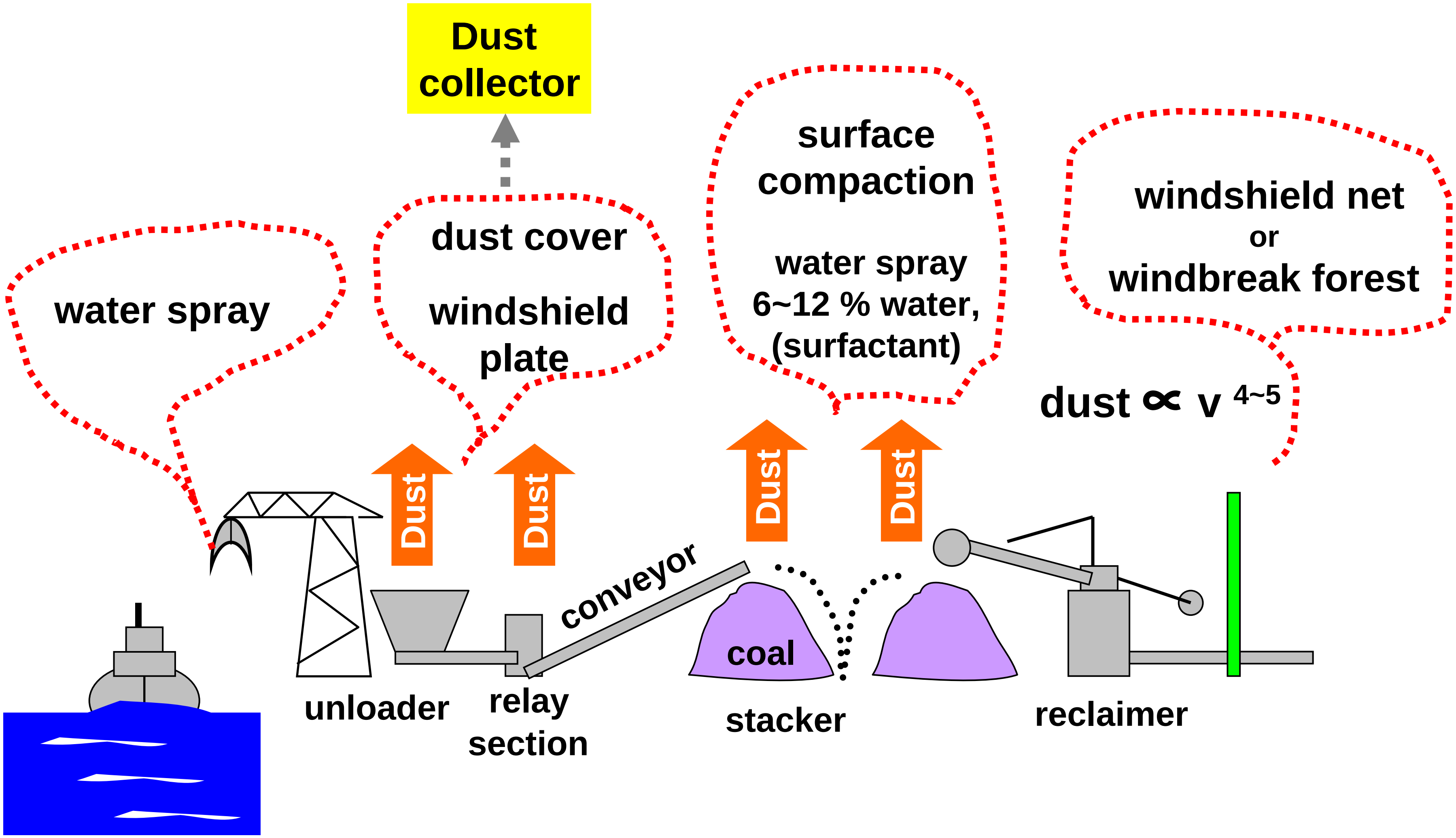


BOG: Boil-off Gas

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 → NOx → Denitrication
3. Sulphur → SOx → 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 → NOx (thermal type) → Denitrification
3. Sulphur・・・None

3. Combustion Control

3-1-1 Coal Properties

Effect of Coal Properties on Pulverized Coal Combustion

Ignitability & Combustibility	optimum range	effects in case of off-spec.
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 μm	increase of non-burn loss
Dryness	H_2O < 20 %	lowering mill performance

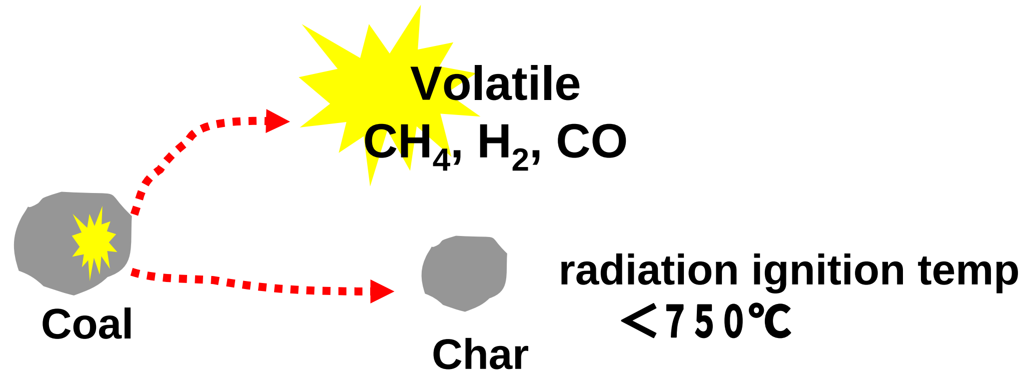
Slagging		
Ash Melting Temp.	> 1,300℃	slagging
Ash Alkaline Ratio	< 0.5	slagging
Fe_2O_3 ／ CaO	< 0.3～3 <	slagging
S ／ coal	< 2%	slagging

Fouling	basic content; Na_2O, K_2O, Cl, CaO, S	fouling on inner furnace, radiation heating surface
Wear-out Nature	quart, Fe_2O_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

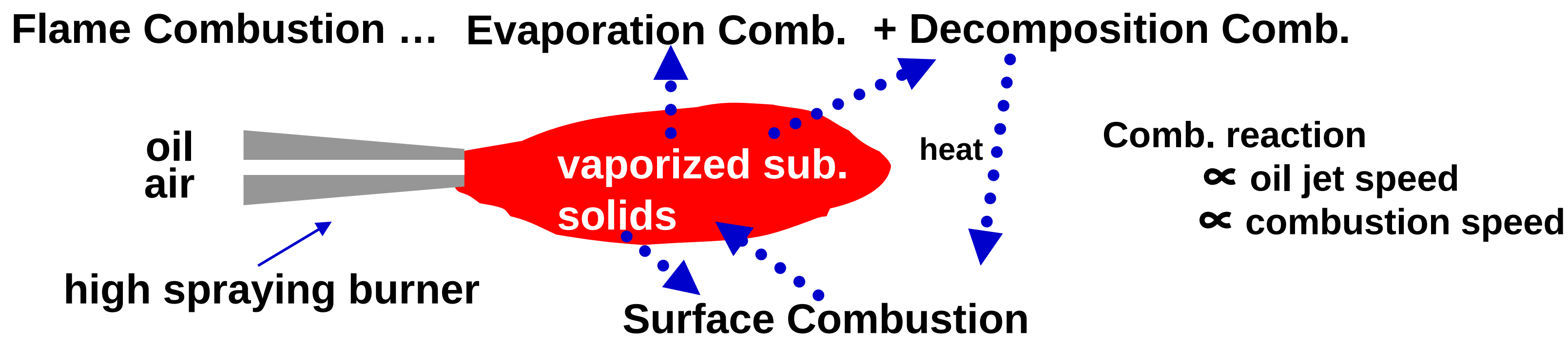
1st Process
— furnace >900℃ HC decomposition
— O_2 existing
— reductant HC > chemical equivalent O_2

2nd Process
— atmosphere temp. > reaction temp. of non-burned portion
— sufficient O_2

3. Combustion Control

3-2-1 Oil Combustion

Oil Combustion Mechanism



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 (SOx)	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 - NOx Generation

NOx Generation and its Control in Oil Combustion

Generation

Thermal NOx (N in Air)

- Flame temp.
- O_2 concentration
- Retention time

Fuel NOx (N in Fuel)

- O_2 concentration
- Nitrogen in fuel

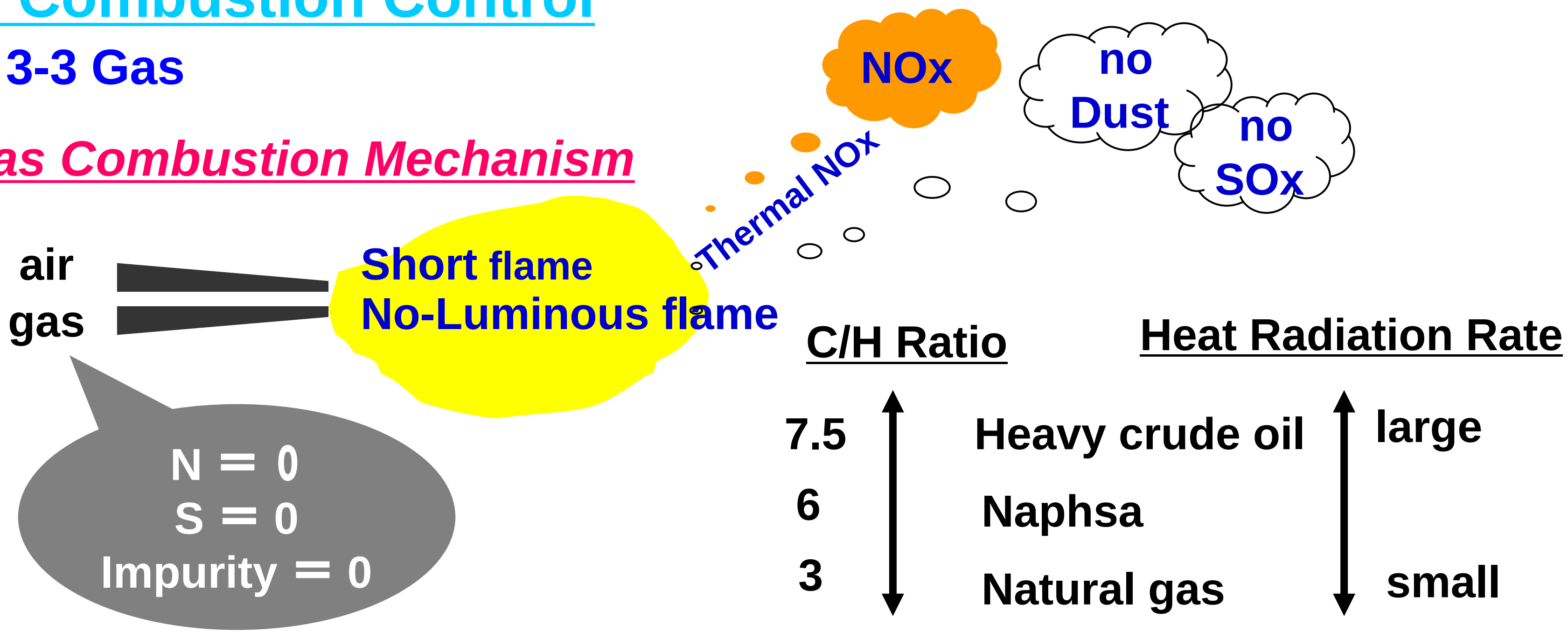
Control Measures

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

3. Combustion Control

3-3 Gas

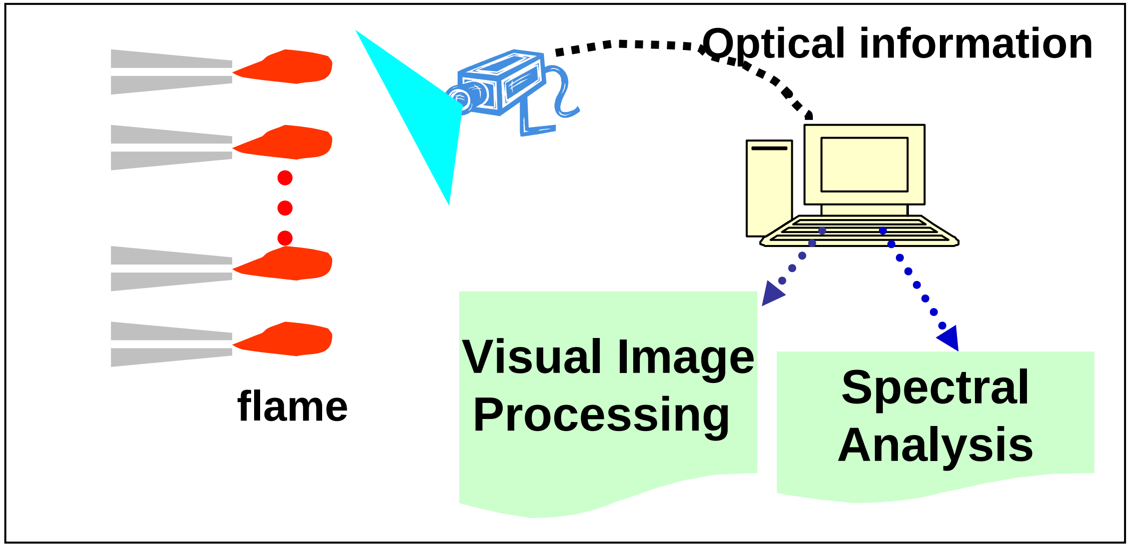
Gas Combustion Mechanism



Control of NOx Generation

+

Oscillating Combustion Preventive Measures



4. Dust Collector

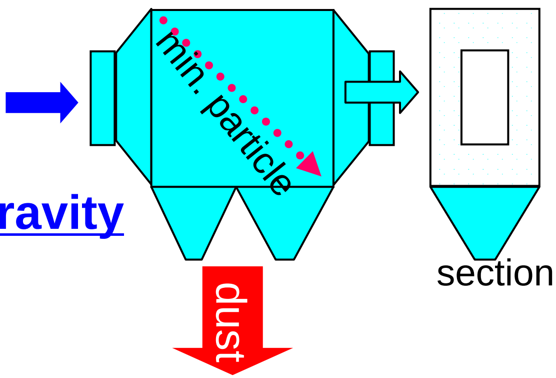
d.p.: dew point
S: small M: medium L: large

4-1 Type of Dust Collectors

Type	Applic. Particle (µm)	Operating (℃)	Cutback Level	Pressure Drop (mm H_2O)	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

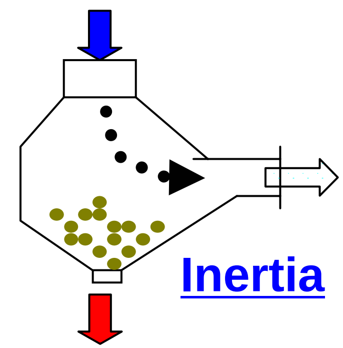


Gravity

Stokes' Law

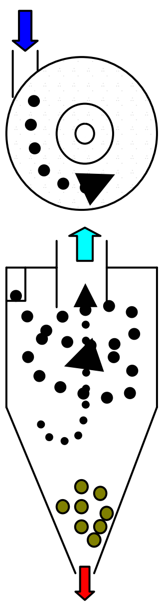
$$V=(g/18\mu)(\rho_1-\rho)D^2 \quad (cm/s)$$

- V: settling velocity (cm/sec)
- g: gravitational acceleration (cm/s^2)
- μ: gas viscosity (kg/ms)
- ρ_1: particle density (g/cm^3)
- ρ: gas density (g/cm^3)
- D: particle diameter (cm)



Inertia

Principle of dust collection ;



Centrifugal force (F) = mv^2/R (N)

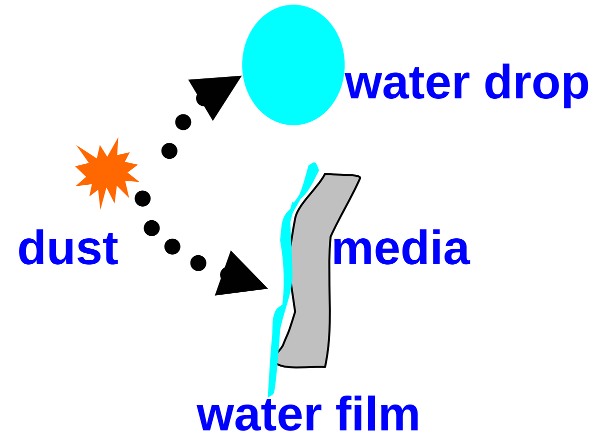
- m: particle mass (kg)
- V: particle velocity (m/ s)
- R: cyclone radius (m)

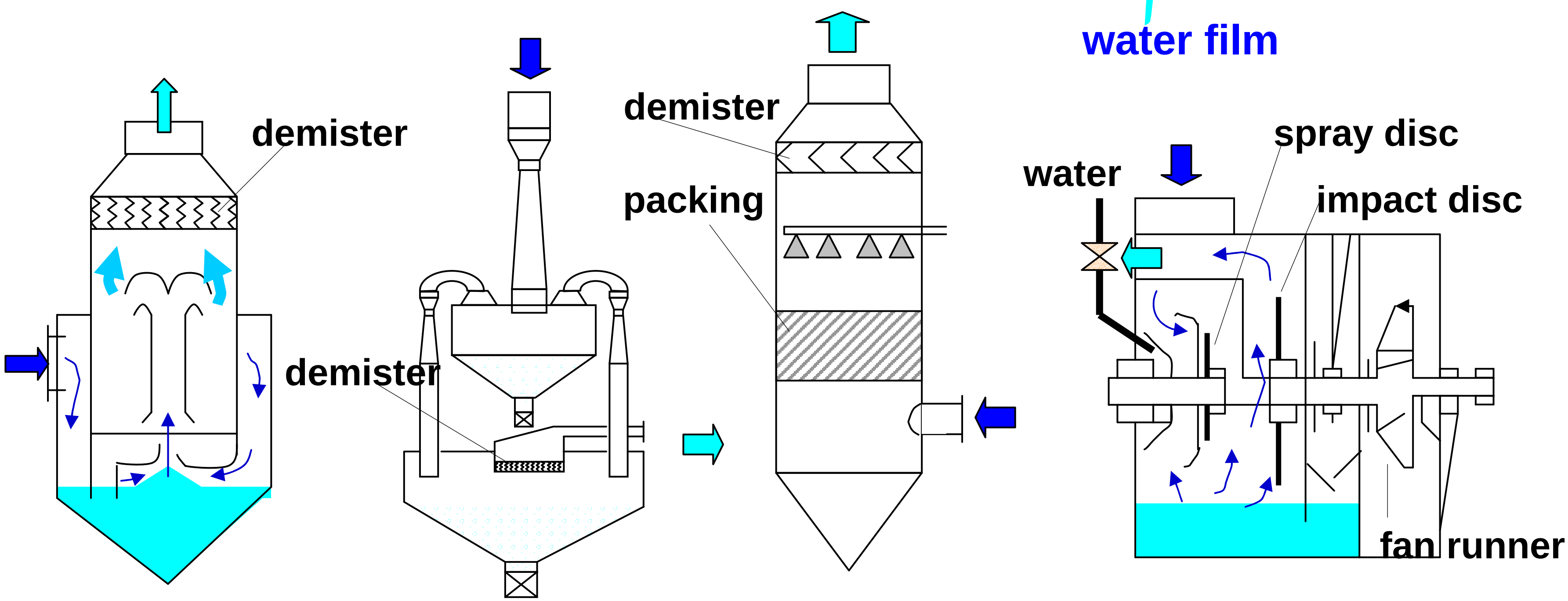
Centrifugal

4. Dust Collector

4-3 Scrubbing Dust Collector

Principle of dust collection ;

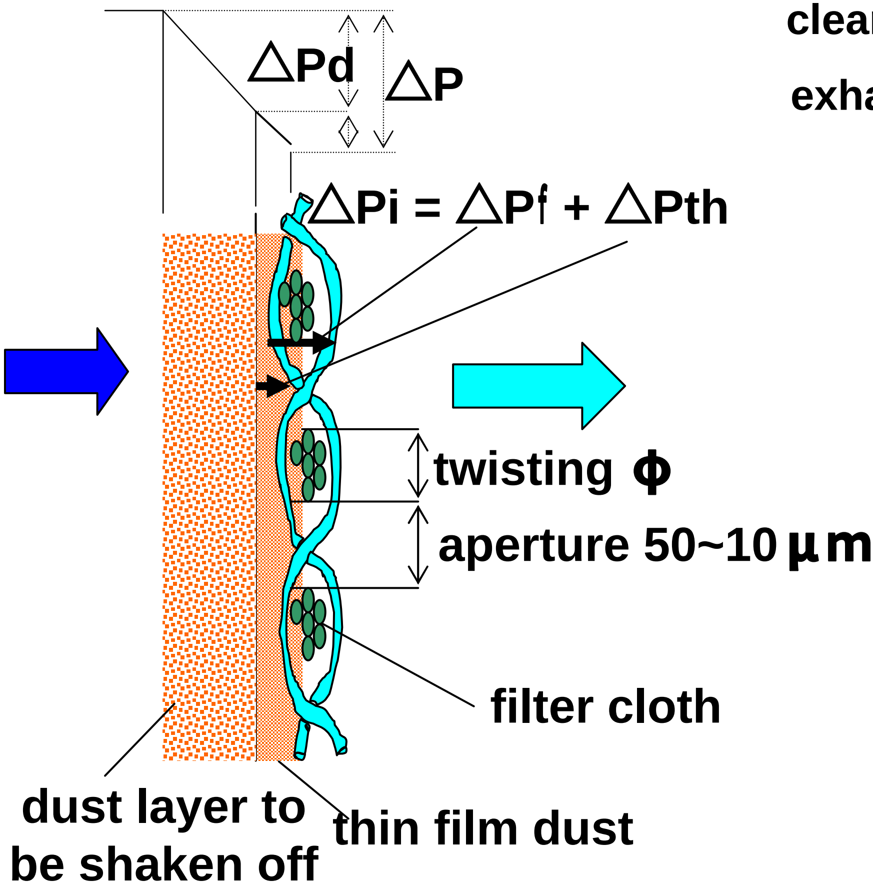




Reservoir type **Pressurized water type** **Packed bed type** **Rotary type**

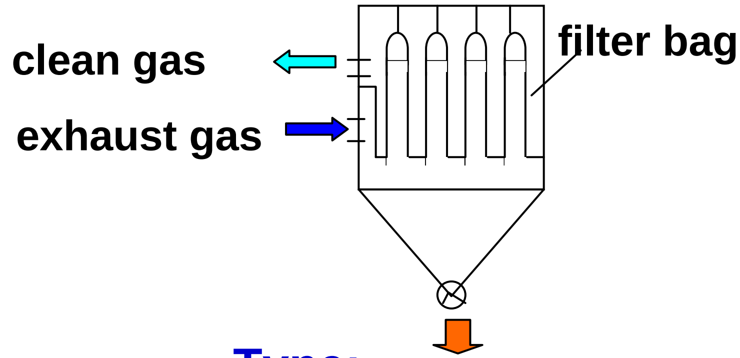
4. Dust Collector

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

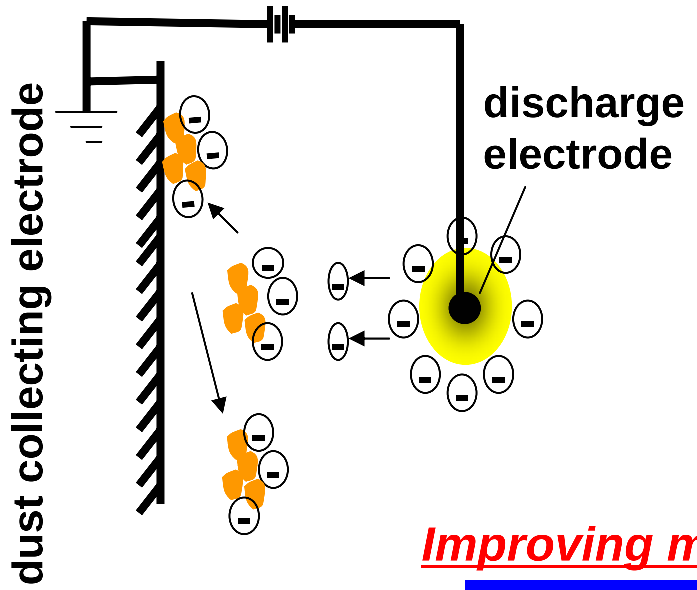
Dust shake-off:
(1) intermittent
(2) continuous

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 ϕ	μm	1~3	20~30
SiO_2	Wt %	15~20	60~75
C	Wt %	50~60	0.4~0.8
ρ Rate	$\Omega \cdot cm$	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

- SO_3 mist

- temperature
- water
- SO_3 mist
- composition of dust

Improving method

- NH_3 injection

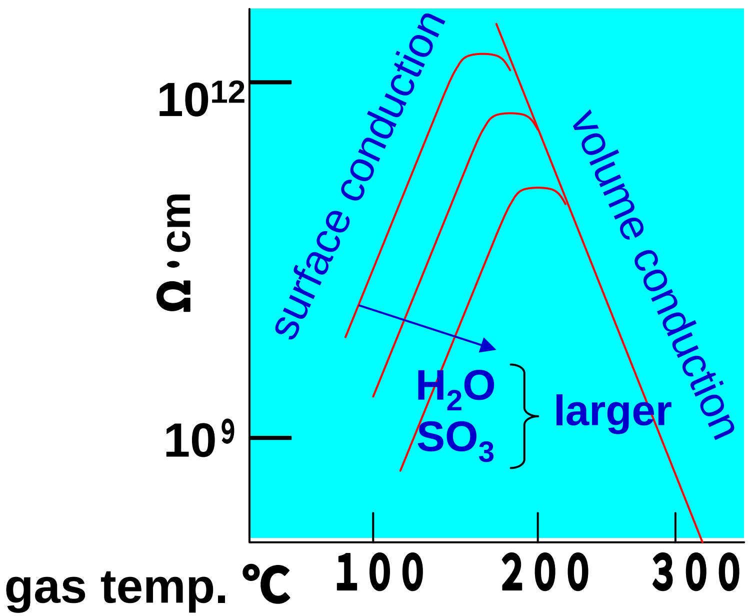
- tempering flue gas
- electric charge control
- dust removal on (+) electrode
- selection of gas temp.

Appropriate ρ

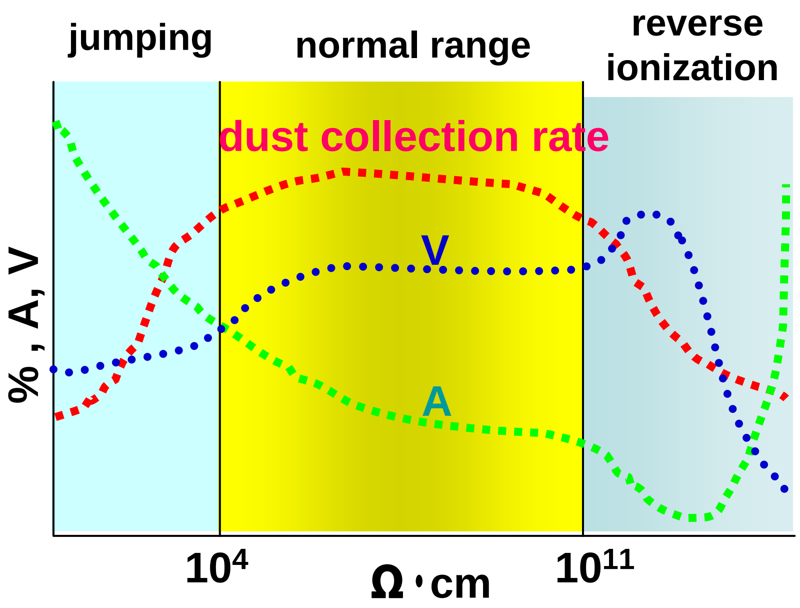
4. Dust Collector

4-5-2 Factors Working on EP

ρ versus gas ℃



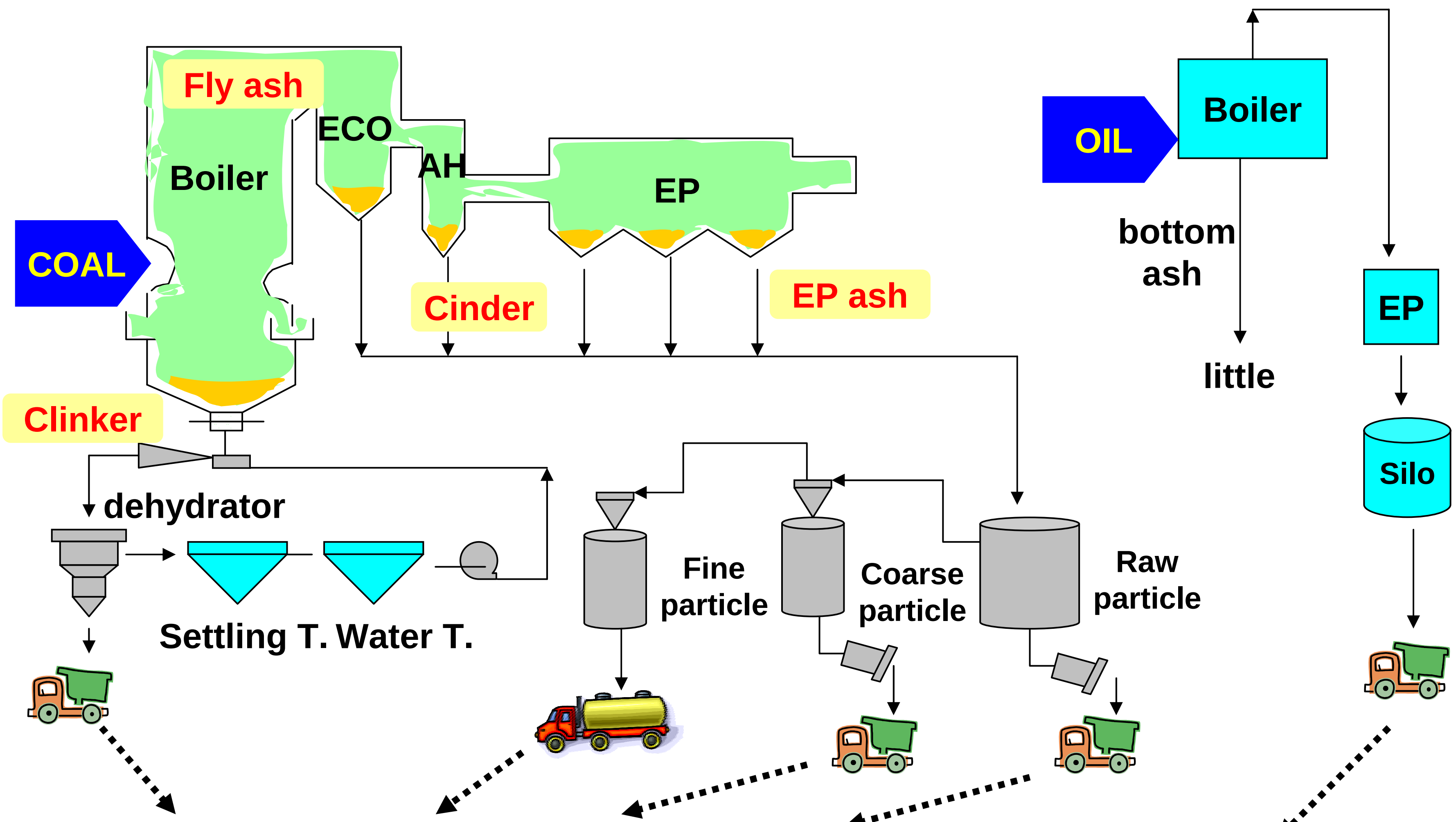
Dust removal versus Ω·cm



Advantages and disadvantages of EP

Advantages	Disadvantages
large gas volume	initial cost – expensive
fine particles of submicron	affection of apparent ρ (Ω- Cm)
high temperature gas	system size- large
wet type dust collection	high level accuracy in manufacturing
suitable operation	
inexpensive maintenance	

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_2SO_3 solution	Na_2SO_3, $NaNO_3$, SO_2, gypsum
	NH3-water	$(NH_4)_2SO_4$, 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_2SO_4	gypsum
Dry type	Activated carbon	$(NH_4)_2SO_4$, gypsum, S, H_2SO_4

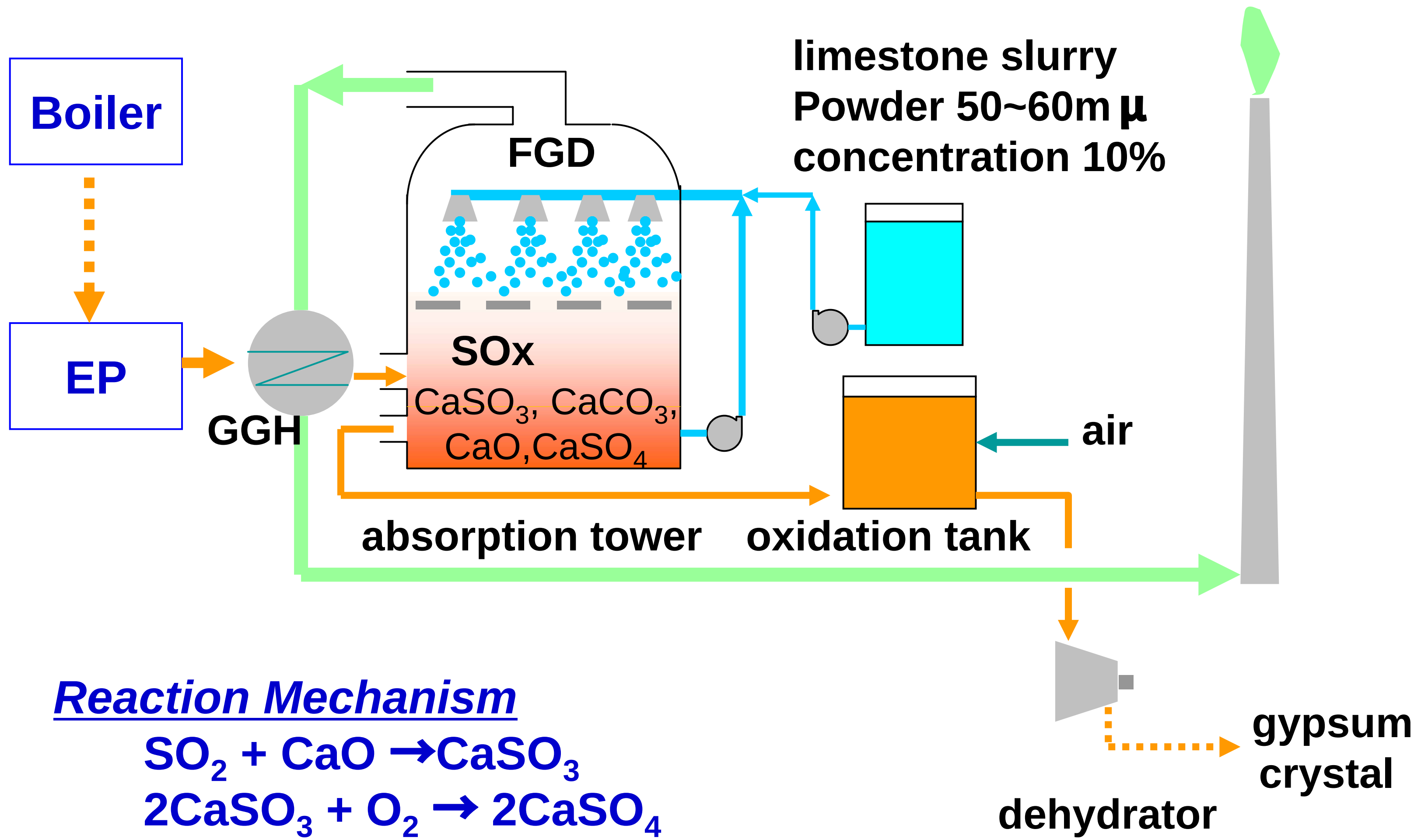
most popularly used method in Japan

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



Reaction Mechanism

$SO_2 + CaO \rightarrow CaSO_3$

$2CaSO_3 + O_2 \rightarrow 2CaSO_4$

$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$

5. Flue Gas Desulphurization

5-3 Simplified FGD System

Comparison of Simplified FGD with Conventional FGD

	Lime & Gypsum Method	*Simplified FGD* Semi-dry Method Intrafurnace Desulphurization + Water Spray Method
Alkali	Ca CO_3 powder	$CaCO_3$ powder
Reaction	$SO_2 + H_2O \rightarrow H_2SO_4$ $H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$ $CaCO_3 + H_2SO_4 + H_2O$ $\rightarrow CaSO_4 + 2H_2O + CO_2$	$CaCO_3 \rightarrow CaO + CO_2$ $SO_2 + CaO + 1/2O_2 \rightarrow CaSO_4$ $SO_2 + CaO + 1/2H_2O$ $\rightarrow CaSO_3 + 1/2H_2O$
Advantages	☆useful gypsum ☆large flue gas ☆high-level removal	☆no wastewater ☆compact size, less space ☆simple process, excellent in economics
Disadvantages	★wastewater treatment ★anticorrosion material ★large area ★high maintenance cost	★slagging inside boiler ★lower removal ★lower alkali utilization
Cost Equipment Operation	 100 100	 20~30 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

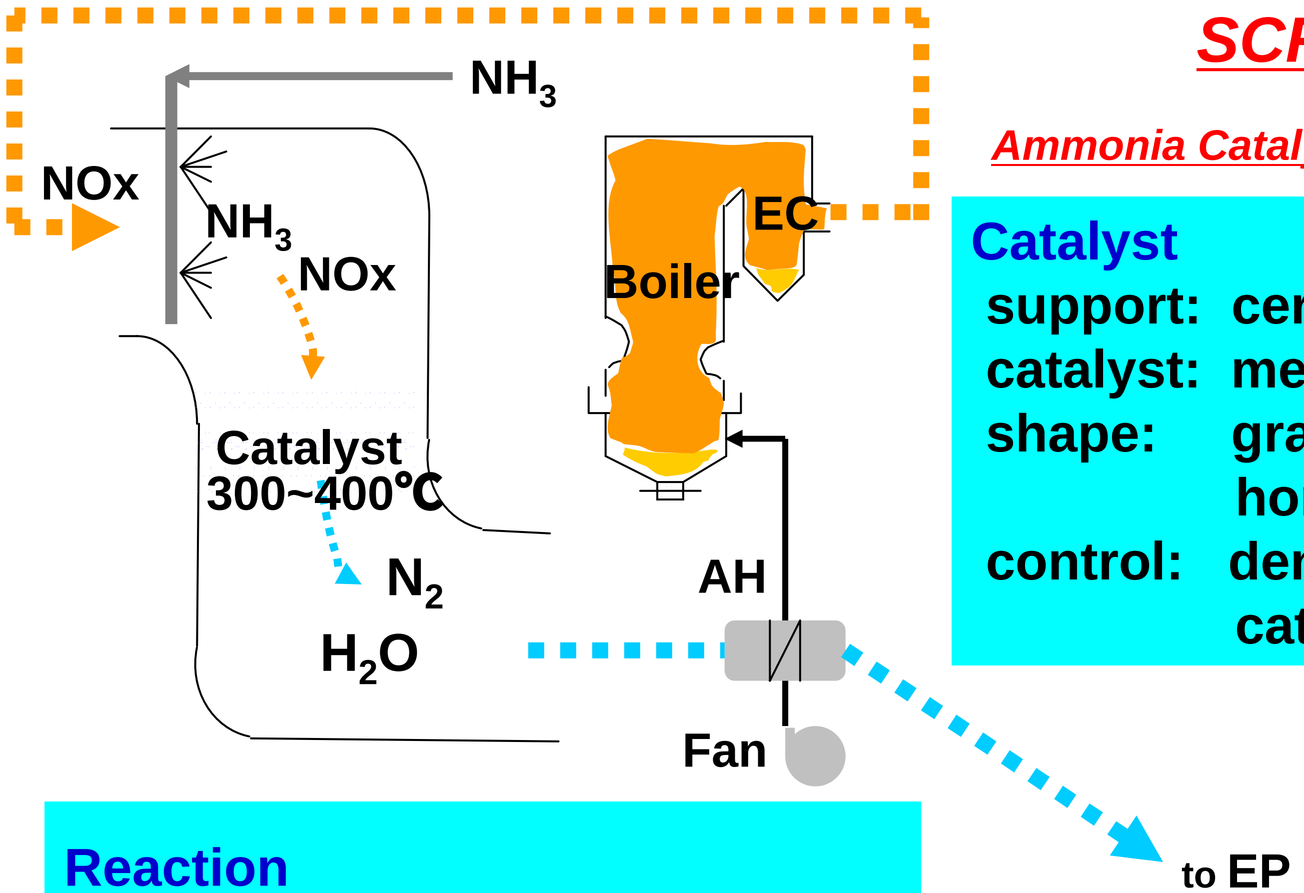
T-NOx: Thermal NOx
F-NOx: Fuel NOx

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 NH_3 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

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

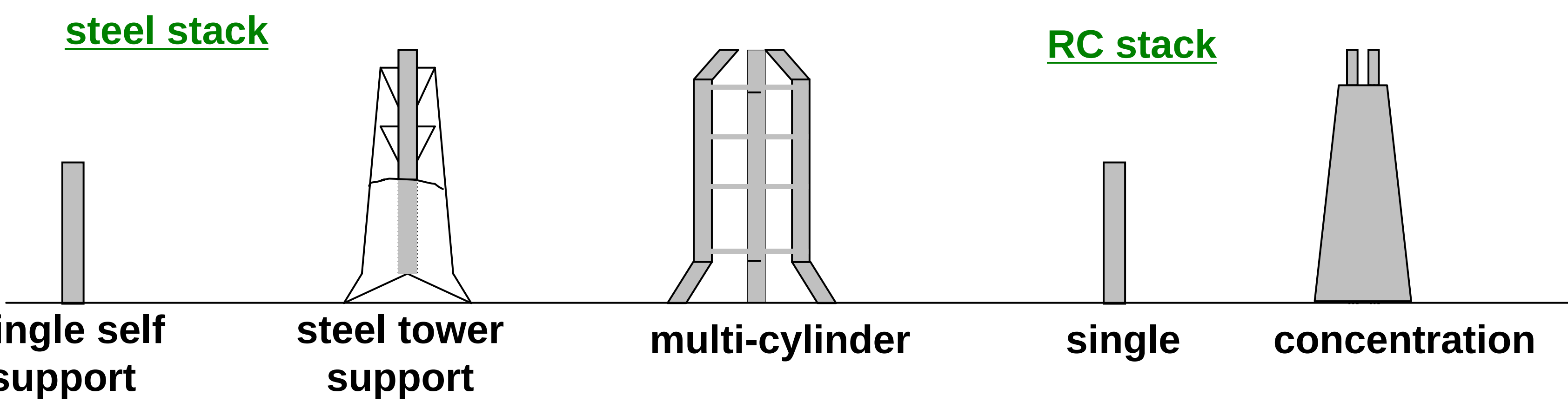
$$2NO_2 + 4NH_3 + O2 \rightarrow 3N_2 + 6H_2O$$

7. Stack

Stack height & Draft force

$$(\gamma a - \gamma g) H_0 + Peb \geqq Vg^2 / 2g \cdot \gamma g + \Sigma \triangle h > 0$$

$(\gamma a - \gamma g) H_0$: theoretical draft force (kg/m^2)
γa: air specific weight at atmosphere temp. (kg/m^3)
γg: exhaust gas 〃
H_0: stack height from datum level (m)
Peb: effective blower pressure (kg/m^2)
Vg: exhaust gas outlet velocity (m/s)
g: gravitational acceleration (m/s^2)
$\Sigma \triangle h$: total pressure loss in exhaust gas route = $\alpha \cdot V2 / 2g \cdot \gamma g$ (kg/m^2)
α: resistance coefficient
V: flue gas velocity in route (m/s)



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